July 23, 2024

REPORT #E24-343

# Refrigerator Policy and Test Procedures: Rationale and Benefits for a Move Towards IEC


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# *Introduction*

This report was commissioned by the Northwest Energy Efficiency Alliance (NEEA) to complement its submission to the US Department of Energy (DOE) on the proposed changes to test procedures for household refrigerators (CFR 430 Appendix A and Appendix B) as set out in the US Department of Energy document *2021-10-12 Energy Conservation Program: Test Procedures for Refrigeration Products; Final rule* (US Department of Energy 2021a)[1]. The purpose of this document is to provide the Department with more information on the following topics:

- History of technology development for household refrigerators
- History of regulation of refrigerators in the US
- A close look at the current DOE test procedure specified in CFR 430 together with a detailed comparison with the new global International Electrotechnical Commission (IEC) standard
- Detailed notes that compare and contrast CFR 430 with IEC and the likely energy impacts of a change to IEC
- Issues to consider when transitioning from CFR 430 to IEC and pros and cons of a move from CFR 430 to IEC
- Areas where more research is required in the US context.

The paper then includes a series of detailed appendices that provide more technical information:

**Appendix A: Technical differences between CFR 430 Appendix A and IEC 62552-3** – this provides a clause by clause review of the technical similarities and differences between CFR 430 and IEC.

**Appendix B: Energy consumption during normal use – key drivers** – this provides a wide range of technical background data on the key drivers of energy consumption in household refrigerators and examines the ways that these can be best characterized in test procedures. It also looks at field data and how this varies by context.

**Appendix C: Background on the development of the new global IEC test method** – this sets out the historical background and the drivers to develop a new global approach to energy testing for household refrigerators and some detail about the key components.

**Appendix D: Lessons learned from US CFR 430 and IEC laboratory tests commissioned by NEEA** – this looks at the detailed test data measured by UL, who were commissioned by NEEA to undertake comparative test for CFR 430 and IEC. It identifies key issues and potential weaknesses in current refrigerator testing.

Detailed references are also provided.

[1] See https://www.regulations.gov/document/EERE-2017-BT-TP-0004-0029

# *History of Refrigerator Design and Technology*

Refrigerators are an important energy consuming appliance in the residential sector and, to some extent, in the commercial sector. Refrigerators are now ubiquitous appliances, with most households in developed countries having at least one, while there is rapid growth in ownership in developing countries (McNeil, Letschert & de la Rue du Can 2008; Rao & Ummel 2017). Global sales of new refrigerators are around 150 million units a year (Euromonitor International Ltd 2017; GfK Marketing 2017) and the global stock in 2009 was estimated to be around 1.6 billion household refrigerating appliances (Klinckenberg Consultants 2009). These appliances are estimated to consume as much as 6% of global electricity (Negrão & Hermes 2011) and improving their efficiency is an important aspect of future climate change mitigation.

Household refrigerators and freezers have been an important part of many households in the US and other developed countries for more than 70 years. This is an appliance that we now often take for granted. Their primary role is to keep food and beverages at temperatures that are suitable for consumption, storage and preservation for later use. Residential household refrigerators are for personal use, in contrast to commercial refrigeration, which display items for sale in retail outlets and other forms of commercial refrigeration such as cool rooms for bulk storage and professional cold storage in restaurants and institutions. To achieve this functionality, refrigerating appliances must maintain internal temperatures within a defined range to control or stop the growth of pathogens and other undesirable organisms.

Most household refrigerators use the vapor compression cycle to move heat from inside an insulated cabinet, which is then rejected to the ambient room in which the appliance operates (Stoecker & Jones 1982). A temperature control system maintains the internal temperature, even with changes in room temperature and with varying internal heat loads (user interactions such as insertion of warm food/drink and door openings). While the first demonstration of the vapor compression cycle was in the mid-1700s (University of Glasgow 2013), the first industrial application was not until the mid-1800s (Culture Victoria 2013) with the first continuous refrigeration system developed in the late 1800s (Linde Group 2014). The first self-contained domestic style refrigeration units were developed in the US by Frigidaire and a few other small companies before 1920 (Wikipedia 2022). By the 1930s, production of refrigerators in the US had started to increase, although these were still a luxury item owned only by a few wealthy households. Large scale mass production did not start in the US until 1946[2]. The production and ownership of household refrigerators and separate freezers increased dramatically during the 1950s and 1960s, with most households having at least one refrigerating appliance by the early 1960s.

[2] Some households had gas or paraffin powered refrigerators in the early days – these use the absorption cycle to cool. Ice chests were also common, where users would purchase large blocks of ice on a regular basis to keep food cool inside an insulated cabinet.

The design and construction of household refrigerators evolved as production increased through the 1960s and 1970s and as new technological developments became available. A few of the key changes over time include:

- A change from fiber insulation to injected polyurethane through the 1960s and 1970s
- Gradual increases in insulation thickness and U value of insulation as manufacturing techniques were refined and improved and as energy became an important factor (especially after the oil embargos and subsequent energy crises of 1973 and 1979, which resulted in lingering elevated oil prices[3])
- Introduction of automatic defrost systems for some models from the 1960s: these were initial hideously inefficient; they became more mainstream with improved efficiency for the most common products (refrigerator-freezers) by the 1980s
- 1995 saw the phase-out of CFC refrigerants (R12) and insulation foam blowing agents (R11) as part of the Montreal Protocol[4] to protect the ozone layer – following this transition, the main refrigerant used for household refrigerators was R134a in the US, with various synthetic gases (e.g., HCFCs and HFCs) used for insulation foam blowing
- Many developed economies around the world moved to hydrocarbon insulation foam blowing agents (such as cyclopentane) in polyurethane after the Montreal Protocol came into force, but these were used only in a limited extent in the US (noting that hydrocarbons tend to have a slightly poorer thermal performance than most synthetic gases, so these came with some energy penalty)
- For frost free products, defrost intervals were originally set by a mechanical compressor run-time controller (many low-end products still use these today): these were reliable and predictable but tended to defrost frequently to ensure adequate performance in all possible climates and under a wide range of usage conditions
- Electronic defrost controllers appeared in the 1990s
- After 2000 electronic defrost control systems became mainstream along with efficient DC air circulation fans – these enabled better air temperature control in each compartment (with the use of internal motorized dampers to control air flow between compartments), and more adaptive defrost systems[5] that adjusted defrost frequency depending on evaporator frost loads
- Improvements in insulation have been gradual, but polyurethane remains a mainstay
- Vacuum panel insulation was used in some products from around 2000. However, these remain expensive and difficult to implement: their main advantage is to increase the

[3] More detail on the oil embargos of 1973 and 1979 and the associated energy crises can be found in https://en.wikipedia.org/wiki/1970s_energy_crisis

[4] Under the Montreal Protocol in 1990, it was agreed to ban nearly 100 substances with significant Ozone Depleting Potential (ODP) - see https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

[5] Called “variable defrost systems” in IEC 62552-1, but also called “long time automatic defrost systems” in the US (US Department of Energy 2021b).

available storage volume inside the appliance (for a given external dimension and insulation effectiveness) rather than to improve the overall energy consumption

- The only mainstream compressors available for household refrigeration were driven by fixed speed induction motors until well after 2000, when variable speed (e.g. inverter-driven) systems started to become available
- After 2010 inverter-driven compressors became more common – these are high-efficiency brushless DC motors where the speed of rotation is controlled by switching DC currents to the motor windings (using a variable speed inverter in the controller) to set the speed and torque of the permanent magnet rotor – many of these compressor motors have complex behavior any many do not have on/off cycles under some operating conditions, confounding the approaches set out in older test methods that assume the use of single-speed (cycling) compressors
- After 2000 significant parts of the global refrigerator market moved towards hydrocarbon refrigerants (with R600a (isobutane) being the most prevalent). Hydrocarbons have excellent refrigerant properties, zero ozone depletion potential (ODP), and almost no global warming potential (GWP); however their use was highly restricted in North America due to safety concerns (risk of explosion). All of Europe and much of Asia now use hydrocarbon refrigerants.

# *History of Refrigerator Regulation in the US*

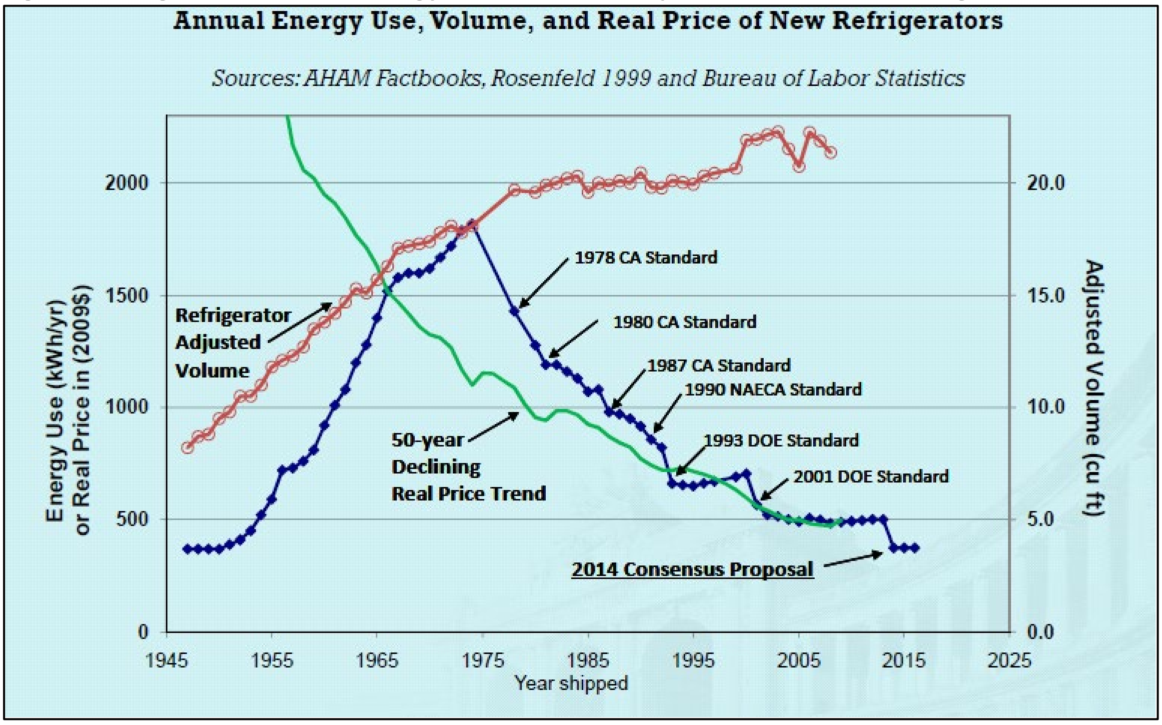
Refrigerators are one of the few appliances that remain “on” continuously and, as such, consume a significant amount of electricity during normal use. Electricity consumption of refrigerators typically ranges from 100 to 1,000 kWh or more per annum, depending on the design, size, features, and efficiency. Given that refrigerators are significant users of electricity, it is hardly surprising that they are the focus of attention of many programs that aim to reduce electricity consumption and greenhouse gas emissions associated with power generation. There are nearly 100 countries that have some program to regulate the energy efficiency of refrigerators (Energy Efficient Strategies & Maia Consulting 2014; Energy Efficient Strategies et al. 2021).

It is useful to briefly examine the history of energy regulations for household refrigerators in North America. While various energy labeling schemes were introduced for household refrigerators in Europe in the 1960s and 1970s, none were mandatory, and few remained in place for any length of time (Harrington 1995). The mandatory Energy Guide label was introduced in the US in 1980. This followed the introduction of an early version of the EnerGuide label in Canada in 1978, with both programs covering household refrigerators. These were the first mandatory energy labeling schemes anywhere in the world. This policy spawned mandatory energy labeling for refrigerators in Australia in 1986 (Harrington & Wilkenfeld 1997) and later for a wide range of appliances, including refrigerators, in Europe from 1994 (European Commission 1994, 1992).

The US also led the way on the introduction of energy efficiency standards (called Minimum Energy Performance Standards or MEPS in this report). US Federal MEPS were first introduced for refrigerators in 1990 (US Department of Energy 1989), with an update in 1993 (US Department of Energy 1993). More stringent standards were again introduced in 2001 (US Department of Energy 2001) and then again in 2014 (US Department of Energy 2011a, 2011b). Prior to federal standards in 1990, California also had local efficiency standards for refrigerators in place, with several iterations through the 1980s. Federal standards pre-empted all state MEPS levels once they came into force.

A well-known visual depiction of the trends in energy consumption, size, and actual product price for refrigerators is shown in Figure 1.

**Figure 1. Long term trends in energy, volume and real price for household refrigerators in the US**




*Notes:* Sourced from McMahon (2011). The original data analysis for the figure was prepared by David Goldstein when he worked at Lawrence Berkeley National Laboratory in the 1970s. Various people worked on the underlying data over many years, including Art Rosenfeld[6] when he was at the DOE. Multiple versions of the figure appear in a number of publications (Goldstein 2009). It appears that the energy data for the US was based on manufacturer measurements back to 1972. The data prior to 1972 was based on very limited estimates – essentially looking at the laboratory measurements on a new 7 cu ft refrigerator in 1972 (which was very small in comparison to average products at the time) and comparing that with a measurement of a 1949 model (also tested in 1972) of comparable size. The energy intensity of the old unit was found to be double, so this was assumed to increase linearly back to 1949. Therefore, there is some question regarding the accuracy of the energy prior to 1975. The original researcher stated quite clearly that it is not possible to attribute the decline in energy to any particular event or program (at least in a scientific manner) (e.g., the dramatic fall in energy from the late 1970s). Goldstein's personal opinion is that standards are the most significant factor followed by utility-sponsored incentives, which ENERGY STAR then complements after about 1990. It appears that a range of other factors, such as the energy crises of the 1970s and energy labelling (which were introduced partly in response to the energy crises), would also have influenced energy trends at the time.

As the figure notes indicate, there appears to be a strong influence of more stringent efficiency standards over time and the decline in the energy consumption of refrigerators. However, the original researcher is not attributing all the energy savings (which are considerable) to MEPS alone.

There are several interesting pieces of information in Figure 1. Firstly, in the 40 years from 1975 to 2015, the energy consumption of refrigerators decreased by 75% while the size increased by around 20% over the same period. Secondly, the real price[7] of refrigerators decreased by a factor of six-fold over the period 1955 to 2015. This data has been replicated in Australia and is very comparable in terms of magnitude and trend over a similar time period (Harrington 2011; Ren et al. 2021). The US data, as well as comprehensive data from a large number of countries, show that real prices and energy consumption have both been declining for some 30 years and show no sign of abating (Ellis et al. 2007; Energy Efficient Strategies 2016; Weiss et al. 2010; Desroches 2012, 2013; US

[6] Julie Chao, "Art Rosenfeld, California's godfather of energy efficiency, dies at 90," Accessed, December 6, 2022, https://www.universityofcalifornia.edu/news/art-rosenfeld-californias-godfather-energy-efficiency-dies-90

[7] The real price is the price that has been adjusted for the impact of inflation over time, so reflects the relative purchasing power at an earlier time compared to an equivalent value now (or in a specified year).

Department of Energy 2011c). An example of more recent refrigerator prices and energy trends in the US is provided in Figure 2.

**Figure 2. Trend in real price and energy consumption of refrigerators in the US, 1985-2010**

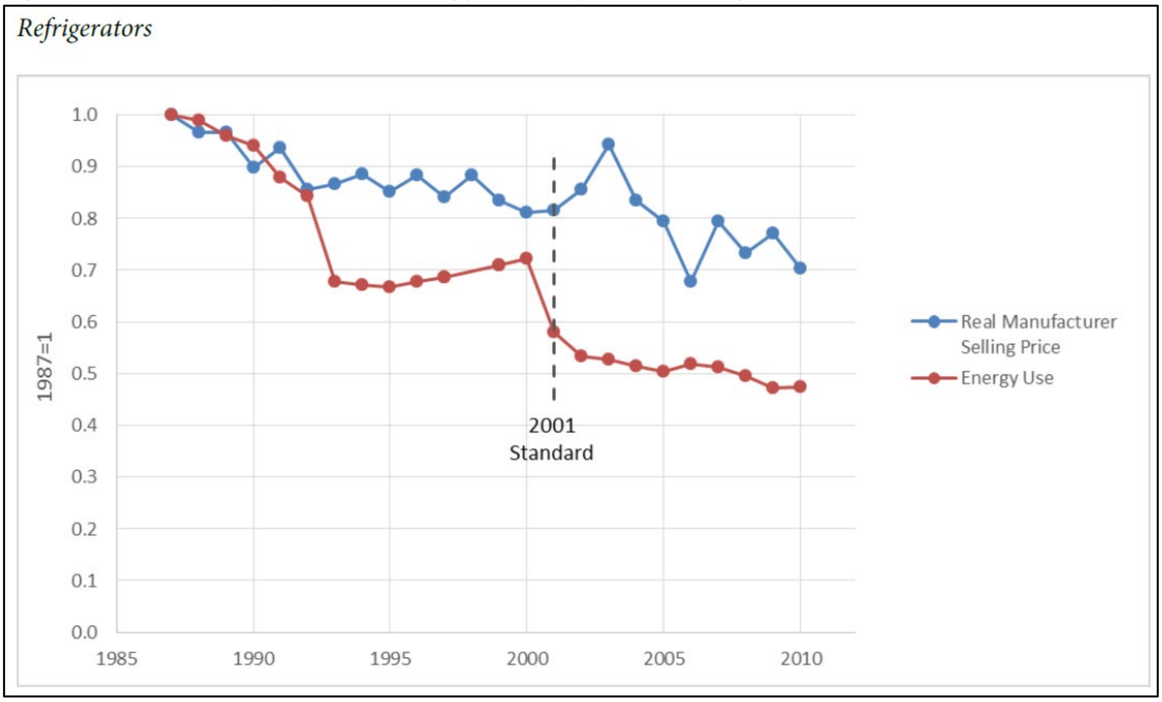
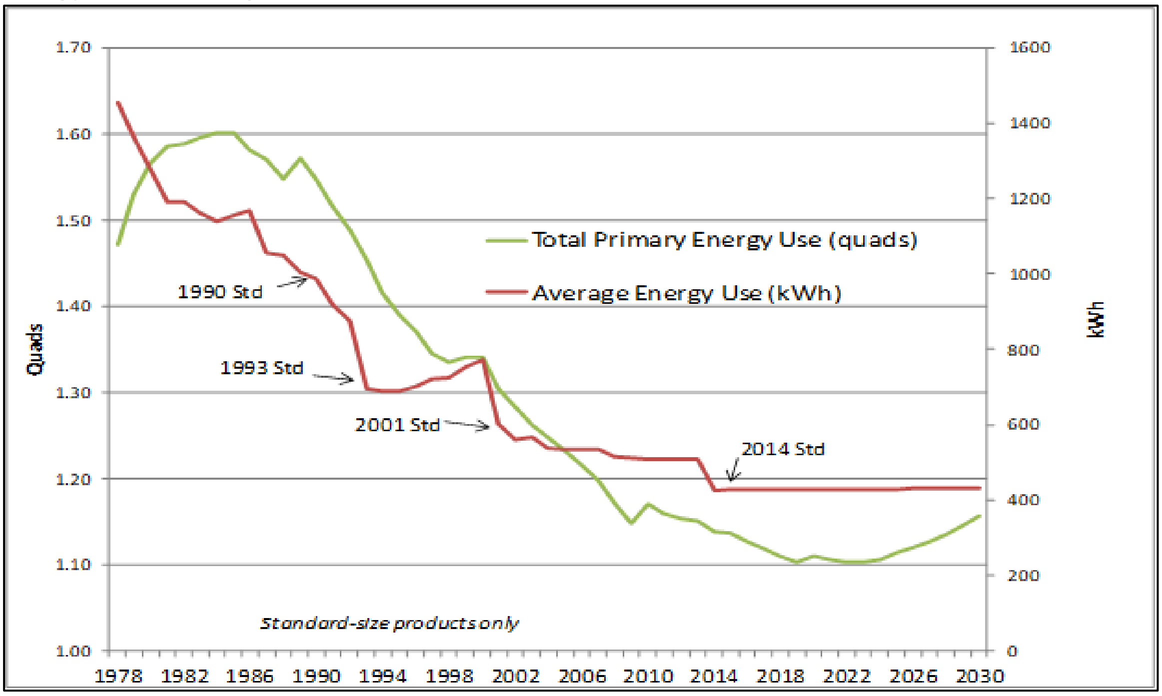



Figure notes: Source is Figure 1 from Nadel and deLaski (2013).

There would seem to be little doubt that MEPS, particularly for household refrigerators, has created strong downward pressure on the energy consumption of household refrigerators. Lawrence Berkely National laboratory prepared a detailed evaluation of all federal standards programs for the US Department of Energy (Meyers et al. 2016; Meyers & Cubero 2021). This includes some evaluation of the energy impact of federal standards for refrigerators, as shown in Figure 3. The report states that the average new refrigerator-freezer in 2010 used only 44% of the energy per year as an average new unit in 1985. Total stock energy use has declined even as shipments increased and the average size of new units grew. Nationally, in 2010 the stock of refrigerator-freezers used one-third less total energy than in 1985 even though there were 70 million more units in use. In the absence of any new future MEPS for refrigerators, primary energy is projected to continue to decrease until at least 2025. The increase in total energy use depicted after 2025 is due to growth in purchases of refrigerator-freezers and increasing numbers in the stock. If the standard is updated as required by the Energy Policy and Conservation Act (1975)[8], the declining trend will continue.

[8] US Federal law 94-163 – see https://www.govinfo.gov/content/pkg/STATUTE-89/pdf/STATUTE-89-Pg871.pdf#page=1

**Figure 3. Refrigerator-Freezer Energy Use Trends: Average Energy Use for New Products and Total Energy Use for Refrigerator-Freezers**




*Notes:* Source Figure 1 from Meyers et al. (2016).

# *Refrigerator Test Procedures*

## *Introduction*

Energy is an attribute that needs to be measured as it cannot be assessed by inspection (unlike size or volume, for example). Test procedures provide a critical underpinning of any energy policy. Test procedures provide standard definitions and measurement approaches for energy use and energy service. As consumers, we are not interested in energy in its raw form (e.g. gas or electricity) – we want the services that energy can deliver. Energy services can include cold beer, hot showers, light for reading, heat for cooking and comfortable indoor temperatures. Energy services can be thought of as outputs. The energy consumed to supply these services can be considered as inputs.

Test procedures provide a common language on what energy efficiency is: energy service delivered per unit of energy consumption (or energy outputs over energy inputs). These two attributes are needed to define any meaningful energy efficiency metric.

The objective of a product test method can be set out in general terms using some common goals as stated by the IEC. Ideally, a test procedure should be:

- Repeatable (same result on the same product in the same lab on retest): this is a combination of the test consistency and the product behavior or uniformity under constant operating conditions;
- Reproducible (the ability to achieve the same result on the same product in different labs): this is made up of repeatability plus inter-laboratory differences;
- Technically simple but able to cope with new and emerging technologies;
- Inexpensive, avoiding the need for costly specialized equipment where possible;
- Quick as practicable;
- Representative: the ability to reflect of consumer use and be consumer relevant.

While all of these objectives are desirable, some tend to be mutually exclusive for some products; this is especially so for refrigerators (Harrington 2009).

International standards must be developed with a global perspective in mind - this means the ability to adequately (and accurately) deal with regional and climatic issues across different regions. This is particularly difficult and important for those products for climate control (heating/cooling) or refrigeration and, to some extent, water heating or other weather/climate-affected products. Until recently, ISO standards for air conditioners and IEC standards for refrigerators did not reflect consumer use and were not relevant across different regions (i.e. they were unable to reflect climate driven factors). International test procedures are not necessarily good if they have not been developed with these high-level objectives in mind (water heaters, for example, suffer from a lack of a coherent global approach).

Understandably, regulators have focused on the issue of reproducibility, as this is a key element that underpins the enforceability and integrity of their energy programs. A test procedure that cannot be reproduced in different laboratories cannot be enforced. So this has been a fundamental requirement for all test methods.

In terms of simplicity and low cost, testing of refrigerators has never been able to fulfill these objectives. Tests have always been expensive, slow and complex. Refrigerators are a complicated thermodynamic product, the energy service is difficult to assess accurately, and accurate control and measurement of ambient and internal temperatures are required. However, the most up-to-date test procedures use sophisticated data logging equipment, making analysis more accurate and faster.

Unfortunately, historically little attention has been given to the issue of consumer relevance and the ability to accurately represent actual use, in part because this presents some challenges and complexities. This is astounding for a product that accounts for such a significant share of household energy worldwide and for a product that is the most globally regulated in terms of energy efficiency.

Energy test procedures for refrigerators were first set in 1977 in the US Code of Federal Regulations (US Department of Energy 1977). The original ambient test room temperature of 90 °F was derived from the Association of Home Appliance Manufacturers (AHAM) standard HRF-2-ECFT-1975, which was referenced in the CFR 430 test procedure. At the time, a submission to DOE suggested that energy measurements be conducted at a room temperature of 104 °F, but this was rejected. Interestingly, an energy factor of 0.85 was applied to vertical freezers, and an energy factor of 0.7 was applied to chest freezers to more closely reflect the likely energy consumption during normal use (compared to a static test at an ambient of 90 °F). While there have been several updates to the US DOE test procedure for refrigerators in Appendix A and Appendix B of CFR 430 (US Department of Energy 2021b) until 2011, there were few significant changes to the US refrigerator test method since its initial introduction.

## *Assessment of Differences between DOE CFR 430 and IEC 62552-3*

In 2012, the US DOE issued a new test procedure for household refrigerators (US Department of Energy 2012). US delegates had been actively participating in developing the new IEC global test method since 2006, and there was significant cross-fertilization between the US and IEC on many technical aspects of refrigerator testing. Some of the key areas where there ended up being closer alignment were:

- IEC adopted the US volume determination procedure
- There was closer alignment on compartment definitions and temperature ranges
- There was general agreement on compartment target temperatures (although the US still uses °F rather than °C)

- One of the ambient temperatures test temperature for IEC was 32°C (but the US decided to stick with 90 °F = 32.2 °C) – IEC now includes an approach that will allow for a correction of energy measurements to an exact target ambient temperature, which can be used to adjust IEC data to the exact US conditions (within permitted tolerances)
- IEC adapted the DOE equation for long time defrost controllers for variable defrost systems
- IEC configuration for automatic ice makers is the same as US requirements (but IEC permits additional checks)
- IEC approach to anti-sweat heaters accommodates US requirements
- IEC requires regions to specify local climate data for the assessment of ambient controlled anti-condensation heaters – this is in a format that is compatible with US requirements
- IEC allows more sophisticated interpolation of test results around the compartment target temperatures (two or multiple point testing including triangulation and use of matrices) – DOE already includes a form of linear interpolation and now permits triangulation, so is reasonably closely aligned in terms of outcomes
- The IEC adapted the use of the US Part 1 and Part 2 energy measurement approach to separate the energy impacts of defrost and recovery from steady state operation, allowing a more accurate energy calculation for any given defrost interval (as the defrost interval encountered in a laboratory test may not be fully representative of operation in the field).

Areas where some differences remain between IEC 62552-3 and DOE CFR 430 (2012) are:

- IEC includes an additional ambient temperature (16 °C) for the measurement of energy consumption
- IEC has more sophisticated criteria for acceptance (or rejection) of steady state data to improve accuracy of results and flexibility of testing
- IEC has more sophisticated criteria for acceptance (or rejection) of defrost and recovery periods to improve accuracy of results and flexibility of testing
- IEC corrects the steady state energy for small deviations in measured ambient temperature (within tolerance) encountered during the measurement period
- DOE ignores the impact of compartment temperature excursions during a defrost and recovery period: these are measured but are not included (this does not impact the testing method, and it is possible to calculate US results from IEC data if desired)
- IEC has a test method for assessing the load processing efficiency.

The IEC test includes a method for measuring the additional energy associated with making ice for tank type ice makers. However, neither the DOE nor IEC test method yet includes a method for measuring the additional energy associated with making ice for mains water type ice makers. The IEC also includes a suite of other performance-based tests. The most important is the storage test (IEC 62552-2 2015), which ensures that the product can maintain suitable compartment temperatures over a wide range of ambient temperatures. An equivalent test is included in AHAM HRF-1, but this is not mandated by the DOE.

## *Issues for a Transition from CFR 430 to IEC 62552-3*

Superficially, the test requirements set out CFR 430 Appendix A and B appear to be very different from IEC 62552-1 and IEC 62552-3. However, on a deeper technical review, the overall differences are relatively minor in nature. Notably, most of these are unlikely to significantly impact on energy consumption measurements if adopted in the US. While the previous section outlines some of the overall similarities and differences between CFR 430 and IEC 62552-3, this section looks at more detailed technical requirements. Importantly, it provides an initial assessment of the differences' significance, in terms of energy consumption. The test requirements are broken up into broad categories for analysis as set out in the following tables.

**Table 1. Comparison of Test Setup and Test Condition Differences**

| Test Parameter | Nature of difference | Energy impact |
|---|---|---|
| Use of a test platform | No practical difference, both allow bare floor if temperature within specified limits | Negligible |
| Rear clearances | No practical difference | Negligible |
| Ambient temperature sensor positions | No practical difference | Negligible |
| Temperature gradients | No practical difference | Negligible |
| Internal temperature sensor positions | Small differences in unfrozen compartments, almost the same in frozen compartments | Small |
| Minimum sensor clearance | No practical difference | None |
| Warmer energy test ambient temperature | US specify 32.2 °C, IEC specify 32.0 °C | Impact around 0.5% lower energy |
| Cooler energy test ambient temperature | US not specified, IEC specify 16.0 °C | Not applicable |
| Sensor masses | US permit larger masses, metal not defined | Very small impact on average temperatures |
| Data sampling rate | US requires ≤4 min (≤1 min for multi compressor) – IEC is ≤1 min | None |
| Compartment loading | Both standards specify compartments are unloaded for energy test (same) | None |
| Ice storage bin configuration | No differences | None |
| Convertible compartments | Highest energy mode – same in IEC (IEC term is variable compartments)(IEC permits additional modes to be tested as secondary configurations) | None |
| Anti-sweat heaters | US require average of ON and OFF – IEC accommodates this requirement | None |
| Demand response controls | US specifies factory settings (IEC does not specify) – this could be a regional setting | None |
| Compartment standardized temperatures | Fresh food 3.9 °C (IEC 4 °C), freezers -17.8 °C (IEC -18 °C), freezer compartments in refrigerators and cooler refrigerators -9.4 °C (IEC no equivalent), cooler compartment 12.8 °C (IEC cellar 12 °C) | Impacts generally ≤±1% [a] |
| Special compartments | No equivalent provision in IEC – IEC forces all compartments and sub-compartments to be one of the defined standard compartment types | Likely small |
| Volume measurement | US and IEC approaches are aligned | None |

*Notes:* (a) US compartment types are mostly similar to IEC compartment types in terms of standardized temperatures (target temperatures), except for freezer compartments in refrigerators and cooler refrigerators, which sit between one-star and two-star. IEC has a larger range of specified compartment types. Refer to Table 4 for a full list of IEC compartment types and their target temperatures.

**Table 2. Comparison of Definition and Testing Method Differences**

| Test Parameter | Nature of difference | Energy impact |
|---|---|---|
| Definition of stable operation | Similar – IEC is more strict and will be more accurate | Negligible in most cases |
| Variable anti-sweat heater control | IEC allows current US requirements to be fulfilled (IEC term is ambient controlled anti-condensation heaters) | None |
| Definition of automatic defrost | US excludes passive defrost systems (with no active heating), IEC includes these and the method will assess their energy accurately, these products are still unusual | No difference for most products (IEC accurately quantifies passive defrost if present) |
| Variable defrost control | Same term and definition | None |
| Defrost test period and defrost interval | Small differences in how defrost intervals are calculated depending on defrost type, elapsed and run-time controllers will be accurately assessed by IEC, variable controllers use a similar calculation approach using Part 1/Part 2 concept | Small to none [(a)] |
| Temperature impacts of defrost and recovery | US specifically exclude temperature excursion during defrost and recovery (unclear why), IEC include but this is added via calculation | Small to none [(b)] |
| Temperature control settings | US has a prescriptive approach, IEC would permit US approach if this was specified locally, but this should be unnecessary | None (IEC more flexible and accurate) |
| Interpolation (2 points) | US specifies a form of linear interpolation from specified temperature control settings | Negligible (IEC more flexible and accurate) |
| Interpolation (3 points) | US permits triangulation – fully aligned with IEC | None |
| Defrost stability | US specifies tight temperature range on cycle before and after defrost. IEC assess larger data blocks before and after as well as power, IEC allows the blocks to be moved depending on the product operation | Negligible (IEC more flexible and accurate) |
| Multiple compartments | US approach combines all of the same type of compartments into a single value, IEC always keeps compartments and sub-compartments separate | None [(c)] |
| Correction factors (K) | US specifies field use factors for various product configurations. These are regional factors and are not specified by IEC | None (continue to apply) |
| Load processing efficiency | Not defined in the US. Optional additional test available in the IEC | Not applicable |

*Notes:* (a) If the US continued to use the current approach to define defrost intervals, the energy impact would be zero. This constitutes only a difference in post-test calculations. (b) Temperature impacts during defrost and recovery are quantified in IEC and these are added after the as part of the post-test energy calculation. The US could elect to specify that defrost temperature impacts are zero in this calculation to maintain continuity with historical data (or both could be calculated). The temperature impact of adding defrost excursions is typically very small – of the order of 0.2 °C or less in a test period, but this depends on the individual product. Including temperature excursions during defrost in energy calculations encourages manufacturers to minimize this in their product designs. (c) IEC always documents all compartments separately. IEC data would allow like compartments to be combined to give an equivalent US value, if desired.

While Table 1 and Table 2 cover an extensive list of topics, most of these are primarily aligned between current US requirements and IEC. The vital point to note is that if the US decided to adopt the IEC test method, there would be little to no impact on practical energy measurements in all but a few areas. In terms of the test setup and appliance configuration, any differences are minor and any energy impacts, once implemented, would be one-off in nature. The only significant area would be applying IEC temperature set points for ambient and compartment temperatures. In general terms, these would be less than 1% impacts (for ambient temperature, this would be in the favor of the suppliers in that the energy would be slightly lower by around 0.5%). The US may elect to continue defining compartment and ambient temperatures in Fahrenheit rather than Centigrade. In that case, there will almost certainly be a need to retest many products, as in most cases meeting both IEC and

US test conditions with a single set of test data can be difficult. Given that most international suppliers are now routinely testing to IEC, this will increase the testing burden for importers and for US suppliers that are exporting. Regarding the lower test ambient in IEC (16 °C), the US could make this an optional additional test during a transition period, with some incentive or reward for products that include this data. Adopting IEC would also mean that the US would have to consider transition arrangements for products with "special compartments".

The current US and IEC are largely compatible in terms of testing approaches. IEC is considerably less prescriptive in how products are tested, providing a lot more flexibility for test laboratories[9] (control settings selected and how the data are processed), and the IEC methods applied will generally result in a more reliable and accurate test result (stability and validity of defrosts and steady state data). None of these should result in any systematic differences in energy consumption.

To summarize, these are the areas where there may be small differences in energy that would need to be managed in any transition from the current US method to the IEC:

- Defining all temperature set points (ambient temperatures, compartment temperatures, target (standardized) temperatures) in Celsius using IEC defined values – these will result in some minimal energy impacts, but generally, much less than 1% as most of the US temperatures are already very close to IEC. Unless Celsius temperatures are used, there will likely be few harmonization benefits arising in the short term as US-specific retesting will be required in many cases.
- The US could adopt the lower ambient temperature energy measurement at a suitable timetable (with an appropriate transition timetable, perhaps voluntary initially with some policy incentive leading to an eventual mandatory requirement, if desired).
- Special compartments would need to be allocated to IEC compartment types.
- Demand response configuration would continue to be specified as a local, regional requirement (no change).
- The US would continue to specify regional requirements for manually switched anti-sweat heaters (no change).
- The US could continue to define defrost intervals for the currently defined defrost types by using IEC data and applying some post-test adjustments to the data as a US regional requirement (note that the measurement method is identical, only the subsequent processing of the data would be subject to a regional requirement).
- The US could continue eliminating the temperature impact of defrost and recovery in energy calculations. Again this would use IEC data and apply some post-test adjustments to the data as a US regional requirement (note that the measurement method is identical, only the

[9] Because the IEC test method measures different elements of the product energy consumption separately, this provides greater flexibility for test laboratories. However, the stringent validity criteria for each element in IEC ensures that each energy component is valid, which reduces opportunities for gaming of product energy claims.

subsequent processing of the data would be subject to a regional requirement). However, there is no technical basis for excluding this particular impact.

- The US currently combines all fresh food and freezer readings into a single value - this loses visibility of individual compartment behavior. There is no technical reason why this is necessary, but the US can derive an equivalent value from IEC data if required.

## *Advantages and Disadvantages: To Adopt IEC or Not to Adopt….*

When considering a transition to IEC or not, several perspectives need to be considered. These can be broadly broken down into four categories:

- Moving to IEC – advantages and disadvantages
- Retaining CFR 430 current requirements – advantages and disadvantages.

The following sections attempt to set out some of the core elements of each briefly.

### *Moving to IEC*

Moving to the IEC has a number of advantages and some possible disadvantages. These are summarized below.

#### Test Procedure Alignment - plus

Using the IEC test method would align the US with other major regions in the world with respect to refrigerator test methods. This has a range of advantages, most importantly eliminating the need to retest products exported from or imported to the US. It will facilitate international trade and will potentially decrease testing and approval costs. Importantly, a common test procedure facilitates international performance comparisons and technology transfer (because a uniform performance metric can be applied), putting ongoing downward pressure on energy consumption.

The IEC test method is currently used in Japan, Australia, New Zealand, Europe, China and Korea. Additionally, many South American countries and east Asian countries are in the process of transitioning to IEC.

#### Greater Accuracy - plus

IEC test methods are state of the art in terms of measurement approach and data processing. Robust validity rules have been developed to provide assurance that test results are accurate and reproducible. While many of the test elements can be completed in very short times for stable and well-behaved products, the method requires the test time to be extended for unstable or poorly behaved products. This is critical in terms of achieving repeatable and reproducible results. The IEC covers all major household refrigeration technologies and controls, and therefore, provides comprehensive cover for any energy program.

Another important consideration is that the IEC test method routinely subjects appliances to a greater array of test conditions. Consequently, circumvention is harder to implement for suppliers and easier to detect for test laboratories under the IEC test regime. Many of the validity checks monitor key aspects of the product behavior and performance, which can flag circumvention activity in a product more readily.

### Options for Additional Performance Tests and Regional Energy Estimates - plus

Adopting the IEC standard provides a range of options for additional performance tests that could be adopted if required. In particular, the IEC storage test (IEC 62552-2 2015) provides a straightforward pass/fail test that assesses the capability of the appliance to maintain internal compartment temperatures across a range of ambient temperature conditions encountered in normal use. This is a fundamental assessment of whether the appliance can deliver the primary energy service it is claiming to provide.

Because the IEC method measures a number of performance parameters separately, it is possible, in the medium-term, to generate online estimates of energy for different regions and even different household sizes, based on the likely “normal use” conditions across the country. This could provide targeted and more useful information to consumers and would allow them to compare the likely energy consumption of different products under conditions that are more representative of their local region and/or household configuration.

### Test Time and Test Complexity - minus

While the setup and configuration of an appliance for testing under IEC is no more complex or difficult than any other refrigerator test method (similar number of compartment and ambient sensors, energy recorded at short intervals, etc.), the IEC test data can take longer to collect than many other existing refrigerator test methods, including CFR 430. The additional time is generally required to ensure that each test element measured meets the required validity requirements. There is no question that testing for two ambient temperatures certainly does take longer and does take more laboratory resources. A typical set of product tests, including run-in, multiple control settings, defrosting, and load processing, can be completed comfortably in a week for most products at each ambient. There is no doubt that testing time can be reduced with laboratory experience and knowledge. As noted, poorly controlled or badly behaved products can take longer to test as more data are required to meet the strict IEC validity requirements. However, this is a desirable consequence in the interests of reproducibility. The IEC method does require more complex post-test data processing, but this impact is negligible once the relevant software is set up.

While the additional resources for testing do appear to be a significant consideration, it is important to consider these additional resources in the wider context:

- These additional testing resources will be offset for exporters as only a single set of tests[10] should be required for all countries that use the IEC test method
- The more complex energy analysis requirements can be covered by software available from a range of suppliers – these can simplify the testing schedules and streamline data processing.

## *Sticking with the Current CFR 430 Approach to Refrigerator Testing*

Keeping the existing CFR 430 test procedure for household refrigerators has several disadvantages, with a few advantages, as summarized below:

### Test Procedure Alignment - minus

Retaining CFR 430 in its current form results in North America continuing to be an island in terms of refrigerator test methods. This results in retesting for all products exported from or imported into the North Amercian Free Trade Agreement (NAFTA) region, which covers the US, Canada and Mexico. If the US moved to adopt IEC, most likely Canada and Mexico would also follow.

### Simple and Quick Refrigerator Testing - plus

The current requirements and approaches used in CFR 430 are well known and understood by suppliers and manufacturers, so there is understandably some reluctance to move to a new set of requirements. While the current CFR 430 is moderately complex and time consuming, there is no doubt that a move to IEC testing would increase testing resource requirements to some extent, at least in the short term. Retaining CFR 430 will also mean that, exporters and importers, increasingly, will have to test their products to CFR 430 and IEC in any case (when selling into IEC markets).

### Representativeness of the Energy Measurement - minus

The current CFR 430 provides a single energy value. Testing for energy at a single ambient temperature gives a relatively poor estimate of energy consumption during normal use across the normal range of indoor ambient temperatures. Detailed research and analysis of test data shows that the changes in energy in response to changes in ambient temperature vary considerably, even for products of a similar size and configuration. Analyses also reveal that an elevated ambient temperature is a poor proxy for estimating the impact of user interactions and other influences, such as changes in ambient temperature, experienced during normal use. There is currently no way to estimate the additional energy consumption associated with user interactions from CFR 430 data. By

[10] For single speed compressors that are rated for a specific voltage and frequency, separate tests are generally required for each rated voltage/frequency combination – this applies to all test procedures (not just the IEC). Some products that use variable speed compressors may be able to generate a single set of test results that are valid for the most common voltage/frequency combinations, but this depends on the product configuration.

only testing at a single elevated ambient temperature, product designers will only optimize the energy consumption of their products at this single elevated ambient temperature. This method does not directly encourage good energy performance across a range of normal use conditions.

Because CFR 430 only conducts a few tests at a single, elevated ambient temperature without door openings, it is generally easier to design controls to circumvent that test procedure to give unrepresentative energy values during testing. There are certainly examples of this in the past (see Appendix B for more details). Defrost behavior for products with electronic defrost controls is likely to be an area where "pushing the limits" in terms of defrost intervals under test conditions is not uncommon[11].

There is currently no test method to measure the additional energy to make ice. Currently, CFR 430 only has a fixed placeholder energy value specified in the test method, regardless of the efficiency of the icemaking system. This fixed value does not encourage the design of efficient ice makers in normal use.

## *Some Notes on Defrosting as Measured in Test Procedures*

While the defrost energy measurement method in the IEC is very competent and accurate, the frost loads in a test laboratory setting are necessarily much lower than would be expected in the field. This is because latent loads from the test room are low (low relative humidity at an elevated temperature and few door openings), and there are no latent loads from food or drinks stored in the appliance during the test. This manifests itself in two ways:

- Frost loads on the evaporator at the time of defrost tend to be somewhat lower than in normal use;
- Defrost intervals initiated by the defrost controllers are much longer than in normal use for variable defrost controllers (less so for run-time controllers);
- There is the possibility of using defrosts in a laboratory setting after only a short period of operation (when first started after a period of non-use with a dry evaporator), resulting in an evaporator with a very low frost load and corresponding low energy.

The US test procedure in CFR 430 has the option used in IEC[12] to quantify the additional energy associated with defrost and recovery separately, but still suffers from the same issues. One area

[11] Many products with electronic defrost controls will naturally have very long defrost intervals under typical test conditions as the ambient humidity is generally low and there is low air exchange because there are few door openings and no food loads (90 hour defrost intervals are not uncommon). This is not necessarily circumvention, but where the product responds in a non–linear manner to small changes in user interaction, then this may be the result of gaming. These very long defrost intervals cause problems for CFR 430 as a valid test period normally has to commence with a defrost. IEC can accept defrosts as they occur and the energy impact is added mathematically afterwards, so not all compartment temperature control settings tested need to have a defrost included. The practice of "forcing" defrosts to start a new test period is convenient for test laboratories, but this tends to generate artificially low defrost and recovery energy, which cannot be detected when testing to CFR 430 as the defrost is nearly always bundled with the following steady state data.

[12] The IEC approach of separately quantifying steady state power and defrost and recovery energy was derived from the US Part 1 and Part 2 approach specified in AHAM and CFR 430.

where there is likely to be "pushing of the envelope" by manufacturers is how defrost intervals are determined. It is relatively easy to detect when a product is under test in CFR 430 (elevated ambient, no door openings). It is easy to push defrost intervals out to long periods. While there is language that states that the defrost controller must operate over a "continuum of possible intervals", this is not that easy to check, and laboratories are rarely asked to investigate.

These factors need to be understood and considered when applying the IEC method in an energy policy, particularly when attempting to estimate normal use.

# Areas for Further Research in the US

While there has been some excellent research on refrigerator energy consumption in the US over the years (see Appendix B for some examples), there are some topics that are still poorly understood where further research is warranted. These issues need to be documented to better understand the energy consumption of refrigerators in normal use. Some of these general topics are listed below.

## Indoor ambient temperatures

There is no doubt that indoor ambient temperatures, where the vast majority of household refrigerators and freezers operate[13], are the most important driver of energy consumption for these appliances, typically explaining as much as 70% of the total energy consumption in normal use. The compilation of indoor temperature data in homes around the US will be a key piece of information to ascertain, especially typical indoor temperature distributions (time of day) and seasonal variations by region. Indoor temperature distributions will depend to some extent on the climate (ambient outdoor conditions), the building shell performance and the degree of indoor space conditioning used at different times of the day and year.

This type of data are readily available for a significant sample of the population through internet enabled thermostats, although this data may not be fully representative of all household types (especially those without any form of central space conditioning). This type of data will allow energy consumption of individual models to be tailored more accurately to reflect typical conditions of use in different regions (for example through a custom web based comparison tool that takes local conditions into account). This would require energy data at two ambient temperatures (as measured in the IEC) in order make such estimates.

## User interactions

User interactions are the next most significant driver of energy consumption for household refrigerators during normal use and these are poorly documented in most regions. This obviously

[13] A small minority of appliances will be located outdoors (on verandas) or in unconditioned garages and sheds. This is also important information to document when estimating stock energy.

varies by household and demographics, but also by climate. Naturally, user interactions will vary considerably across households, depending on habits and practices. Field monitoring of energy and ambient temperature can be used to quantify the impact of user interactions. A methodology to separate energy consumption into its key components is set out in Harrington, L., Aye, L., and Fuller, R. (2018(a)).

With high quality field data, it is relatively straight forward to see the effects of user interactions in the energy consumption profile and to separate these out from ambient temperature affects and defrosting energy (see next section). What is more complex is to make an estimate of the likely sensible and latent heat loads that are directly generated by user interactions. To convert the induced additional energy consumption in the refrigerator into raw sensible and latent heat loads requires an estimate of the refrigeration system efficiency (Coefficient of Performance or COP). System efficiency is known to be highly variable by model and this does not directly correlate to steady state energy consumption, as shown by recent NEEA testing (see Appendix D). For a given fixed quantum of sensible and latent heat load, this will appear as a small induced additional energy consumption for a high efficiency system and as a large induced additional energy consumption for a low efficiency system.

The system COP is difficult to estimate from any generally available data. The IEC load processing efficiency does provide a reasonable estimate of the marginal system COP under normal use conditions. If attempting to quantify user interactions in the field, it would be important to have information on the likely load processing efficiency of each model monitored to enable the measured induced energy from user interactions to be converted back to raw sensible and latent heat loads (which are directly linked to user behavior and actions), which can then be applied more generally to the population.

Another approach where user induced energy can be indirectly estimated is using door opening data. A small early US study showed that door opening data was a critical indicator of user interactions (Gage, C.L. 1995). A larger sample in Australia found that door openings correlated strongly with total user induced load, even though the air exchange from the door openings themselves accounted for less than 40% of the total sensible and latent heat loads. Door openings are an indicator of user interaction but the cooling of food and drinks accessed via door openings accounts for a larger share of user related energy.

## *Defrost behavior of refrigerators in the field*

While there is excellent data on the defrost behavior of many products in the test laboratory, there is surprising little field data available that enables direct comparison of the same (or similar) products in the test laboratory and in the field. From an energy policy perspective, this is a critical piece of data if we are to make reasonable estimates of energy consumption in the field during normal use from laboratory measurements. There are many reasons why laboratory data will be different to field data. The important thing is to understand the differences and drivers and to convert laboratory measurements to more representative field estimates wherever possible. There are two main areas where defrost behavior in the field needs to be examined – differences in incremental defrost and recovery energy and defrost intervals. To quantify these elements, high quality energy data[14] is required from a significant sample of appliances installed in representative homes.

### *Defrost and recovery energy*

Most defrost systems use a heater to actively melt frost from the evaporator[15]. Heater energy has to raise the temperature of the evaporator metal, the air around the evaporator, the refrigerant and the heater element itself. It also has to raise the temperature of the frost on the surface of the evaporator to around 0°C, then overcome the latent heat of fusion of the adhered frost at 0°C and then raise the temperature of any remaining surface water above 0°C. So there is a fixed component of heater energy (even when the evaporator is dry) and a variable component of energy that is in proportion to the frost load (Harrington, L., Aye, L., and Fuller, R. 2018(c)). See Appendix B – Defrost impacts for a more detailed technical explanation.

Once the heater operation is terminated (this is usually controlled by one or more surface temperature sensors on the evaporator that detect when the evaporator surface is well above 0°C), the appliance then "recovers" from the heating operation by starting the compressor to cool the key components (evaporator metal, refrigerant, air, heater element, any remaining surface water) back to their normal operating condition. This longer than normal compressor run is effectively fixed and is dictated by the heat energy to be removed and the operating COP of the compressor under those conditions. So the defrost has three distinct components: fixed component of heating, variable component of heating (proportional to frost load) and the fixed recovery component (this can vary slightly with changes in ambient temperature that will affect the condensing temperature and compressor COP).

While field measurement of defrost behavior is critical to understand how to convert laboratory data to field data, there are some complexities that need to be understood when reviewing field data. Firstly, defrosts can occur at any time in the field, so some will be during periods of heavy use and some will be during periods of no use (in the middle of the night). Defrosts, where there is little

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[14] High quality in this context means power or energy data collected each minute at a resolution of 0.1W or better (true average power per interval) or an energy accumulator with a resolution of 0.01Wh or better. Power factor and voltage data is desirable, but not essential. It is also critical to collect ambient temperature data from the room where the appliance operates (ensuring that this is unaffected by heat sinks and sources, including the appliance itself). The data collection interval can be longer for ambient temperature (5 to 10 min is usually adequate). Internal compartment temperatures and door opening counts can also be very useful, but these are notoriously difficult to install reliably in appliances where users are constantly interacting with the appliance by adding and removing food and drink.

[15] Passive defrost systems do exist in all-refrigerators (and other products) where all compartments are above freezing. Passive systems periodically increase the compressor off time to allow frost to melt off the evaporator. These type of products generally result in some compartment warming during the longer compressor off and assessing their performance in the field would be difficult without compartment temperature measurements.

or no use, can be analyzed to get a comparable estimate defrost and recovery energy as determined by the IEC test method.

The second issue is that defrosts can usually be clearly discerned in the data as the defrost heater is typically a very different power to the compressor. If the power of the defrost heater is similar to the compressor power (common in some Asian products), the separation of the heater energy can be difficult without power factor (or phase angle) data. Mapping the heater power over the seasons will provide a good insight to the defrost controller and how it operates.

Analysis of field data versus laboratory data in Australia found that field defrost heater energy was typically 20% to 30% higher than laboratory measurements in the same or similar models. This is not surprising as humidity levels in homes will be higher and the level of user interactions will be higher (door openings, humidity generated by food and drink).

Field data showed that variable defrost controllers, which use algorithms to keep the defrost heater energy within a target band, generally had fairly constant defrost heater energy through the seasons, while the defrost compressor run time varied through the year. This manifested as fairly large changes in defrost interval through the year. In contrast, run time defrost controllers (which are still used, but are becoming less common), had constant compressor run-time between defrosts but the defrost heater energy varied by season (lower in winter as humidity loads were lower). Harrington, L., Aye, L., and Fuller, R. 2018(c) provides some detailed guidance on the analysis of defrost energy collected during normal use in homes.

This is an area where the relationship between laboratory data and field data in normal use needs to be quantified for the US.

## *Defrost intervals*

This is possibly the most difficult area to characterize and compare laboratory data and field data. There are three main types of defrost controller: compressor run-time, variable (electronic) and demand defrost[16]. Each of these is discussed in turn. It is important to bear in mind that, while in some cases defrost intervals in the field are difficult to estimate from laboratory data, defrost energy only makes up a very modest share of total energy during normal use (typically less than 10%), so inaccuracies in defrost interval will only generate small inaccuracies in the overall energy consumption. Of the topics noted for additional research, defrost interval has the least impact.

[16] Fixed elapsed time defrost controllers do exist but these are unusual (there are some in Asia).

### Compressor run-time controllers

These are relatively straight forward controllers[17] that keep track of hours of compressor running and at the specified total run-time, the system initiates a defrost and recovery. Typically compressor run-time controllers range from 5 hours to 12 hours of compressor run-time, but some models can be longer. Depending on the season, room temperature and degree of user interaction, defrost intervals can range from 6 to 24 hours. As these types of controllers only user compressor run time to determine defrost initiation, the defrost intervals in the field can be accurately predicted from laboratory data (once the effects of ambient temperature and user interactions can be estimated). Run-time controllers are only used on single speed compressors, so their use is declining as inverter driven compressors grow in popularity.

### Variable defrost controllers

These are electronically controlled defrost controllers (also sometimes called long time defrost controllers in the US, which is a related but different type of controller) that use multiple variables to determine when the next defrost event should occur. Typically these controllers use run-time (or a proxy for run-time based on operating hours and compressor speed) and door openings as means of estimating the likely frost load for the next defrost. Some systems use other variables such as room temperature and humidity. The estimated frost load is then compared to the actual heater on time in the next defrost and then the weighting of various parameters is adjusted to improve the next frost load estimate. They typically use an algorithm that aims to keep the defrost heater on time within an optimal window, as determined by the product designer. This is a simple form of machine learning, where the control responds to changes in local conditions in a controlled way by extending or reducing the defrost intervals to keep the defrost heater on time within the optimal range. Under test conditions in a laboratory, these types of systems typically push defrost intervals out to be very long as there are few (if any) door openings, no user loads and low ambient humidity with low air exchange.

The IEC standard requires suppliers to declare the longest and shortest defrost interval that is possible during normal use conditions (this was originally at an ambient temperature of 32°C, but it is proposed that this be at any ambient temperature in the forthcoming IEC 62552-3 Amendment 2). An equation is then used to calculate the nominal defrost interval for the product at 32°C. The equation used in IEC was adapted from CFR 430 Subpart B Appendix A *Clause 5.2.1.3 Variable Defrost Control*, but modified to be based on declared defrost *interval* (elapsed time) rather than declared *run-time* to take into account the behavior of inverter driven compressors (where there is no direct equivalent of run-time).

[17] Typically these are small synchronous motors that operate when the compressor is on and when the allocated accumulated run time is reached, they trip a relay to start the defrost event and then reset themselves.

The area that needs to be researched is how to convert the calculated defrost interval, based on the supplier declared values for shortest and longest defrost interval, into realistic defrost intervals under different usage conditions. Observed performance in the field will obviously be affected by ambient conditions and user interactions, so this is potentially a complex investigation. Initial data for Australia showed that the IEC declared values appears to give overly long defrost intervals, compared to those found during normal use, but this may be different in the US.

### Demand defrost

These are systems that directly measure the frost load on the evaporator, typically using an optical sensor, and use this estimate of frost thickness to decide when to defrost. These systems are relatively unusual. CFR 430 does not deal with these types of controls directly, but would categorize them as long-time defrost controllers. IEC have default parameters for the calculation of defrost intervals for demand defrost, but all systems get the same default values and there is way to differentiate their performance in the test laboratory or in the field. This is clearly where some field research and associated laboratory testing would be useful if these types of defrost controls become more prevalent. If their performance in the field is found to be superior, there would be a strong case to recognize and reward this in both test procedures and energy policies.

# *Appendix A: Technical Differences between CFR 430 Appendix A and IEC 62552-3*

Table 3 on the following two pages sets out a list of technical differences between CFR 430 and IEC 62552-3. In particular, the 2020 editions of the following test methods were reviewed when compiling this table:

- Appendix A to subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Refrigerators, Refrigerator-Freezers, and Miscellaneous Refrigeration Products
- Appendix B to subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Freezers

CFR 430 was reviewed clause by clause, with the corresponding clause in IEC 62552-3 (or IEC 62552-1 as applicable) noted. The requirements of CFR 430 are briefly noted, with a direct comparison of IEC requirements and any comparison notes included where relevant.

When considering this comparison, it is important to note that CFR 430 Appendix A is approximately 15 pages in length and cites AHAM HRF-1-2008[18] for some key testing elements. In contrast, IEC 62552-3 (energy testing) alone is over 150 pages and IEC Parts 1 and 2 together are around 100 pages. Of course, not all parts of the IEC are relevant to this comparison, but in general terms, it does indicate that IEC tends to cover more technical detail and is more definitive than CFR 430 for some of the testing requirements.

[18] CFR 430 published January 2022 incorporated by reference *AHAM HRF–1–2019: Energy and Internal Volume of Consumer Refrigeration Products*. This has changed the structure of CFR 430 Appendix A but not the technical content to any great degree, other than a refinement of the volume measurement method.

**Table 3. Similarities and Differences between CFR 430 Appendix A and IEC 62552**

| Test Parameter | CFR 430 App A reference | IEC reference | Requirement CFR 430 (IEC in red text brackets) | Comparison and Notes |
|---|---|---|---|---|
| Definition of stable operation | 1 Definitions | IEC 62552-3 B.3.2 | Temperature slope comparable at <0.023°C per hour (IEC <0.025 K/h) | Comparable |
| Variable anti-sweat heater control | 1 Definitions | IEC 62552-3 F.2 | IEC term is ambient controlled anti-condensation heater | Same meaning |
| Variable defrost control | 1 Definitions | IEC 62552-1 Clause 3.5.5.4 | (Same term) | Same meaning |
| Warmer energy test ambient temperature | 2.1.1 | IEC 62552-3 clause 6.3 | Ambient 90°F = 32.2°C (IEC 32.0°C) | Almost the same, within test tolerance |
| Cooler energy test ambient temperature | Not specified | IEC 62552-3 Clause 6.3 | (IEC 16.0°C) | Not specified in CFR 430 |
| Ambient vertical gradient | 2.1.2 | IEC 62552-1 A.3.3.2 | Vertical gradient 0.9°C per meter (IEC 1 K/m) | Almost the same |
| General lab configuration | 2.1.2, 2.1.3, 2.8 | IEC 62552-1 A.4, Annex B | Platform, side sensors, rear clearance | Comparable with IEC |
| Anti-sweat heaters | 2.3 | IEC 62552-3 A.2.5 | Anti-sweat ON and OFF (IEC includes these options) | IEC allows any regional combinations |
| Compartment configuration for energy tests | 2.4 | IEC 62552-3 A.1 | Compartment unloaded (IEC same) | Same |
| Sensor masses | 2.4 | IEC 62552-1 A.2.6 | Sensor masses any metal 29mm (IEC brass or copper, 18mm, max 25g) | US larger masses, very small energy impact |
| Ice storage bins | 2.6g | IEC 62552-3 A.2.6.3 | Bins empty (IEC same) | IEC includes checks for circumvention |
| Convertible compartments | 2.7 | IEC 62552-1 Clause 3.3.4 | In highest energy mode (IEC term is variable temperature compartments) | Same technical meaning and requirements in IEC |
| Special compartments | 2.7 | IEC 62552-3 Clause 5.1 | Requirements defined for special compartments (not permitted in IEC) | IEC force all compartments into a standard type |
| Data sampling interval | 2.9, 4.2.3.1 | IEC 62552-1 A.2.6 | ≤4 min except for multi compressor ≤1 min (IEC ≤1 min equal intervals) | IEC exceeds US current requirements |
| Demand response controls | 2.10 | N/A | At factory settings (IEC not directly specified) | IEC in accordance with manufacturer's instructions for normal use |
| Compartment standardized temperatures | 3.2 | IEC 62552-3 Clause 4.1 | Fresh food 3.9°C (IEC 4°C), freezers -17.8°C (IEC -18°C), freezer compartments in refrigerators and cooler refrigerators -9.4°C (IEC no equivalent), cooler compartment 12.8°C (IEC cellar 12°C) | IEC term is "target temperatures", freezer in a refrigerator is halfway between one-star and two-star[19] |
| Temperature control settings | 3.2.1 | IEC 62552-3 Annex E | Set mid-point control initially, then coldest or warmest if resulting temperature is above or below standardised temperatures (one point must have all temperatures below standardised temperatures) | IEC do not prescribe control settings, but is compatible with US general approach |
| Interpolation (3 points) | 3.3 | IEC 62552-3 Annex E | Permits triangulation as per AS/NZS4474[20] App M | IEC the same |
| Interpolation (2 points) | 6.2 | IEC 62552-3 Annex E | Indirectly defines linear interpolation | IEC compatible but more comprehensive |
| Defrost test period | 4.1, 4.2 | IEC 62552-3 Annex C | Test period from defrost to defrost. Long time defrost uses two-part approach (comparable to IEC) | IEC compatible but more comprehensive |

[19] IEC 62552-3 defines the target temperature for a two-star compartment for energy consumption as ≤ -12°C and for a one-star compartment as ≤ -6°C.

[20] AS/NZS4474, "Performance of household electrical appliances—Refrigerating appliances: Part 1: Energy consumption and performance"

| Test Parameter | CFR 430 App A reference | IEC reference | Requirement CFR 430 (IEC in red text brackets) | Comparison and Notes |
|---|---|---|---|---|
| Defrost stability | 4.1, 4.2 | IEC 62552-3 Annex C | Compartment temperature before and after defrost 0.3K for one control cycle: non-automatic 4.1, Automatic 4.2 (IEC Period D and F and 0.5K) | US requirements are very tight and hard to achieve—IEC assesses large block before and after defrost, US does not assess power |
| Temperature sensor placements | 5.1 | IEC 62552-1 Annex D | As per Figure 5.1 and 5.2 of AHAM HRF-1-2008 | Small differences in unfrozen, very similar for frozen. See discussion below |
| Minimum sensor clearance | 5.1b | IEC 62552-1 D.2.4.7, D.2.4.8 | 1” (25mm) (IEC same) | Same |
| Temperature impacts of defrost and recovery [(a)] | 5.1.2 | IEC 62552-3 Annex C | Excludes temperature deviation during defrost (IEC includes) | IEC includes temperature impacts |
| Multiple compartments | 5.1.3, 5.1.4, 5.1.5 | IEC 62552-3 Annex C | Multiple fresh food and freezer compartments are aggregated into a single average temperature (IEC always records each compartment and sub-compartment separately) | Can generate a US value from IEC data if required |
| Correction factors (K) | 5.2.1 | N/A | 1.0 for refrigerators and refrigerator-freezers; 0.55 for coolers and combination cooler refrigeration products to adjust for average household usage, App B = 0.85 for vertical freezers, 0.7 for chest freezers | These are regional factors and are not defined in IEC |
| Defrost interval | 5.2.1.2, 5.2.1.3 | IEC 62552-3 Annex D | Actual test interval; OR one defrost per 12 hours of compressor run time [Long-time Automatic Defrost]; OR variable defrost use formula for run time based on min/max interval [CTL and CTM are default 6 and 96 = default run time of 24 hours] | IEC uses modified version of the US variable defrost equation, otherwise comparable (IEC allow more accurate correction for run-time controllers) |
| Volume measurement | 5.3 | IEC 62552-3 Annex H | As per AHAM HRF-1 (IEC same) | IEC based their volume measurement on AHAM HRF-1 |
| Variable Anti-Sweat Heaters | 6.2.5 | IEC 62552-3 A.2.5 | Defines humidity map for 22°C (IEC requires regional maps to be specified) | IEC allows humidity maps for 16 °C, 22°C and 32°C, IEC covers US |

*Notes:* The reason temperature impacts are excluded from defrost and recovery events in the US is unclear. The US test methods influenced the early Australian test method (AS1430 1986). In AS1430, the temperature and energy were determined over a number of compressor cycles in the last three hours prior to the next defrost (effectively the steady state period). This was thought to be specified as most temperature measurements were recorded on charts in the 1980s, and it required a human to extract the temperature data manually. Inclusion of the temperature rise period during a defrost was possibly deemed too difficult to interpret accurately from a chart. An updated version of this standard (AS/NZS4474. 1 1997) included integration, but still permitted use of temperature determination over the last three hours prior to defrost. With the advent of electronic defrost controls through the 1990s, it was found that a number of suppliers were operating their appliances at warm temperatures after a defrost for long periods and then cooling only in the last three hours prior to the next defrost. This was clearly circumvention as this effect was not evident with door openings or at normal ambient temperatures. The warmer compartment temperatures resulted in much lower energy use for the measured compartment temperatures in the preceding three hours. The next edition of the standard (AS/NZS4474. 1 2007) mandated the integration of compartment temperatures over the entire test period to eliminate this behavior. The IEC standard also mandates the integration of all temperature data at ≤1 min intervals. There is no technical reason why temperature excursions during defrost should continue to be excluded in the US with all data now collected digitally.

From January 2022, CFR 430 adopted the updated temperature sensor positions specified in AHAM HRF–1–2019: *Energy and Internal Volume of Consumer Refrigeration Products*. It is understood that the updated diagrams are substantially unchanged from the 2008 edition of HRF-1. AHAM specifies larger brass or copper cylinders with both dimensions at 29 mm, while IEC specify a maximum dimension of 18 mm. This results in the AHAM mass being approximately four times the thermal mass of the IEC temperature sensors. While this does slow the response time of the sensors, almost all measurements in both standards are focused on average temperatures over fairly long periods (hours and days), so the difference in thermal mass will have negligible effects on the measured results.

**Unfrozen temperature sensor placements**: In terms of temperature sensor placements, AHAM defines positions for three sensors in unfrozen compartments, with these located at 0.75, 0.50 and 0.25 of the vertical height in a simple compartment with no features. The US appears to have retained its historical sensor positions in 2011 and did not align these with IEC. Where there are vegetable drawers at the bottom of the compartment, AHAM specify sensors at 0.67 and 0.33 of the vertical height from the top of the vegetable drawers, with a 25 mm (1") clearance for the bottom sensor above the drawer. The IEC basic configuration for unfrozen compartments is three sensors, with the top two at 0.75 and 0.50 of the vertical height and the bottom sensor 50mm from the bottom of the compartment, with[21] or without vegetable drawers.

Both standards provide detailed guidance on placing sensors where internal fittings interfere with default placements and for non-standard compartment shapes and features. AHAM has retained the location of a temperature sensor under any box evaporator (similar to the specification in ISO15502), while IEC has discontinued this requirement as these configurations are now rare. IEC also provides guidance on sensor placements for very small unfrozen compartments and low height compartments.

Both standards specify slightly different temperature sensor positions for most configurations. However, the practical difference in the measured temperature from these different positions will be generally very small to negligible. While differences will naturally vary by model, the average impact of changing positions should be less than 0.2K, which equates to an energy impact of less than 0.5% in a typical refrigerator-freezer and less than 1% in an all-refrigerator.

**Frozen temperature sensor placements**: In terms of temperature sensor placements, AHAM defines positions typically three or five sensors in most frozen compartments. For taller compartments (>36" or >914mm) the middle three sensors generally at 0.75, 0.50, and 0.25 of the vertical height (quarters) and the bottom sensor is 19mm (¾") from the bottom and the top sensor 31mm (1¼") from the top of the compartment, all located on the center line but with the bottom sensor towards the front and the top sensor towards the back. For compartments less than 914mm height, the sensors at 0.75 and 0.25 are eliminated. For narrow chest freezers (<914mm width) there are temperature sensors at 0.50 of the vertical height with a bottom sensor 19mm from the bottom and a top sensor 31mm from the top of the compartment, all located on the center line. Chest freezers wider than 914mm have an additional top and bottom sensor at 0.25 and 0.75 of the width respectively (this can be a mirror image, depending on the compressor step). There are other variations, such as refrigerated shelves, where three sensors are required between each pair of shelves.

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[21] Where there are vegetable drawers that are the full compartment width, these are treated as the compartment bottom. Various rules apply to part width features.

The IEC configuration is similar, with intermediate sensors at 0.75, 0.50, and 0.25 of the vertical height and 50mm clearance at the top and bottom for compartments taller than 1,000mm, but using two sensors at the top and bottom (total of seven) – top left front and back, bottom right front and back). IEC adapted the US positions for taller freezer compartments, so these are similar. However, for compartments with a vertical height of less than 1,000mm, IEC requires only five sensors (two at the top left front and back, two at the bottom right front and back and one at 0.50 of the vertical height), which in practice will be very similar to AHAM. IEC does not differentiate chest freezers from other types of freezers. IEC gives detailed guidance on placing sensors when internal fittings interfere with default placements and for non-standard compartment shapes. The practical difference in the measured temperature from these positions is likely to be negligible as the positions are very similar in both standards.

Technical details are set out in the AHAM standard and an Asia-Pacific Economic Cooperation (APEC) working document (AHAM-HRF-1 2008; APEC Energy Working Group 2016) and in the relevant AHAM standards.

# Appendix B: Energy Consumption during Normal Use—Key Drivers

## Introduction

Refrigerators are complex thermodynamic appliances. Their energy consumption will obviously be impacted by ambient temperature and user-related heat loads (air exchange from door openings and cooling of warm food and drink). A number of factors affect the energy consumption of a refrigerator[22]. The most important of these are:

1. Ambient temperature;
2. Design and energy associated with the defrost and recovery (for frost-free products);
3. Internal compartment temperatures (user settings);
4. Processing load from the addition of warm air and humidity through door openings and processing load from the addition of food and drink to be cooled (effectively, the efficiency of the refrigeration system);
5. Impact of additional internal humidity in terms of the response of the defrost system (including frequency of automatic defrost cycles) to remove this moisture; and
6. Additional related features including ice and water dispensers, additional doors, multiple compartments, and special use zones.

Test procedures historically have ignored ambient temperature (Item 1), have included the impacts of defrost and recovery (Item 2) (for frost-free systems, at least in a cursory way), and have focused closely on temperature control settings (Item 3). Items (4) to (6) are directly or indirectly related to user loads. User loads have been largely ignored in test procedures around the world[23]. The US attempted to develop a procedure to measure the energy associated with ice makers, but has since opted for a placeholder energy value for this feature based on average data rather than the measurement of specific model performance.

A detailed analysis of field use of more than 250 household refrigerators in Australia over a long period revealed the breakdown of energy consumption impacts attributable to ambient temperature, defrosting and user loads (Harrington, Aye & Fuller 2018a). The paper estimated that across the sample measured, room temperature accounted for around 70% of the total energy, user interactions for approximately 20% of total energy, and defrosting accounted for around 10% of

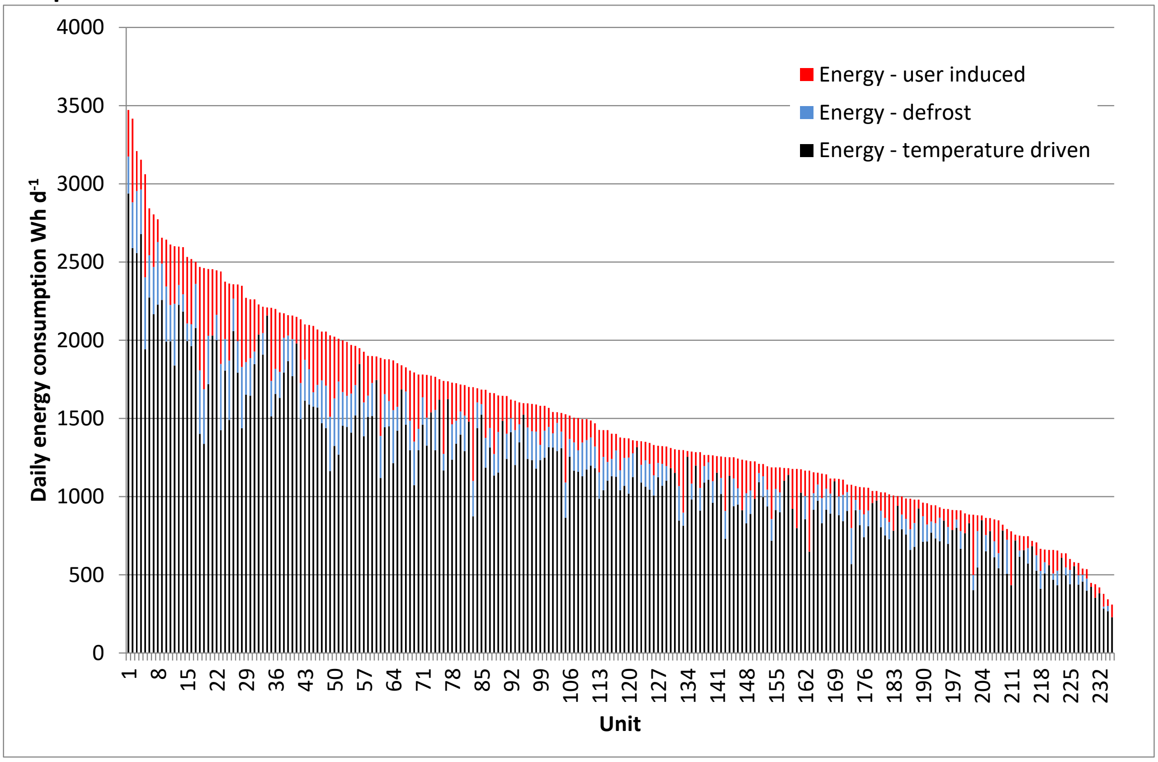
[22] There is also possible longer term deterioration in energy performance with age (wear and tear, failure of components, insulation degradation), although this is complex and difficult to quantify so is not addressed in this paper.

[23] The main exception here is in Japan where their test procedure JIS-C9607 (1986) did include a schedule of door openings. From the late 1990s to around 2006 Japan used ISO15502, but this created many problems. They then reverted to JIS-C9801 (2006) which had door openings and as schedule of added food and drink loads. Some of these elements were adapted for the load processing test in IEC 62552-3 (2015). Japan now uses the IEC standard.

energy during normal use. User interactions vary from less than 5% for secondary appliances and separate freezers to 40% for large households. Interestingly, these end-use shares held across a wide range of climates from tropical to cool temperate (the absolute energy consumption was considerably higher in tropical climates, for example). The ambient temperature share of energy was derived from a function of the estimated steady state energy across the range of ambient temperatures that the appliance experienced during the monitoring. Knowing how the appliance responds to ambient temperature and the likely distribution of indoor temperatures during normal use are vital pieces of information.

A visual depiction of the energy breakdown by end use component is illustrated in Figure 4.

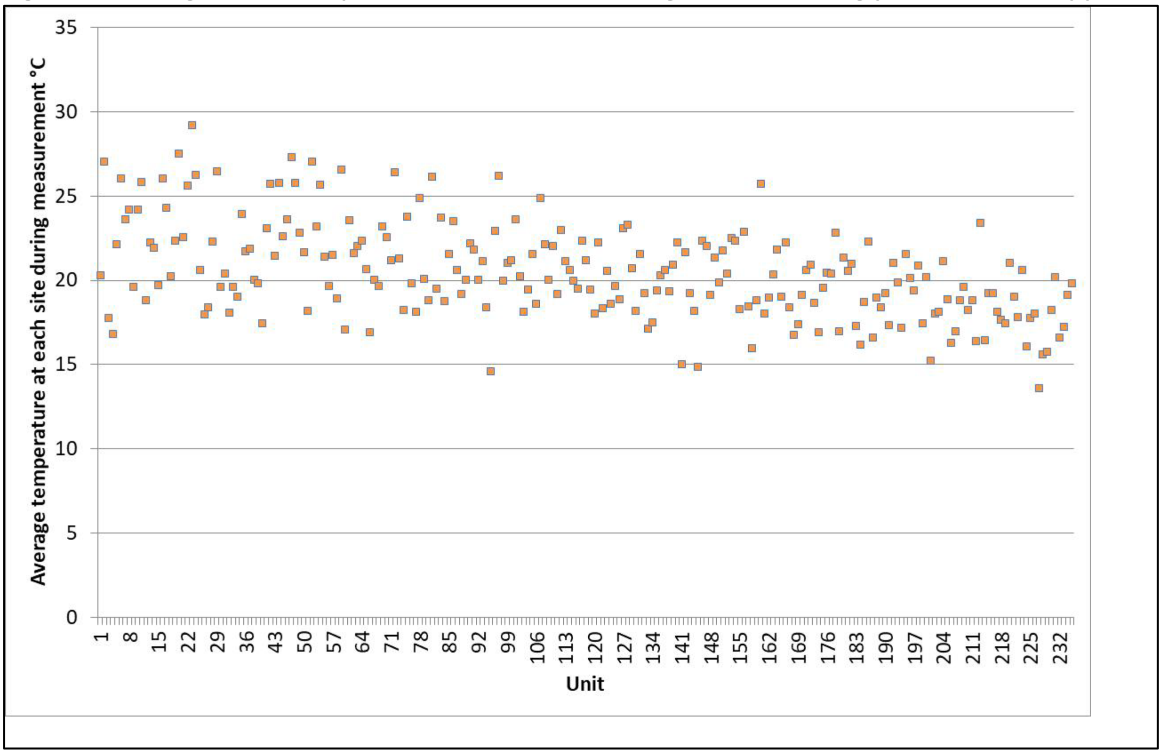
**Figure 4. Average daily energy consumption of 235 appliances disaggregated into end use components**




*Notes:* Source—Figure 7 from Harrington, Aye & Fuller (2018a). Field data collected and analysed by the paper authors. Units sorted by total measured daily energy.

One of the most interesting features of Figure 4, which is found in many end use data sets for refrigerators, is the extraordinarily large spread of energy consumption. In this sample, the highest energy consumption is around a factor of 10 more than the lowest energy consumption. Clearly, this depends to a fair extent on the design and configuration of the individual appliance, the ambient conditions in which it operates as well as the user interactions. The average temperature recorded over the monitoring period for each of the appliances in Figure 4 is illustrated in Figure 5. This clearly explains some of the variations in energy consumption, but far from all of it.

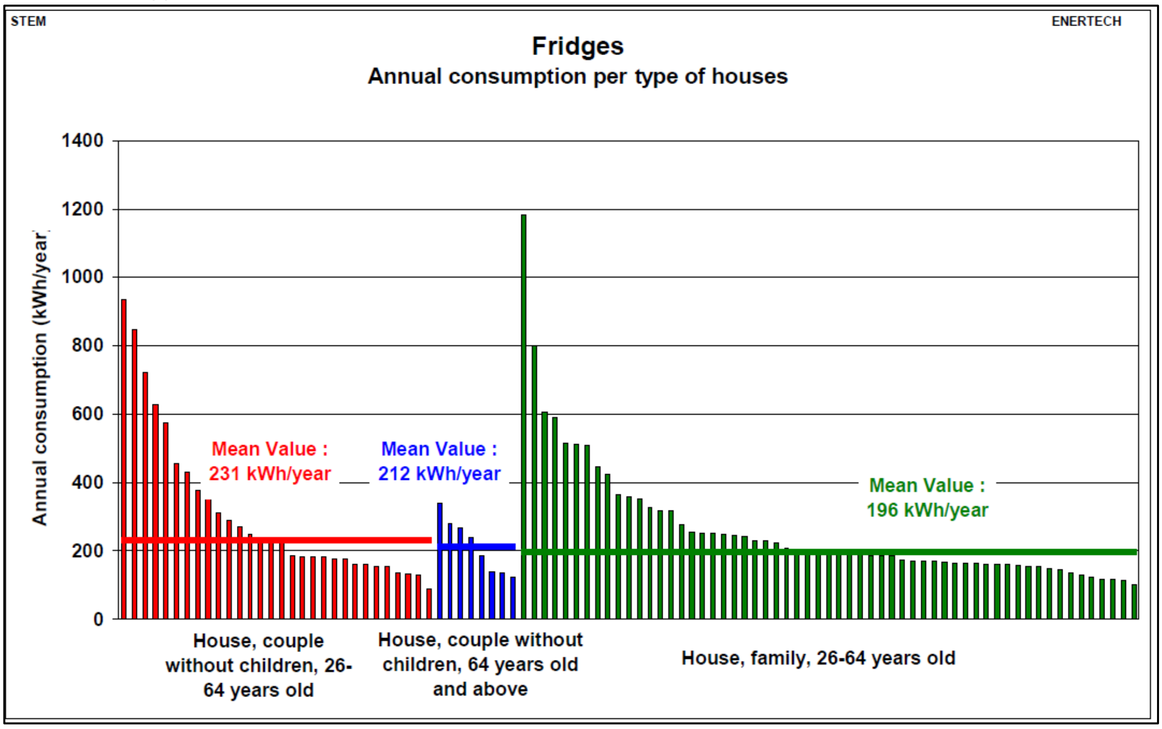
**Figure 5. Average room temperature at each site during the monitoring period for 235 appliances**




*Notes:* Source—Figure 8 from Harrington, Aye & Fuller (2018a). Field data collected and analysed by the paper authors. Units sorted by total measured daily energy (same as Figure 4 above).

Similar distributions are seen in large monitoring samples in other countries as well. A study of 300 houses in Sweden found a wide range of refrigerators' energy consumption, as shown in Figure 6. While the difference between the lowest and highest is not quite as high as that illustrated in Figure 4 (factor of about 8), this should be considered in the context of Swedish homes, which are generally a fairly constant temperature for most of the year (Zimmermann 2009).

**Figure 6. Variation in measured annual energy for single door refrigerators in Sweden by household type**




*Notes:* Source—Figure 2.189 in Zimmermann (2009).

Many refrigerator test procedures set out elaborate techniques to ensure that compartment temperatures are set in accordance with standard requirements (Item 3). This is somewhat important to allow energy measurements to be repeatable and reproducible. However, field research suggests that most users rarely or never adjust their temperature controls (and the few users that do adjust them frequently appear to do so in response to poor temperature regulation by the appliance). Analysis of laboratory test reports for more than 1,000 appliances showed that the energy impacts of adjusting compartment temperature controls are modest at best (Harrington & Brown 2012). Based on reported test data, the energy impact of changes in compartment temperatures was around 5% per °C temperature change for single compartment products; for refrigerator-freezers it was around 3.5% per °C temperature change of freezer temperature and 1.5% per °C temperature change of fresh food temperature in the same appliance. Given the range of types and frequency of compartment temperature control changes in the field, the likely energy impact of this element is less than 5% during regular use in most cases.

## Ambient Temperature Impacts

In simple terms, the energy consumption of a refrigerator under any operating condition (excluding user interaction) is determined by two main factors:

- The effective overall average insulation of the cabinet walls (including penetrations, seals). The insulation determines the heat flow from the surrounding ambient air into the refrigerator cabinet; and
- The efficiency of the refrigeration system that removes the heat gained through the walls, penetrations, and door seals, etc., to maintain constant internal temperatures.

The heat gain into a refrigerator is a function of the insulation effectiveness (thermal transmittance or U value) and the overall temperature difference between the internal compartment temperature and the ambient air temperature surrounding the refrigerator. Actual refrigerators may have several compartments, each with a different U value and each with a different operating temperature, as well as door seals. Even where there are multiple compartments, the total heat gain into the appliance is still linear with changes in ambient temperature because many linear changes (with different slopes) still add to a linear change overall. The change in heat gain can always be considered linear with ambient temperature changes.

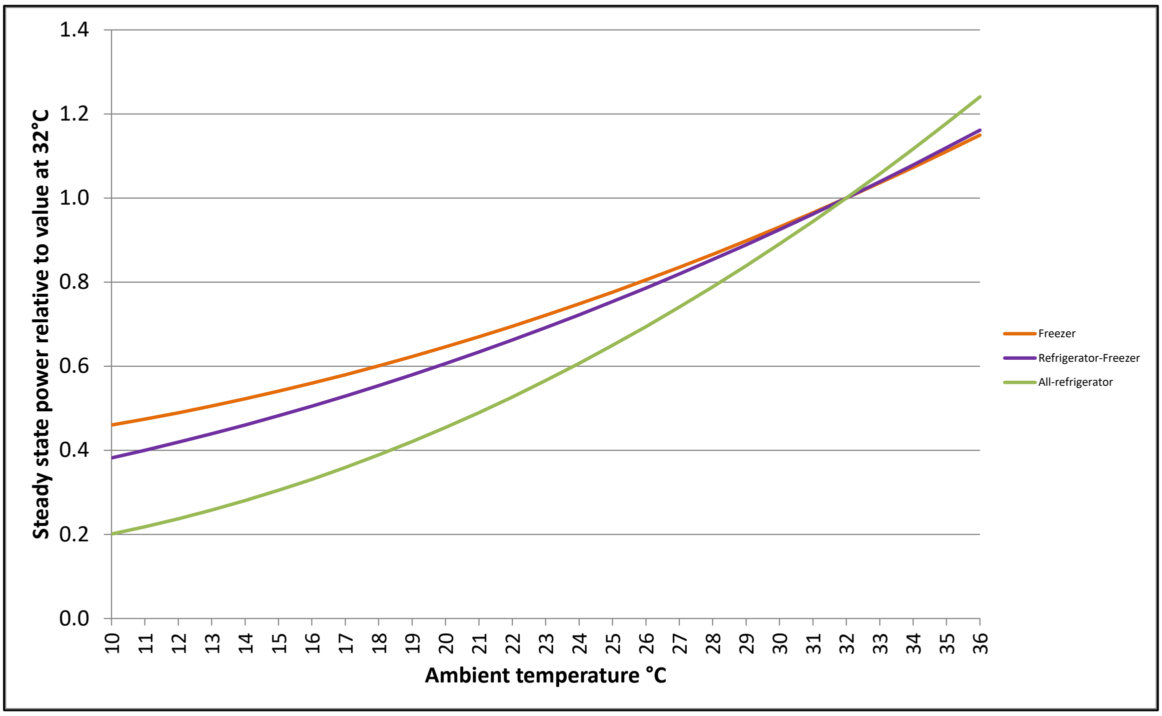
Refrigerators during normal use have other factors that can add to the internal heat load, such as automatic defrost systems, auxiliaries, and heaters. User interactions also add to the internal heat load. These additional internal heat loads must be extracted by the refrigeration system.

The refrigeration system's efficiency depends on a range of factors such as the compressor efficiency (Coefficient of Performance, or COP), the design of the condenser and evaporator, and the expansion system used (typically capillary tubes in household refrigeration). The COP of the compressor is affected by both the evaporating temperature and the condensing temperature. Under normal operating conditions with a constant compartment temperature control setting, the evaporating temperature will remain fairly constant (typically 5°C to 10°C colder than the coldest compartment temperature), while the condensing temperature will increase as the ambient temperature increases. The COP of the compressor is a function of the temperature difference between the evaporating temperature and the condensing temperature. As the ambient temperature increases, the heat gain into the compartment increases linearly, while the refrigeration system’s efficiency decreases. This explains why the energy consumption appears to be a curve as the ambient temperature increases.

Numerous authors have attempted to characterize the energy-ambient temperature response of refrigerators (Grimes, Mulroy & Shomaker 1977; Meier & Jansky 1991; Koa & Kelly 1996; Gage 1995; Harrington, Aye & Fuller 2018b). All have concluded that ambient temperature is a critical factor that influences the overall energy consumption of refrigerators. While some authors have developed generalized factors to estimate the impact of ambient temperature in broad terms, the response of individual products to changes in ambient temperature varies considerably, depending on the design and components used.

Some comparative laboratory data from Australia shows that the energy response for different product types varies substantially, as illustrated in Figure 7. This shows that an all-refrigerator has a much stronger response to ambient temperature changes than a refrigerator-freezer or a separate freezer. This response is because the relative temperature change is larger for an all-refrigerator[24] compared to the other configurations.

**Figure 7. Normalised ambient temperature response for an all-refrigerator, a refrigerator-freezer and a freezer**

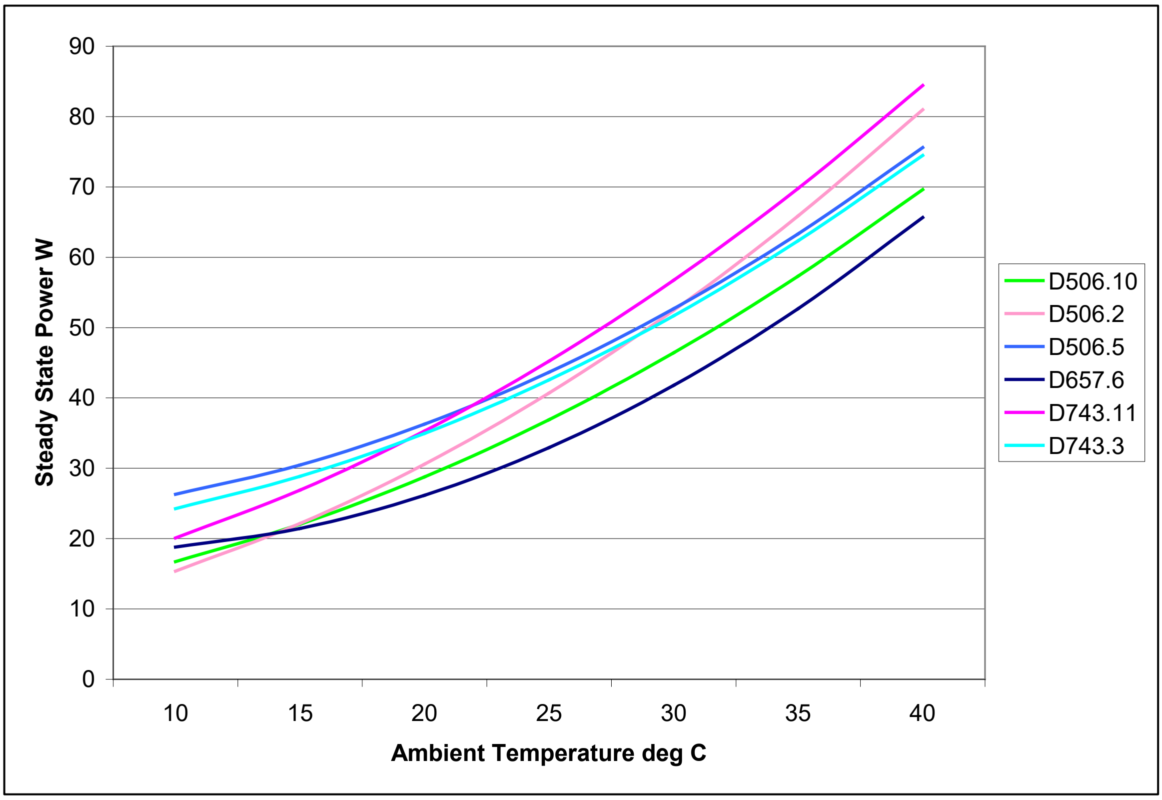



Source: Harrington (2018).

Even for similar product configurations and size, the ambient temperature response can vary considerably, as illustrated in Figure 8. Even though these products are of a similar type and configuration, the ranking changes with ambient temperature.

24 For an all-refrigerator at an ambient temperature of 32°C with a compartment temperature of 4°C has a temperature difference of 28°C – this falls to a temperature difference of 6°C at an ambient temperature of 10°C (a reduction in ΔT of almost 80%). In contrast, a freezer operating at at an ambient temperature of 32°C with a compartment temperature of -18°C has a temperature difference of 50°C – this falls to a temperature difference of 28°C at an ambient temperature of 10°C (a reduction in ΔT of 44%).

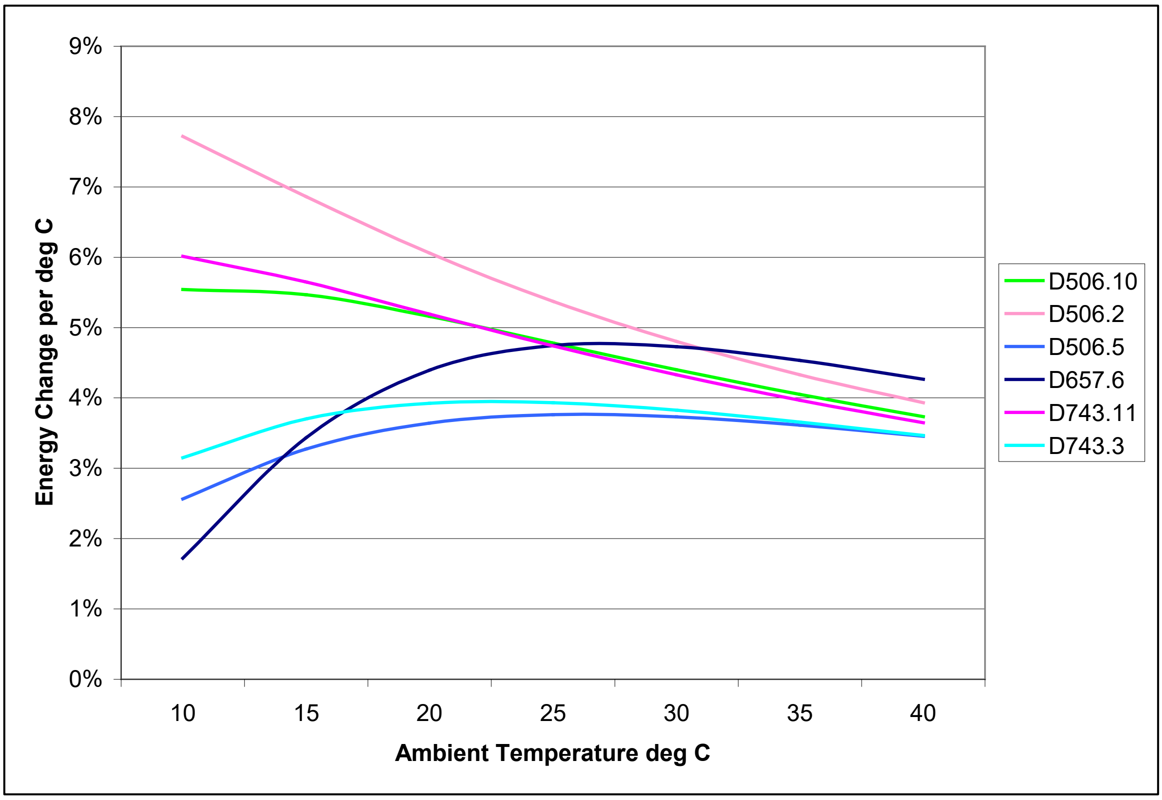
**Figure 8. Energy temperature curve for five bottom-mounted frost-free refrigerators (<14cu ft (400L))**




*Notes:* Source—Figure 2, Harrington (2009).

Importantly, the change in the energy slope with a change in ambient temperature also varies considerably, as illustrated in Figure 9. The slope is affected by the design, construction, and components (temperature performance of the compressor, use of auxiliaries and heaters, etc.).

**Figure 9. Energy temperature slope for five bottom-mounted frost-free refrigerators (<14cu ft (400L))**




*Notes:* Source—Figure 3, Harrington (2009).

Even these very similar products offer little likelihood of accurately predicting the steady state energy consumption under normal use conditions (say at around 68 °F or 20°C) from a single test at an elevated temperature of 90 °F (32°C). However, directly measuring the energy consumption at a higher and lower ambient temperature (as specified in IEC 62552-3) provides an accurate approach to estimating the energy consumption at all intermediate temperatures. See the IEC technical report IEC TR 63061 for guidance on the use of energy measurements at two ambient temperatures to represent operating conditions at intermediate temperatures (International Electrotechnical Commission 2017).

## *Defrost Impacts*

Automatic defrost systems (predominantly frost-free systems) became available in the 1960s. Typically these products use a remote evaporator with air circulation fans that pass air from the refrigerator cabinet over the evaporator coils (typically a tube and fin design). For a product with a freezer compartment, the evaporator temperature will typically be very cold (considerably colder than -18 °C or 0 °F). Any humidity in the circulated air will sublimate to form a layer of frost on the evaporator fins. As this builds up over time, air flow through the evaporator is restricted, and the heat transfer performance of the evaporator degrades (as the frost layer acts as an insulator and reduces heat transfer). Consequently, the evaporator needs to defrost periodically. While a number of possible technical options exist for defrosting (such as reversing the flow of refrigerant for a short period), these are almost never used in household refrigerators (Li et al. 2017). Almost all household refrigerators use an electric heater embedded in the evaporator for defrosting[25]. Defrosting from time to time is necessary to maintain cooling performance. However, an energy penalty is associated with defrosting and recovery (heating the evaporator, refrigerant, air, melting frost, and then bringing the components back down to their operating temperature again). The additional energy required for defrost and recovery has two components that are largely fixed (heater energy to heat refrigerator components and compressor energy to cool these again) and a variable component, which is the energy to melt the frost. These can be characterized as a fixed heater energy component and a variable heater component (that is, in proportion to frost load). This process is now well-understood and well-documented (Harrington, Aye & Fuller 2018c). These fixed and variable elements of a defrost are now quantified in IEC 62552-3 Amendment 1 (2020).

Defrosting energy has been recognized for many years in most test procedures that have dealt with frost-free products. The US test procedure approach, also adopted in some other test procedures, is to start the energy measurement period on a defrost (so the effect of a defrost is included in the measured energy) and to continue for a specified period (typically 24 to 48 hours) or until the next defrost occurs, whichever comes first. While this approach will inevitably lead to some inaccuracies, it must be borne in mind that the additional energy associated with defrosting is approximately 10% of total refrigerator energy in normal use, so some small imprecision in this component may be acceptable.

Early defrost systems were typically controlled by a compressor run-time controller. This is effectively a mechanical counter that keeps track of the hours of operating time for the compressor. A run-time of six to 10 hours is fairly typical for these types of controllers (but they may be a long as 24 hours). Once the compressor operating has reached the allocated time, a relay stops the compressor and then initiates the defrost heater operation. A temperature sensor on the surface of the evaporator terminates the heating operation once the evaporator is well above freezing (typically around +41 °F/5 °C to +50 °F/10 °C). At this point, no frost should remain on the evaporator[26]. The compressor run-time controller is reset and starts to count run time again. This type of system has been in use for over 60 years and is highly reliable. However, the trip time on the controller has to be set at a value that will ensure satisfactory operation in any likely usage condition or climate; these tend to be shorter than necessary for many applications. Run-time defrost

[25] The exceptions to this are in products such as an all-refrigerator, where the compartment operating temperature is above freezing (0°C or 32 °F), where it is possible to passively defrost the evaporator by periodically increasing the compressor off time to allow any frost to melt naturally during the associated compartment warming. Some plate evaporator systems in fresh food compartments can use a passive approach to melt any surface frost or they may use a very small heater in each compressor off cycle to ensure no frost accumulates (these are sometimes called cyclic defrost systems).

[26] One aspect of good refrigerator design (which is somewhat imperical) is to place evaporator temperature sensors in a position that ensures that no frost remains on the evaporator at the defrost termination temperature and to design the heater in a manner that melts the frost as uniformly as possible to minimise energy consumption in this process.

controllers are still present in many products (typically lower-end products). They can generally only be used with a single-speed compressor.

Since around 1990, refrigerators have increasingly included electronic defrost controllers. These operate on a more sophisticated basis and are able to adjust the defrosting interval to match the load and usage conditions experienced by the appliance. While a range of systems and approaches are available, most use the heater on-time during the defrost to estimate the frost load on the evaporator indirectly. Most systems use algorithms that aim to keep the defrost heater on-time within an optimum range (for example, 18–22 minutes). The controller may monitor several other parameters to decide when a defrost is required, such as door openings, compressor on-time or speed, and the ambient temperature. Typically, some form of simple artificial intelligence is used to lengthen the defrost interval if the defrost heater on-time is too short (not enough frost), or to shorten the defrost interval if the defrost heater on-time is too long (too much frost), using the monitored parameters to make better defrost interval estimates over time.

An inherent mismatch exists between the frosting conditions in the test laboratory and in the field. In the test laboratory, there tend to be few door openings, no food in the refrigerator (e.g., fruits and vegetables that respire, or uncovered liquids), and the laboratory ambient air is heated for the test, creating a low relative humidity. During normal use there are many door openings, significant food and drink loads that generate internal humidity a higher relative humidity.

A comparison of field data for over 100 models measured in the field with laboratory data showed that, on average, defrost and recovery energy (per defrost) was around 25% more than for the same models measured in the laboratory (Harrington, Aye & Fuller 2018c). This applied to run-time controllers and variable (electronic) defrost controllers. The overall energy impacts for run-time controllers were similar, as the laboratory defrost interval was generally comparable to the field. However, for variable controllers, the defrost interval in the laboratory tended to be very long (more than 80 hours in some cases) compared to 15 to 30 hours in the field during normal use.

The other issue to consider for laboratory measurements is that many refrigerators are initially tested “out of the box” when new or tested after an extended period of not operating. When a refrigerator is first started in these cases, the evaporator will be effectively dry, so the first few values for incremental defrost and recovery energy will tend to be very low as there is little or no frost load. This can produce a misleading value for the incremental defrost and recovery energy.

### *User Interactions*

The purpose of a refrigerating appliance is to cool food and drinks. The only option for accessing the stored foodstuffs is via the door, so normal use will always involve the opening and closing of doors and the insertion and removal of foodstuffs. Such user interactions are obviously highly variable at a household level and will depend on a range of factors such as the number and age of residents, occupancy factors, habits and practices, and whether the appliance is primary or secondary.

Replicating these types of "normal use" in a test procedure would be challenging because of the diversity of possible actions. This may explain why few test procedures have included specific user interactions in the testing methodology. Two exceptions were the early Japanese Industrial Standard (JIS-C9607 1986) and a later incarnation of this test procedure (JIS-C9801 2006). The JIS standards included testing at two ambient temperatures, a programmed series of door openings for each compartment, and the later edition included the addition of specified heat loads (bottles of water in the fresh food compartment and ice cube trays in the freezer). Implementation of the door opening schedule was particularly demanding on the testing laboratory, so this approach experienced widespread resistance to adoption. The other problem is that the Japanese approach applied a somewhat arbitrary set of user-related actions during the energy measurement. While the energy consumption resulting from these actions was included in the overall results, the impacts of the user interactions could not be separated. However, the experience of the Japanese in refrigerator testing provided a solid foundation for the development of IEC 62552-3.

User loads are particularly difficult to characterize. Firstly, air exchange from door openings is extremely difficult to quantify. The volume of air exchanged depends on the appliance configuration (closed drawers, solid shelves, or wire shelves) and door configuration (front opening or top opening). The air exchange volume is also very dependent on how far the door is opened, the speed of opening and the duration of the opening. Few international studies have instrumented the duration of door openings in their field measurements. A detailed Japanese study found refrigerator doors were opened, on average, 51 times per day for all compartments (JEMA 2009). While no data were provided on door openings as a function of the number of people living in each house, the average number of householders across all houses in the survey was 4.2. The duration of each door opening was, on average, 10 seconds for each compartment type, with a significant spread in the distribution when all openings were considered. An early US study used instruments to count door openings and ascertain the average door opening duration for nine refrigerators installed in homes. The study covered an average of about six months per refrigerator (Gage 1995). This study found an average number of door openings of 10 per person per day for the fresh food compartment and three per person per day for the freezer compartment. The average door opening duration was about 10 seconds for both compartment types. The average duration of door openings for these two studies was consistent with other instrumented studies in the UK (Evans 1998) and Australia (Harrington et al. 2019). The studies consistently found that the self-reported door openings were always much lower than instrumented counts; as a result, user recall of door openings is of low value, even though this is the most common data source cited.

The energy impacts of door openings depend not only on the volume of air exchanged but also the temperature of the air in the compartment and the temperature and humidity of the ambient air surrounding the appliance. Humid air has much higher specific heat than dry air for the same sensible temperature. Very humid air has approximately twice the heat load equivalent of dry air (depending on the temperature being examined). Normal use is likely to generate a large number of door openings, but many of these will be short with limited air exchange. Numerous laboratory studies put the energy impacts of door openings (which may or may not represent normal use in homes) at around 3% to 10% of refrigerator's energy consumption[27] (Grimes, Mulroy & Shomaker 1977; Alissi, Ramadhyani & Schoenhals 1988; Meier 1995; Steen 2012).

Another critical aspect of user interactions is the insertion of food and drinks to be cooled. This is extremely complex and varies daily in each household, and characterizing this effect presents a significant challenge. Attributing the share of user-related load to the cooling of food and drink (as opposed to the energy impact from door openings) is complicated. Still, an analysis of a large end use sample in Australia estimates that door openings account for around one-third of user-related refrigerator energy load, while cooling of food and drink accounts for about two-thirds of user-related energy load[28] (Harrington 2018). However, a count of door openings appears to be an excellent proxy for total user interactions, as more frequent door openings are likely associated with increased cooling of food and drink. To indicate the relative importance of air exchange versus cooling of food, the sensible and latent heat load associated with an air exchange of 3.5 cubic feet (100 liters)(equivalent to a short duration fresh food door opening of less than 10 sec on a large refrigerator of 400 liters) at a room air temperature of 70 °F (21 °C) at a relative humidity of 60%, is equivalent to cooling two fluid ounces of water (around 60ml)(only a very small volume of water equivalent). This qualitatively explains why the majority of user-related load is likely to be associated with cooling food and drink.

Despite the multiple complex heat loads that can arise from user interactions, the refrigerator itself will ultimately see virtually all of these interactions as a sensible heat load on the evaporator (including cooling of exchanged air, condensation of humidity into water in the compartment, and sublimation of humidity as frost on the evaporator). The exception is the rather indirect and relatively small additional energy associated with additional defrosting under more humid conditions. This suggests that the important measurement concerning the impacts of user interactions is how efficiently the refrigerator removes sensible heat from the compartment and discharges it through the condenser to the surrounding ambient air. This testing can be done by adding a known heat load (volume and temperature of water) to quantify the additional energy to remove this added heat load and return the appliance back to a steady state condition (this is the approach adopted in IEC 62552-3). An alternative approach is to establish the steady state power with and without a small internal heater operating to provide a known internal heat load, and then simply calculate the efficiency of removing internal heat.

[27] Note that these studies measured the energy impacts of a door opening sequence that they each devised in their own test laboratory – they did not quantify the impact in homes nor did they claim that the tested door opening sequence was representative of normal use.
[28] Given that user interactions typically account for, on average, of the order of 20% of total energy consumption, this would put door opening energy impacts in the range 5% to 10% of total refrigerator energy consumption, which is consistent with the laboratory studies noted above.

## Comparing Laboratory and Field Energy Consumption

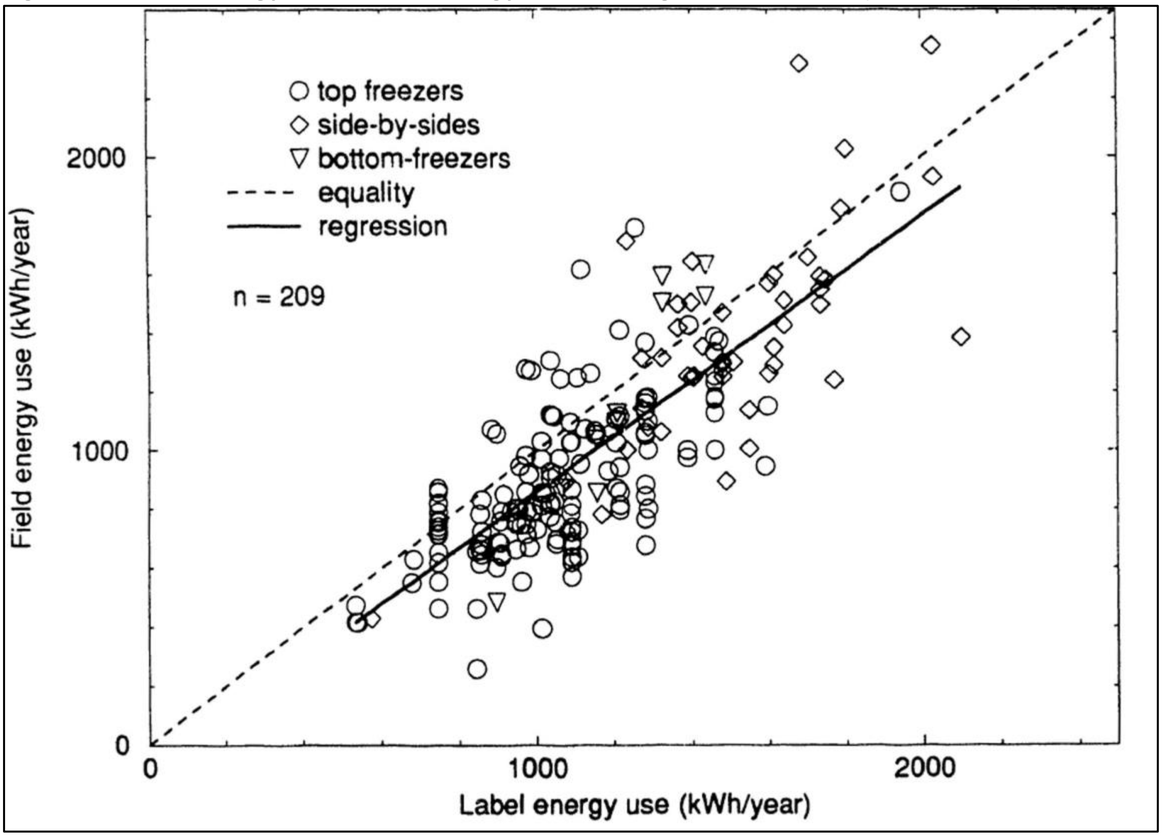
All energy policies rely on a relationship between the energy consumption measured by a test procedure and the energy consumption measured in the field. For many types of appliances, this is relatively straightforward; however, as outlined above, these relationships are particularly complex for household refrigerators as normal use encompasses a large range of possible ambient conditions, user interactions, and differences in product response to these influences. The conversion factor (rule of thumb) used in the US to date has been that field energy consumption is equal to 0.85 of the laboratory-measured data for household refrigerators. The veracity of this appears to be fairly weak based on the assessment of two significant US studies examined below.

The approach adopted by the US in 1977 was that a simple measurement was preferable and that an elevated ambient temperature would somehow provide a proxy for user interactions. One of the earliest technical papers is Grimes, Mulroy, and Shomaker (1977), looks at the impacts of ambient temperature, door openings, loading, internal temperatures, and ambient humidity on energy consumption. The paper concludes that ambient temperature is the most important impact, but it appears that these important conclusions were not considered when energy test methods were developed in Canada and the US.

Alissi, Ramadhyani, and Schoenhals (1988) undertook a similar investigation to examine whether an elevated ambient temperature was capable of compensating for additional energy consumption associated with normal use. The authors state, "The major premise of the current labeling test procedure (in the US) is that closed door performance in a 90 °F (32.2 °C) test environment approximates operation under more realistic environmental conditions, involving somewhat lower ambient temperatures, with door openings" (page 1713). The paper concludes, however, that little field data are available against which to assess the specific experimental regimes undertaken in the lab.

An early US study was conducted by Meier (Meier 1995) and followed earlier studies by the same author (Meier & Heinemeier 1988; Meier & Jansky 1991). The 1995 paper states that "The DOE test (method) is unlikely to correctly predict the consumption of an individual unit to closer than about 40%" (Meier 1995, page 238). The subsequent analysis compiles energy data with indoor temperature data for a number of sites. It correctly concludes that ambient temperature is one of the major drivers for energy during normal use. It is also one of the earliest studies to measure internal storage temperatures in the field. Figure 10 shows US data for refrigerator-freezers—note that for the same energy label value, the likely annual variation in energy is on the order of +30% to -50%. While some industry advocates have cited the 1991 Meier paper as supporting the DOE's 90°F test method and field energy consumption (US Department of Energy 2021a), more recent research does not support this argument.

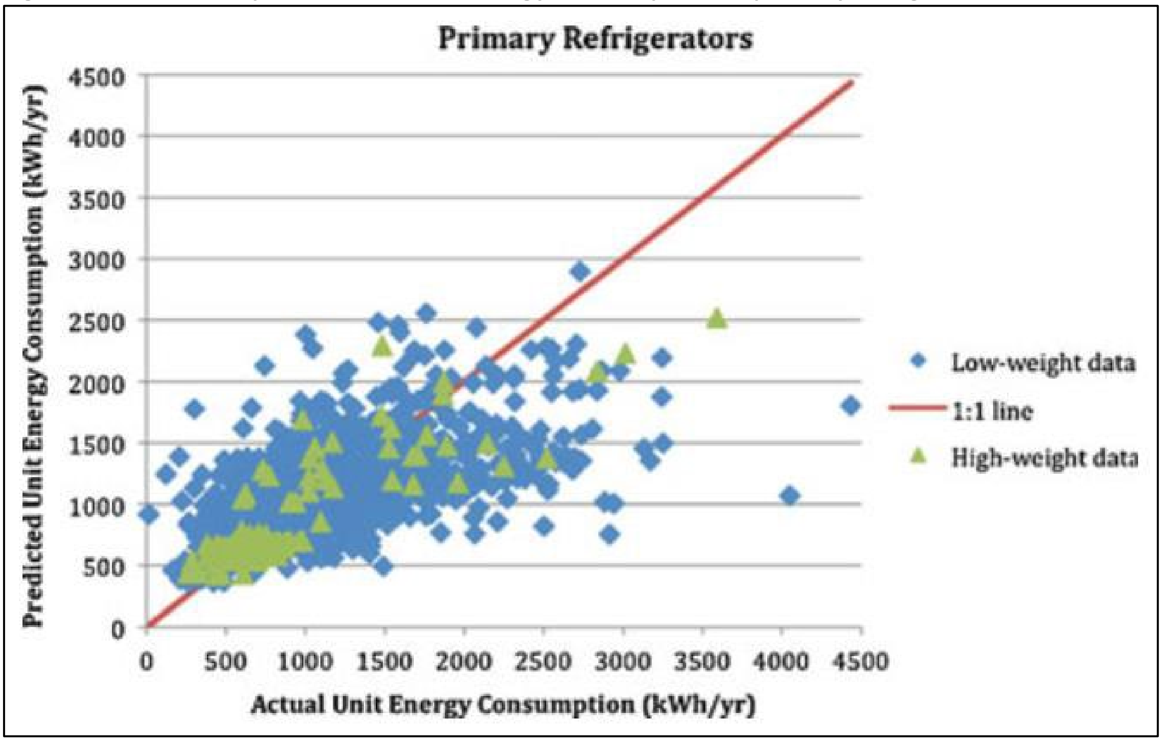
**Figure 10. Label energy versus field energy for US refrigerator-freezers (annual data)**




*Notes:* Source—Figure 4 from Meier (Meier 1995).

A more recent US study used the same approach but a much larger data set (Greenblatt et al. 2013). This study took field-metered energy use data for 1,467 refrigerators and 185 freezers from seven previous studies conducted between 1992 and 2010 and used these to calculate usage adjustment factors (UAFs), defined as the ratio of measured (in the home) to tested (in the lab) annual energy use. While this is an ambitious paper covering an impressive collection of data and analysis techniques, it has some severe weaknesses. Unlike earlier studies (Meier 1995), many of the measured data are for short periods (in some cases less than a day, usually less than a week), and there are no associated indoor air temperature data, no control over seasonal aspects, no data on user interactions during the measurements, and so on. Regressions are undertaken on product type, outdoor temperature data, and climate. The paper shows that variability at a product level is extremely high, which is hardly surprising in the context of the data quality. It proceeds with sophisticated statistical techniques to explain these differences. While the authors claim some success in their analysis, a great deal of noise is generated by poor-quality data that cannot be eliminated, as illustrated in Figure 11. The paper sought a high-level, broad correction between laboratory measurements and field measurements (UAF; however, the results provide limited quantitative insight into energy drivers at an individual product level).

**Figure 11. Actual vs. predicted annual energy consumption of primary refrigerator-freezers**




*Notes:* Source—Figure 6 of Greenblatt et al. (2013). Note that the field measured energy consumption is on the X-axis in this figure, while it is on the Y-axis in Figure 10.

## *Optimization of Product Designs*

Under the current system, refrigerator energy consumption must be measured and declared on the EnergyGuide label (US Federal Trade Commission 2021), and products must meet MEPS levels specified in regulations (US Department of Energy 2021b). In such a competitive environment, suppliers are naturally driven to optimize the energy performance of their products against the test procedure, as this is the only metric against which they are assessed. Suppliers are unlikely to consider optimizing the energy performance against conditions of normal use as they will never be evaluated under these conditions. As discussed above, field measurement of refrigerator energy consumption is complex and difficult at the best of times. Consumers are unlikely to complain about any discrepancy between the label energy and the energy measured during everyday use, as most refrigerator owners do not or cannot meter the electricity consumption of their refrigerator.

An early study tested a range of products against a range of test procedures and attempted to determine whether it was possible to undertake some energy conversion equivalence between them (Bansal & Krüger 1995). The paper concluded that any attempt to do so is fraught because many of the key pieces of information required are not quantified in the test procedures themselves. Bansal and Krüger concluded that products from different regions have their designs optimized for the test procedure against which they are customarily assessed. This early work helped to inspire the development of a new global test procedure for refrigerators under the IEC (IEC 62552-1 2015; IEC 62552-2 2015; IEC 62552-3 2015).

Product design needs to address various performance parameters, including energy efficiency, temperature control, and temperature balance. Energy efficiency under different operating conditions is affected by the heat gain, operating efficiency of the refrigeration system, cycling and associated cycling losses, and the use of heaters and other auxiliaries. These are complex interactions that can only be assessed by direct measurement. Investigations have also shown that the optimum refrigerant charge changes with ambient air temperatures, which can lead to some sub-optimal operation in normal use conditions (Björk & Palm 2006; Boeng & Melo 2014) as appliances are generally configured for optimum performance under the relevant standard test condition.

## Circumvention

IEC 62552-3 defines circumvention as:

*A circumvention device is any control device, software, component or part that alters the refrigerating characteristics during any test procedure, resulting in measurements that are unrepresentative of the appliance's true characteristics that may occur during normal use under comparable conditions. Generally, circumvention devices save energy during an energy test but not during normal use*. (IEC 62552-3 Clause 7)

Computers control most modern mainstream and high-end refrigerators. These controllers monitor internal temperatures, ambient conditions, user interactions, and defrost performance, and make ongoing decisions to optimize the refrigerator’s (or freezer’s) performance. Such computers have little difficulty determining when they are under test in a test laboratory, particularly when the test procedure is simple and constant.

The most common approaches to circumvention in refrigerators are to change the defrost frequency, turn off heaters (anti-condensation or heaters to stop pipes freezing in ice makers), or change the compressor cycling. While some good approaches exist for identifying circumvention, codifying these is dangerous as doing so allows software engineers to develop even more elaborate circumvention approaches. The more diverse the tests and the more conditions examined in the test laboratory, the more difficult it is to achieve circumvention.

The example of Volkswagen evading the emission control standards on vehicles from 2009 to 2015 (so-called Dieselgate) is well-known and received much international press (Mercedes Benz were also found to be undertaking similar circumvention on some of their diesel vehicles). However, both car and appliance suppliers have engaged in similar deceits for many years (Meier 2015). Many historical examples exist of past potential circumvention behavior by refrigerator suppliers. Some notable ones are:

- At least one major manufacturer was found to have configured products to display low energy consumption by switching off auxiliaries with the ice making energy test in order to qualify for ENERGY STAR (Meier 2015).  The same circumvention was also found in products in Australia resulting in an enforceable undertaking by the Australian Government (Australian Competition and Consumer Commission 2010).

- Also in Australia, one manufacturer was found manipulating the compressor cycle length on some products when there were no door openings while the appliance was at an elevated test temperature (32°C). The longer cycles resulted in poor temperature control and lower energy consumption.
- One supplier turned off internal heaters and auxiliaries when the ambient temperature was between 88 °F and 92 °F with no door openings. The heaters and auxiliaries were on under all other usage conditions.
- In Australia in the 1990s, the test method specified that the compartment temperature was determined in the three hours prior to the next defrost. With the advent of electronic controls, a number of suppliers were found to be manipulating the compartment temperatures to be warm for most of the test period and only reduce them again in the three hours prior to the next defrost; this resulted in much lower energy consumption measurements. This behavior was not present at normal ambient temperatures or with door openings. This behavior was only effectively eliminated by mandating integration of compartment temperatures over the whole defrost control cycle, removing any incentive for such temperature manipulation.
- Many suppliers with electronic defrost controllers substantially increase defrost intervals when there are no door openings, but immediately reduce defrost intervals to short periods when some door opening activity is present.

The issue of defrost interval for frost-free products with electronic controllers presents a challenge as it is expected that defrost intervals would tend to be very long under typical test laboratory conditions. Determining whether defrost intervals track frost loading and vary over a continuum of intervals is the key to assessing whether circumvention is present.

Electronic controls should be a good thing as they provide opportunities for appliances to optimize their performance in response to changes in usage and operating conditions, hopefully leading to reductions in energy consumption during normal use. Unfortunately, these same controls can, in theory, be used to reduce energy use during a test procedure measurement but not save any energy during normal use. The solution to this problem may be to subject appliances to a greater variety of test conditions in the test procedure that are more reflective of normal use. This makes it increasingly difficult for a computer to determine whether the product is being tested or not. The other solution may be to expand the range of routine energy measurements in the field. This is critical for energy policy evaluation, but can also identify any potential circumvention behavior during normal use. It is important to remember that the VW scandal was unveiled only by scientists undertaking emission measurements on vehicles during normal use on the streets. In the long term, all appliances should be able to measure their own energy consumption and centrally report this on an ongoing basis. Ultimately this could lead to a large reduction in the need to test products in test laboratories.

One key policy challenge is that test procedures should encourage and reward smart controls that save energy during normal use (e.g., anti-sweat heaters that are operated in response to ambient conditions, adaptive defrost controls that reduce defrost energy consumption during low use periods) but penalize, or at least do not reward, controls that save energy only during the energy test procedure. This is not as easy as it sounds, particularly if the test procedure is not able to represent normal use.

# *Appendix C: Background on the Development of the New Global IEC Test Method*

## *Background*

The International Standards Organization (ISO) developed refrigerator test methods in the 1990s. While these were nominally international standards, they were predominantly developed in Europe. Of particular concern was the lack of experience with frost-free systems—the first frost-free test method was only published by ISO in 1995, some 15 years after the US had commenced mandatory energy labeling for these appliances and 35 years after their widespread use in household refrigerators. The other issue was the existence of four separate ISO standards to cover the normal range of household refrigeration products (ISO5155 1995; ISO7371 1995; ISO8187 1991; ISO8561 1995). Inevitably, having four separate standards for a single product type led to discrepancies and inconsistencies in testing details across these product types. To overcome these issues, a project to combine these four standards into a single test method commenced in 1996 and culminated in the publication of a single ISO standard for household refrigerating appliances (ISO15502 2005). During the development of the new ISO15502 standard, many countries outside of Europe (most notably US, Japan, Australia, and New Zealand) raised serious concerns with the way that energy was measured in these standards[29]. These countries agreed to put aside these concerns if an undertaking was given to develop a new global test method for household refrigerators that incorporated the experience and knowledge of all countries, especially those with extensive experience with frost-free products. The ISO meeting agreed to this proposal and work commenced on a new global standard in 2006, just after publication of the combined standard ISO15502 in 2005.

In 2006, IEC Technical Committee 59 (Household Appliances) took the unusual step of writing to the International Standards Organization to request that responsibility for household refrigeration[30] be transferred from ISO to IEC. This request was accepted in 2007. Subsequently, ISO15502 was republished as IEC 62552 (2007) (identical) and the work on a new global test method was transferred to IEC. This work received strong ongoing contributions from the US, Brazil, many European countries, China, Japan, Korea, Australia, and New Zealand.

IEC recognized that refrigerators are a product for which energy use is strongly influenced by ambient temperature. As this product was already regulated in many countries around the world, there had to be a way for different countries and regions to use one set of standardized test

[29] There were a raft of technical concerns, with one of the major ones being the measurement of energy consumption with freezer test packages present, which slows testing and decreases accuracy.

[30] Household refrigeration was covered by ISO Technical Committee 86, which covered compressors, air conditioners, commercial refrigeration and refrigerants. Household refrigerator manufacturers argued that they had more in common with appliance manufacturers covered by IEC TC59.

measurements to generate locally relevant energy values. Generating worldwide acceptance presented the challenge of finding a way to define a set of measurements without generating disparities in the test approach needed across regions. It was agreed that a single ambient temperature would never provide adequate data applicable to all regions.

## *Technical Development of the Test Method*

Extensive research showed that the energy response of different products to changes in ambient temperature varied considerably and that it could never be accurately predicted from an energy reading at a single (elevated) temperature. Even for products of a similar type and configuration, the response to ambient temperature changes varied somewhat, due to a range of design and configuration differences.

However, when energy values were measured at two widely spaced ambient temperatures, the energy consumption for all intermediate ambient temperatures could be accurately predicted[31]. The two ambient temperatures selected by IEC for energy performance were 16 °C (60.8 °F) and 32°C (89.6 °F) for the following reasons:

- The higher ambient temperature of 32°C was well-established in many existing test procedures such as those in the US, Australia, and ISO tropical.
- The lower ambient temperature of 16 °C was well-established for performance tests in the existing ISO/IEC standards (storage test).
- IEC agreed that 16 °C and 32°C encompassed the likely range of normal use in most climates and regions around the world.
- The Japanese, who previously used two different ambient temperatures (15 °C and 30 °C) (JIS-C9801 2006), agreed to move to the proposed IEC ambient temperatures in the interests of global alignment.
- Europe agreed to move from an ambient temperature of 25 °C to the proposed IEC ambient temperatures in the interests of global alignment.

As outlined previously, the energy consumption of household refrigerators appears as a curve because, while heat gain into each compartment is linear with changes in the difference between ambient temperature and compartment temperature, the compressor efficiency declines as ambient temperatures increase, meaning that the energy use increases more quickly than the ambient temperature. This impact is well understood and is captured accurately by the two ambient temperature energy measurement approach in the new IEC test method. US laboratory tests recently commissioned by NEEA have confirmed this (see Appendix D for details).

[31] Some rare exceptions exist, mainly when significant compensation heaters start to operate at specific ambient temperatures, although these designs are increasingly rare.

Because the new global IEC test method started with a blank sheet of paper, IEC had the opportunity to incorporate the best state-of-the-art test methods, learning from all existing test methods and using the best digital techniques for data acquisition and processing. Key elements of the IEC test method are:

- Compartments are unloaded (air only) for energy measurements.
- Steady state power is established for each temperature control setting (no defrost).
- Defrost events are separately measured and characterized in terms of energy and temperature impacts.
- A separate test has been developed to measure the efficiency of removing heat loads associated with user interactions (load processing efficiency test).

## *IEC Test Method Components*

One of the great improvements in the new IEC method is the range of checks and balances to ensure that steady state power data at each ambient temperature and control setting meet strict validity criteria; this ensures robust and accurate data, even for products that behave poorly in a test laboratory setting. Each defrost event must also meet strict validity criteria before it can be used in subsequent calculations.

When tested to the new IEC test method, suppliers now must be more attentive to their energy performance across all ambient temperatures likely to be encountered in normal use, and optimize it. Issues like ensuring temperature balance between compartments (for refrigerator-freezers), more accurate compartment temperature control, and the elimination of inefficient technologies such as low ambient compensation heaters, are all positive design pressures on suppliers from the IEC test that will generate positive benefits in normal use.

### *Steady State Approach*

The IEC method requires a minimum test period of six hours at each temperature control setting. However, the appliance must be extremely stable for such a short test period to be achieved. A more typical test period is 12 hours for a stable product. The IEC test method requires that any selected test period be broken into three separate blocks in order to assess stability. Each block consists of a whole number of temperature control cycles[32]. Each of these three blocks are checked for length, power, and temperature in each compartment. In order to meet the stability requirements, the spread across all three blocks and the slope across all three blocks must be within strictly defined limits for power and temperature. This approach requires application of some post-test analytical techniques to demonstrate validity. Sampling of test data is at 1 min intervals (or less).

[32] Temperature control cycles can be based on measured compartment temperature cycles or compressor cycles where there is clear and regular cycling of the cooling system.

### Defrosting Approach

Defrosting is a small but significant component of energy consumption in household refrigerators. The IEC approach builds on the Part 1/Part 2 approach used in the DOE test method, but with additional checks and balances. Importantly, the IEC method separately quantifies the incremental energy use for a defrost and recovery event as well as the temperature deviation in each compartment. The method establishes the steady state power and compartment temperatures before and after the defrost. These must return to pre-defrost values after defrosting is complete for the defrost to be valid. The method looks at the total energy for the defrost and recovery and subtracts the steady state power that would have occurred in the absence of the defrost in order to calculate the incremental energy use. Similarly, the temperature impacts during defrost and recovery are determined by calculating the difference in actual compartment temperatures during the defrost compared to the steady state temperatures that would have occured.

Defrost intervals in IEC are directly measured for fixed time and compressor run-time controllers. For electronic defrost controllers, the IEC has adapted a version of the US DOE approach for long-time defrost controllers. However, this has been converted to an equivalent elapsed-time formula to cover inverter-driven compressors that may not cycle in the test (the US formula uses compressor run time to estimate defrost interval; this is not applicable for variable speed or multi-speed systems).

The approach in IEC provides a method for the user to accurately include the incremental defrost energy and the temperature impacts of any defrosts for any selected defrost interval (using a formula).

### Load Processing Efficiency

User loads are an important element of refrigerator energy consumption, accounting for around 20% on average of total energy during normal use. The IEC test method directly measures the efficiency of removing a specified user-added heat load from the refrigerator; this is called the Load Processing Efficiency Test. The test places a defined warm water load into unfrozen compartments and a defined amount of water in ice cube trays into the freezer (as applicable). The volume of water placed in the fresh food compartment is 12g per liter of unfrozen volume and 4g per liter of frozen space. The water is left in the test room for at least 24 hours prior to placement (so it is assumed to be at the ambient test temperature before insertion). It is placed in the appliance with a one-minute door opening at the start of the test. The steady state conditions after this load is processed must return to a condition comparable to the steady state conditions before processing (a valid steady state period must be achieved before the start of the test and at the end of the test). The additional energy used by the appliance to remove this additional heat load is then calculated over and above the steady state power at the end of the test. The additional energy used by the appliance to remove the heat and the known amount of heat removed from the water (based on the ambient temperature and the final compartment temperature) can be used to calculate the efficiency that heat loads are removed from the appliance. The IEC standard allows the calculation of the load processing efficiency (effectively a marginal COP value), which can then be applied to a locally specified user load. Alternatively, the load defined in the IEC test method can be scaled using a multiplier to reflect user energy loads in a specific region.

Though these user loads are not intended to represent any specific set of user interactions, they do measure a key performance parameter for the refrigerator—how efficiently internal heat loads are removed from the appliance. This allows different regions to generate locally relevant user load functions as part of the IEC suite of tests. It allows policy makers to define heat loads representative of user interactions in a particular country or region and then estimate the additional energy consumption for each appliance from these heat loads.

How efficiently the refrigerator removes user added heat loads (as measured by the IEC test) is an important performance parameter that must be measured directly. It correlates poorly with the steady state energy consumption of a refrigerator and, in many cases, only poorly correlates with the technical efficiency of the compressor used in the appliance, so there are no indirect ways of estimating this performance parameter with any accuracy. This is because many other design components can impact the load processing efficiency in addition to the compressor specification. Only by measuring the load processing efficiency is it possible to reward suppliers that make products that remove user heat loads in an efficient manner.

### *Auxiliaries*

IEC has a method for handling the presence of ambient controlled anti-condensation heaters. Its method is broadly compatible with the US approach in that it includes 10 x 10% humidity bins. However, the IEC approach includes optional ambient temperature ranges of 16°C and 32°C in addition to the 22°C used in the US.

The IEC test method includes a procedure for measuring the additional energy to make ice for tank-type ice makers (where there is no mains water connection and water is drawn from a tank that the user manually fills—usually called a water reservoir in the US). This test uses a similar principle to the load processing efficiency test; however, interpreting the results is more complicated as compartment temperatures during the ice making process can be colder or warmer than the equivalent steady state conditions before or after ice making, thus rendering the apparent efficiency of ice making either less or more efficient (respectively). The test procedure determines the additional energy used to make the mass of ice produced during the test process. Typically, whole harvesting cycles are included until the ice storage bin is filled of its own accord.

An equivalent test for ice makers connected to mains water is not yet included in the IEC method. However, an amendment may address this area in the future if the US expresses interest, as the majority of these products are found in North America[33]. Mains water ice makers are a valued and common feature in the US, and recent testing has found that they can consume significant energy (see Appendix D). Testing by NEEA found considerable variation in the efficiency of ice making production, which was not related to steady state power consumption or even to load processing efficiency. These findings suggest that the measurement of the efficiency of ice production is a core parameter that the US should consider.

### *Interpolation*

In order to provide the highest level of comparability among products, the IEC defines target temperatures for each type of compartment, as set out in Table 4.

**Table 4. Target Temperatures for Energy Determination by Compartment Type**

| Compartment type | Target average air temperature °C |
|---|---|
| Pantry | 17 |
| Wine storage | 12 |
| Cellar | 12 |
| Fresh food | 4 |
| Chill | 2 |
| Zero star | 0 |
| 1 star | -6 |
| 2 star | -12 |
| 3 star and 4 star (freezer) | -18 |

*Notes:* Source—Table 1 from IEC52552-3 (2015).

The overall approach to compartment temperatures is set out in IEC 62552-3 Clause 5.1 as follows:

> *The **energy consumption** of an appliance is determined from measurements taken when tested as specified in Clause 6 in an **ambient temperature** of 32°C and an **ambient temperature** of 16 °C. The value for **energy consumption** determined in accordance with this standard shall be for a **temperature control setting** (or equivalent point) where all average **compartment** air temperatures are at or below the **target temperatures** specified in Table 1[34] for each **compartment** type claimed by the supplier. Values above and below **target temperatures** may be used to estimate the **energy consumption** at the **target temperature** for each relevant **compartment** by interpolation.*

A valid value for energy consumption can only be determined when all compartment temperatures are at or below the target temperature specified in Table 4. Suppliers have the option of conducting a single test that complies with these requirements or to measure two or more temperature control

[33] The US had agreed to provide a test method for inclusion into the original IEC standard, but this was not delivered due to policy changes in the US.

[34] Table 1 in IEC 62552-3 is reproduced as Table 4 above in this report.

settings, with at least some compartments above the target temperature, with interpolation to give an estimated energy use estimate at the target temperature for one or more compartments. Annex E of IEC 62552-3 defines approaches for linear interpolation for one compartment (two test points), triangulation[35] for two compartments (three test points), or more sophisticated approaches for interpolation of more compartments using matrices. While these more complex methods are documented, in practical terms, most suppliers find that interpolation for more than two compartments is rarely justified in terms of the extra test time and level of improvement of the measured energy value.

The triangulation approach was adapted from AS/NZS4474.1 (2007), with the matrices approach expanded in IEC to cover more options. Triangulation in AS/NZS4474.1 is already included by reference into CFR 430 in the US Appendix A, and the use of the IEC presents no technical change.

The IEC approach allows suppliers that know their product well to set temperature control settings that put all compartment temperatures at or below the specified target temperature. This yields close-to-the-optimum energy consumption for minimal testing effort. For verification tests, laboratories are generally expected to measure several temperature control settings to estimate the optimal energy consumption (all compartments at or close to the target temperature).

The IEC approach provides the greatest flexibility for suppliers, gives the most accurate and comparable results, and allows the results to be replicated in a clear and concise manner.

[35] IEC 62552-3 allows the use of manual triangulation or matrices for interpolation of two compartments using three test points.

# Appendix D: Lessons Learned from US CFR 430 and IEC Laboratory Tests Commissioned by NEEA

## Background

In order to better understand many of the limitations of the current US test procedure for household refrigerators, NEEA commissioned UL to undertake detailed testing on 6 common household refrigerator-freezers in 2021. These appliances were subjected to both the current US DOE test procedure specified in CFR 430 and IEC 62552-3. This allowed the results to be compared and contrasted and helped to identify limitations and key technical issues with both test procedures.

On 29 December 2021, NEEA made a detailed submission to the US Department of Energy on test procedures for household refrigerators on Docket Number EERE–2017–BT–STD–0003: Preliminary Technical Support Document (PTSD) on Refrigerator, Refrigerator-Freezer, and Freezer Energy Conservation Standards. This submission makes a range of detailed technical suggestions for refrigerator test procedures and includes some key points from the testing commissioned by NEEA. The submission can be accessed at [https://www.regulations.gov/comment/EERE-2017-BT-STD-0003-0037](https://www.regulations.gov/comment/EERE-2017-BT-STD-0003-0037).

This appendix provides a brief overview of the DOE and IEC testing of these refrigerators and summarizes the key technical points for consideration.

## Overview

Six refrigerator-freezers were selected and tested according to IEC 62552-3:2015 for energy consumption. In addition to the ambient temperatures specified in the standard (16°C and 32°C), additional tests were also undertaken at an ambient temperature of 22°C. A summary of the tests undertaken is as follows:

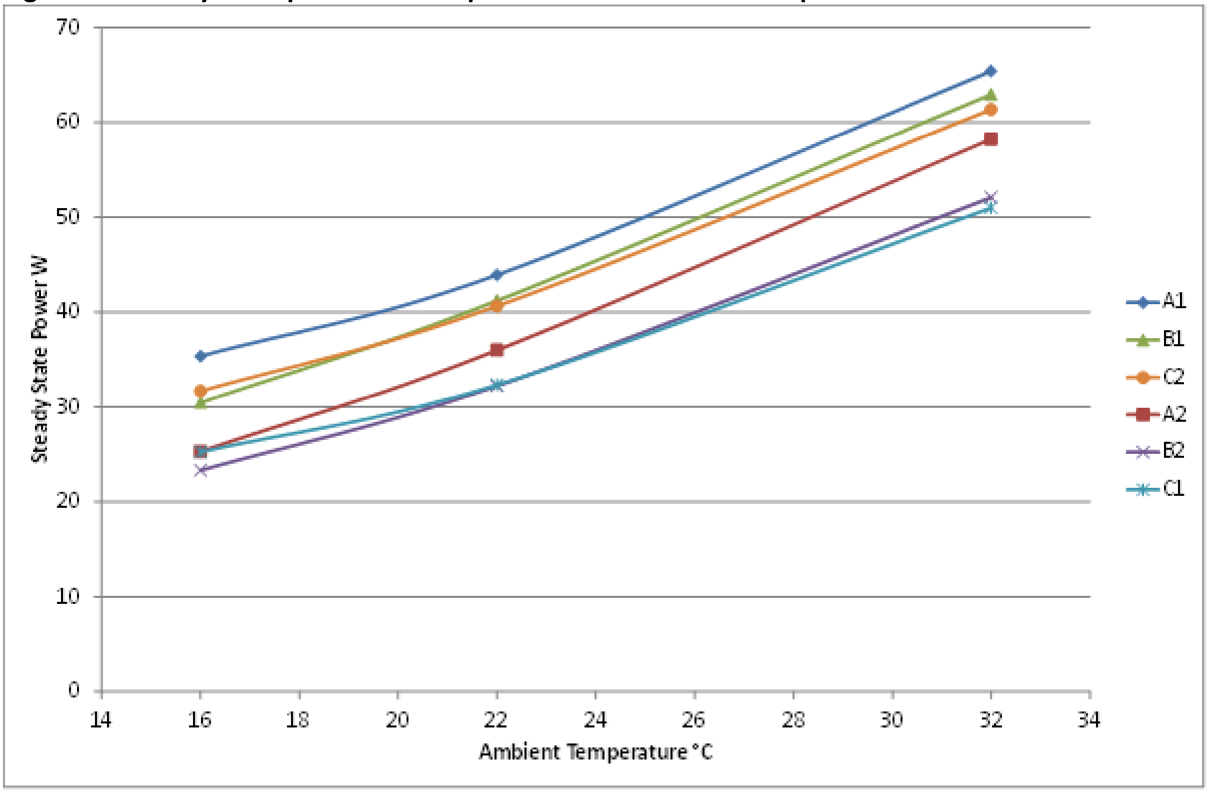
- Steady state power and incremental defrost and recovery energy at each ambient
- Load processing efficiency at each ambient
- Ice making tests at 32°C and 22°C ambients
- A range of energy tests in accordance with DOE CFR430 Appendix A.

The appliances were allocated identifiers A1, A2, B1, B2, C1 and C2. When considering the results of these comparative tests, it needs to be borne in mind that the products tested were in two groups of a similar size and type, so this will generally mean the differences between them for many of the standard tests performed would be expected to be small in many cases. As the more extensive DOE testing has illustrated, variations in performance are greater for smaller products or for different configurations (such as an all-refrigerator or a separate freezer).

## *Steady State Power*

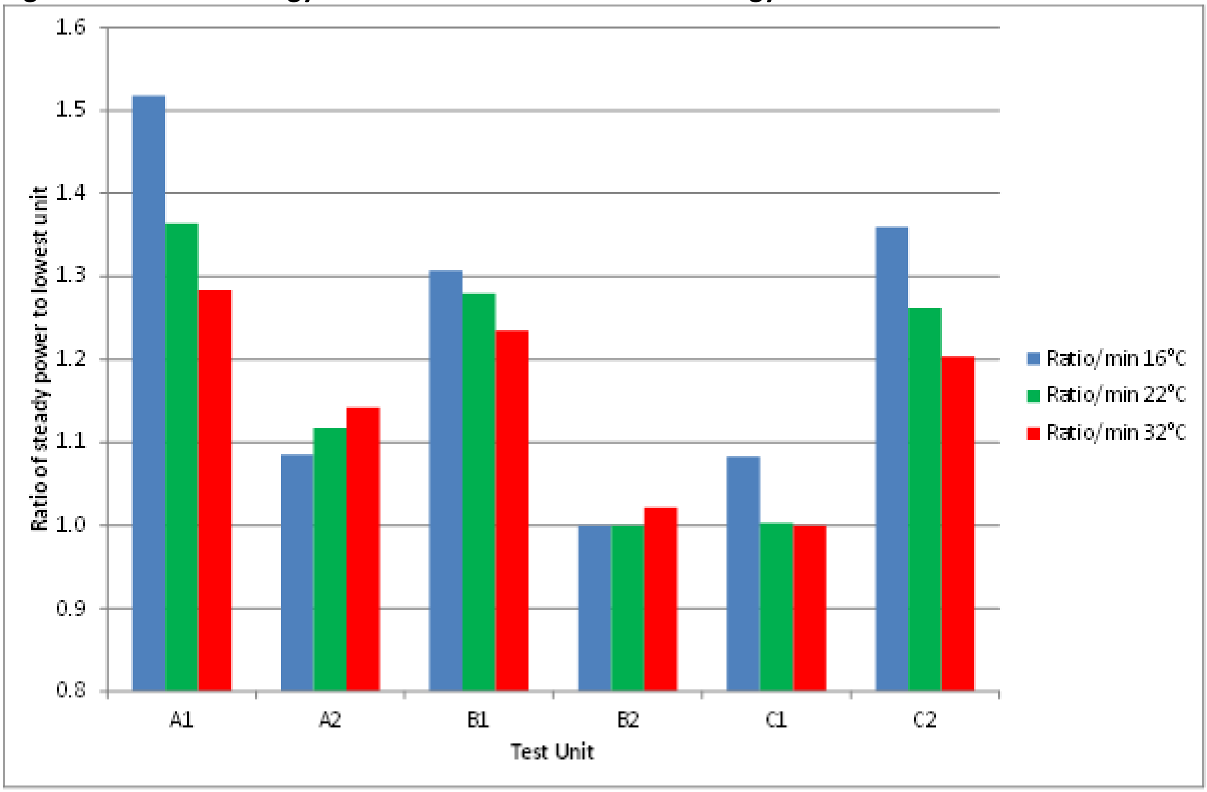
All six appliances were subjected to steady state power measurements at three ambient temperatures: 16°C, 22°C, and 32°C. The ambient temperature range will cover the range of normal use in most households for most of the time. Ambient temperatures of 16°C and 32°C are specified in IEC 62552-3. While the appliances all responded in a similar way to changes in ambient temperature, as expected, the ranking of the appliances did change with changes in ambient temperature. This is illustrated in Figure 12.

**Figure 12. Steady state power consumption at three ambient temperatures**




The six units selected were split into two groups of similar size with similar features: three French door units (A1, A2 and C1) and three side-by-side units (B1, B2 and C2). First impressions suggest that there is not a lot of variation in steady state power between these units. However, if the data at each ambient is examined as a ratio of the lowest energy unit for that temperature, it can be seen that the highest energy unit uses 30% more energy (at 16°C) to 50% more energy (at 32°C) compared to the lowest energy unit as shown in Figure 13.

**Figure 13. Ratio of energy at each ambient to the lowest energy unit**




*Note: Units A1, A2, and B1 are French Door models with advertised capacities of 25-26 cubic feet. Units B2, C1, and C2 are side-by-side models with advertised capacities of 21-22 cubic feet.*

Key lessons from steady state power measurements at different ambient temperatures:

- The energy ranking of products changes as ambient temperature changes.
- This means that testing at an elevated temperature is not a reliable predictor of relative performance at different ambient temperatures.
- The relative differences between products are much larger at low ambient temperatures, where most appliances spend the majority of the operating life.
- These differences become much larger when looking at data for other size ranges and different product configurations.

## *Defrosting performance*

All of the appliances tested appeared to use electronic controls to control their defrosting behavior (variable defrost controls). There were significant variations in the incremental defrost and recovery energy measured under the IEC test method: this ranged from around 60Wh per defrost for the lowest energy defrost to around 160Wh for the highest energy defrost cycle at an ambient temperature of 32°C. The incremental defrost and recovery energy at an ambient temperature of 16°C was generally less than the measured value at 32°C. However, this varied considerably by product, ranging from a few percent less to 50% less. There is no way to predict this variation in defrost energy with changes in ambient temperature other than through direct measurement.

One of the appliances tested had two separate defrost cycles – one for the fresh food and one for the freezer (with the freezer having a larger incremental defrost and recovery energy). Under IEC, these separate defrost cycles are separately quantified and then added into the overall energy consumption. CFR 430 is less clear on how to include the impacts of two (or more) separate defrost cycles into the energy calculation. The dominant defrost is selected and then additional defrosts are included if and when they occur.

The other parameter that is measured in the IEC test method is the temperature change during the defrost and recovery period. The IEC standard recognizes that temperature excursions during a defrost impact on the overall average temperature in a compartment over a whole defrost control cycle, so this impact is quantified and used to estimate the true average compartment temperature when the defrost energy is added. For the products tested there was a large range in compartment temperature changes during defrost[36], ranging from good values around -1Kh to +2Kh for fresh food and +1Kh to +5Kh for the freezer. In contrast, the worst products had temperature excursions of as much as +15Kh in the fresh food and +30Kh in the freezer. This could lead to significant food quality issues and this level of warming certainly impacts on the average compartment temperature over the whole defrost control cycle. For a nominal 24 hour defrost cycle, these temperature excursions lead to a 0.4°C increase in average compartment temperature in the fresh food and a 0.8°C increase in the average freezer temperature. This is equivalent to as much as a 3% error in the calculated energy consumption.

It is of significant concern that the current US test procedure CFR 430 does not take into account temperature excursions during defrost. As defrost temperature excursions are not measured or taken into account in CFR 430, this means suppliers have no incentive to improve the temperature performance during defrosts. It also means that poorly performing products get an unfair advantage in CFR 430, because they get to use the steady state temperature value as measured irrespective of the temperature rise during defrost: this temperature rise will reduce the measured overall energy during the defrost and recovery period.

While the nominal energy associated with a defrost is included in the CFR 430 test procedure, because the energy measurement period nominally commences with and includes a defrost, there is little assessment of the validity of the defrost that is included in the energy consumption determination. There are a number of potential concerns regarding defrost validity, including:

[36] Temperature changes during a defrost are measured in units of Kelvin-hours relative to the steady state temperature. For active defrost systems that use a heater, the temperature excursions during a defrost are usually positive, but this can be minimised by pre-cooling compartments prior to a defrost and implementing measures to minimise heat leakage from the evaporator to the compartment during defrosting.

- Defrosts that occur close to the commencement of testing (when the appliance is new or after storage or non-operation for some days) with have an unrepresentative, low defrost and recovery energy because the evaporator will be dry or will have a low moisture load.
- Some laboratories force defrosts to occur to suit their testing schedules as many variable defrost controllers will have defrost intervals, as long as 80 hours or more in a laboratory setting – forcing defrosts makes the incremental defrost and recovery energy artificially low.
- Changes in control settings or ambient conditions close to a defrost can give an artificially low defrost and recovery energy.

The IEC standard has requirements regarding the first two points. Defrosts that occur in the first 24 hours of operation cannot be used for energy and forced defrosts are not permitted. All defrosts are assessed against validity criteria – this means that there is a period of equivalent temperature and energy data on each side of the defrost before it can be used for energy calculations. The IEC standard also now tracks the defrost heater energy over time as a means of tracking changes in defrost performance and frost load during the test (IEC 62552-3 Amendment 1). These controls and checks mean that IEC defrost data is much more robust than the value that could potentially be measured under CFR 430.

Key lessons from defrost measurements are:

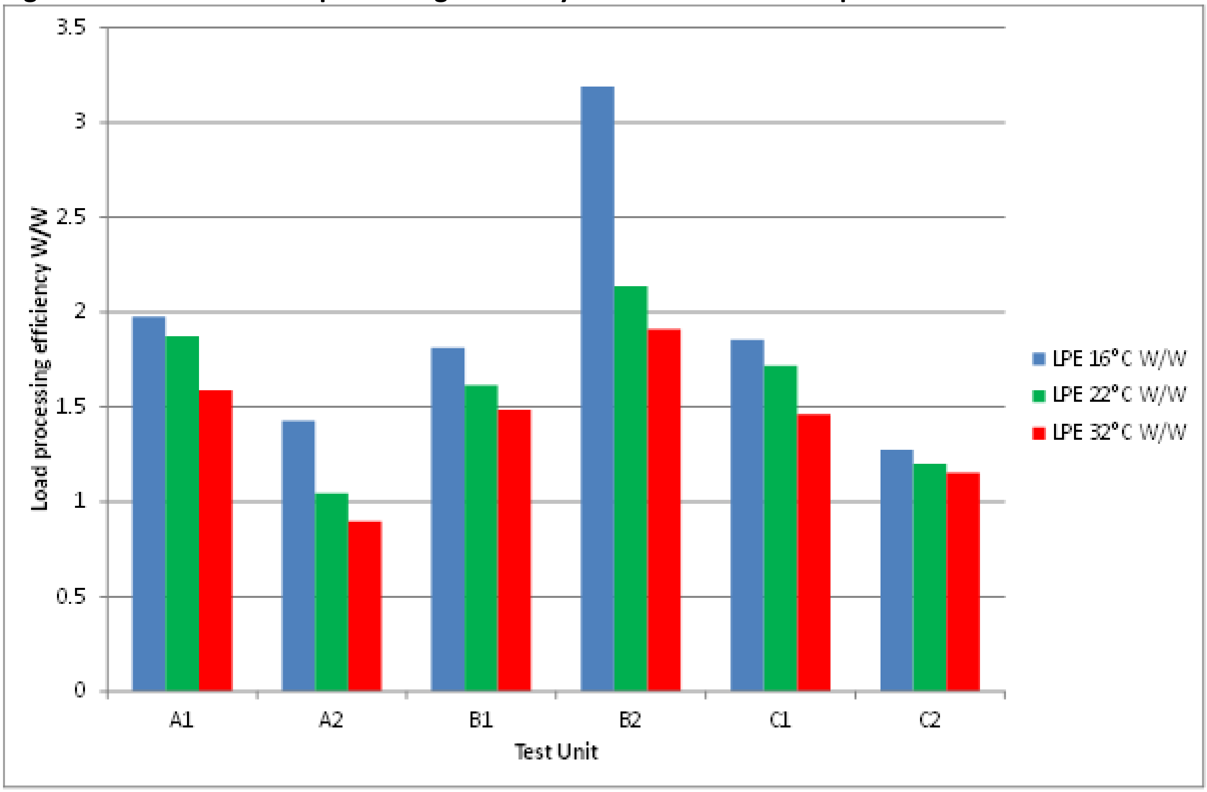
- The incremental energy associated with defrost and recovery varies considerable by appliance. CFR 430 does nominally take this into account by including a defrost at the start of the test.
- CFR 430 does not have the rigorous controls and checks to assess the validity of each defrost event prior to its use in energy calculations, so potentially there are cases where invalid defrosts could be included in a CFR 430 test.
- CFR 430 does not have a method to accurately include the impacts of multiple defrost systems into the energy consumption calculations, although in practice this will be a minor impact if the dominant defrost is selected.
- CFR 430 ignores compartment temperature excursions that occur during a defrost. This means that there is no incentive for suppliers to improve compartment temperature performance (reduce heat leakage) during defrost and recovery (there is a potential disincentive as minimizing temperature excursions may increase energy consumption to some extent).
- Ignoring temperature excursions during defrost and recovery means that the compartment temperature assumed for CFR 430 energy calculations may not be representative of the actual average compartment temperature over a typical defrost control cycle.

### *Load processing efficiency tests*

Each of the units was subjected to a Load Processing Efficiency test in accordance with IEC 62552-3:2015 Annex G. No equivalent test is specified in CFR 430. In this test, a specified mass of water at a known temperature (the laboratory ambient temperature) is placed into the appliance to simulate a user load. The refrigerator has to remove the excess heat energy from the load (cooling warm water in bottles and making ice cubes) and the test determines the additional energy the appliance uses (over and above steady state) to remove this known amount of energy. The ratio of the energy removed from the water to the additional energy used by the appliance is called the Load Processing Efficiency and the units are dimensionless (W/W or Wh/Wh). This is an important parameter as it is a direct measure of how efficiently heat loads that result from user interactions during normal use can be removed. In effective it is a measure of the incremental efficiency of the refrigeration system.

The UL testing included a load processing efficiency (LPE) test on the six test units at three different ambient temperatures, namely 16°C, 22°C and 32°C. According to IEC, the exact volume of water placed in each compartment is a function of compartment volume (12g per liter of volume for unfrozen compartments and 4g per liter for frozen compartments). For the six units tested, the average water mass in the fresh food was 5.44 kg (around 1.44 US gallons) and in the freezer about 0.86 kg (around 0.23 US gallons) in ice cube trays. The energy in the water to be removed by the refrigerator during the test is of the order of 200 Wh at an ambient temperature of 16°C and of the order of 300 Wh at an ambient temperature of 32°C. The results for the LPE tests are shown in Figure 14. Note that a higher value is better for LPE and it indicates a higher overall coefficient of performance.

**Figure 14. Measured load processing efficiency at three ambient temperatures**




When a large user load (like bottles of warm water) is placed into a refrigerator, the refrigerator usually reacts by running the compressor (at a faster speed if inverter driven) to remove the additional energy as quickly as possible. On sensing a large user load, many controllers will enter a defrost. This defrost results in additional appliance energy consumption. The LPE methodology includes a correction for any defrost energy that occurs during the LPE test prior to the establishment of the steady state power at the test completion. The IEC test method measures the LPE with the impact of defrosts removed, on the basis the defrost energy and defrost interval (during typical use) is separately and independently calculated and included in the daily and annual energy consumption.

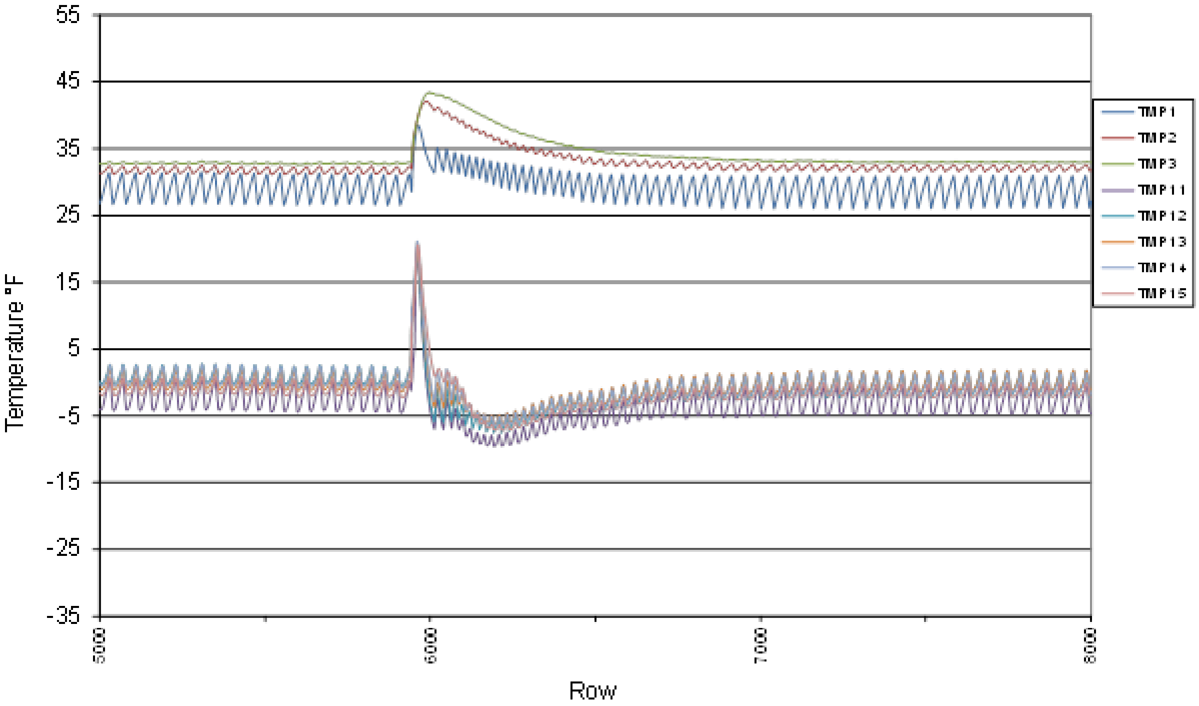
As a general observation, the LPE increases as the ambient temperature decreases. This is expected as the refrigeration system efficiency is dictated by the difference between the condensing temperature, which is influenced by the ambient temperature and the compartment temperature (which is nominally fixed). The relatively low values for Unit A2, in part is driven by the apparent operation of a heater during the load processing test, which changes the temperature profile in the appliance and also reduces the apparent efficiency (as the heater energy is added to both the energy that the appliance has to remove and the additional energy consumed during the test). The values for Unit B2 at ambient 16°C are quite high, but this is typical for inverter driven systems that can operate at low speeds in low ambient conditions.

A key observation from this data is that the ranking of LPE results does not match the overall energy ranking of steady state power. LPE is a measure of how efficiently user load is removed from the appliance during normal use interactions (such as the insertion of warm food and drink and door openings), which broadly reflects the marginal efficiency of the refrigeration system. In contrast, the steady state power is a composite measure of refrigeration system efficiency, insulation performance and energy consumed by auxiliaries and heaters. Products that have similar steady state performance across different ambient temperatures (e.g. Units B2 and C1, Units B1 and C2) have somewhat different measured LPE values. The ratio of the measured efficiency of the most efficient to the least efficient is a factor of two.

Load processing efficiency can be used to determine how much additional energy is induced in the appliance from a specified level of user interaction. Two appliances that are subjected to identical user interactions (heat loads) in terms of warm food and door openings will manifest as different amounts of additional energy used by the appliance, in proportion to the inverse of their load processing efficiency. Field research from other countries shows that user induced energy accounts for a modest proportion of total energy consumption of refrigerators during normal use (of the order of 20% to 30%), but this share will be reduced in cases of products with high load processing efficiency. User heat loads also vary substantially by household. This is an example of a parameter that has an important impact on overall energy consumption of an appliance but cannot be determined indirectly. If load processing efficiency is not measured and suppliers are not rewarded for making improvements in this performance parameter, then suppliers are unlikely to concentrate on improving this parameter. Good LPE performance is a key area to reduce energy consumption of refrigeration appliances during normal use.

Some of the appliances tested exhibited relatively poor temperature control during the load processing test. This is illustrated in Figure 15: on seeing the heat load, the appliance operates the cooling system which overcools the freezer but only slowly cools the fresh food compartment. This occurs because the appliance most likely has a limited ability to modulate the amount of cooling directed into each compartment to match the added heat load. This less than ideal response to the user load means that the efficiency of heat removal is less than it could be and temperature variations are more than they should be.

**Figure 15. Compartment temperatures in response to LPE heat loads (C2, 16°C ambient)**




Key lessons from load processing efficiency measurements are:

- Load processing efficiency is not a parameter that is assessed under CFR 430.
- The load processing efficiency, which is an indicator of how efficiently the appliance can remove heat loads during normal use, varies considerably by appliance.
- The load processing efficiency is not correlated with steady state power consumption, so an appliance that does well in a static elevated ambient temperature test may not perform very well in a normal use environment where there are significant and variable user related heat loads.
- If the load processing efficiency was assessed as part of the normal energy assessment, suppliers would have a strong incentive to focus on this performance in the test laboratory, as this would lead to improved overall energy performance. This would in turn lead to improved performance in the field.
- Heat loads from user interactions makes up a considerable share of the overall energy consumption of an appliance, explaining around 20% to 30% for main refrigerator-freezers in some countries (although an assessment of US data has not yet been made).

## Icemaking tests

### Background

A significant share of household refrigerating appliances sold in the US have automatic icemakers, some with a through-the-door dispenser. With the introduction of the new test procedure for household refrigerators in 2011, DOE had originally intended to develop a test method to measure the additional energy consumption associated with ice making. The original test procedure had a placeholder value of 0.23 kWh per cycle (or an equivalent of 84 kWh/year) (CFR 430 Appendix A Clause 6.2.3.1) while this method was developed. It is understood that DOE propose to reduce this to 28 KWh/year while not proceeding with an icemaking energy test method. NEEA have made submissions to increase this proposed placeholder value to 55 kWh/year, pending the development of a suitable test. NEEA also recommended that the efficiency of icemaking should be measured, as the results from laboratory testing showed considerable variation in the additional energy consumed during icemaking[37].

Neither IEC nor CFR 430 have a method for the measurement of the additional energy consumption associated with icemaking for icemakers supplied with mains water. IEC does have a method that covers automatic icemakers that are supplied with an internal tank (reservoir) that is replenished by the user, but these are excluded from the CFR 430 scope. To explore this issue in more detail, NEEA commissioned UL to undertake a range of energy tests on icemakers. This has enabled NEEA to undertake more detailed analysis of the data and to identify key issues to be addressed in current and future test procedures.

### Summary of Icemaking Tests Undertaken and Analysis Approach

Icemaking tests were conducted at an ambient temperature of both 32°C and 22°C on all six units. At the beginning of the tests, the ice bin was emptied of any existing ice and the icemaking unit was allowed to operate normally. The bin was purged at 6 hour intervals at 32°C ambient or 9 hour intervals at 22°C ambient. For the 22°C ambient test, the icemaker was allowed to continue operation until the storage bin was full and the icemaker stopped making ice of its own accord.

During the tests, all relevant parameters were recorded and analyzed:

- Rate of ice making (mass per hour) at each ambient temperature
- The energy consumption of the appliance during icemaking
- The compartment temperatures during icemaking.

[37] The NEEA submission to DOE dated 6 April 2020 can be accessed at https://www.regulations.gov/comment/EERE-2017-BT-TP-0004-0026

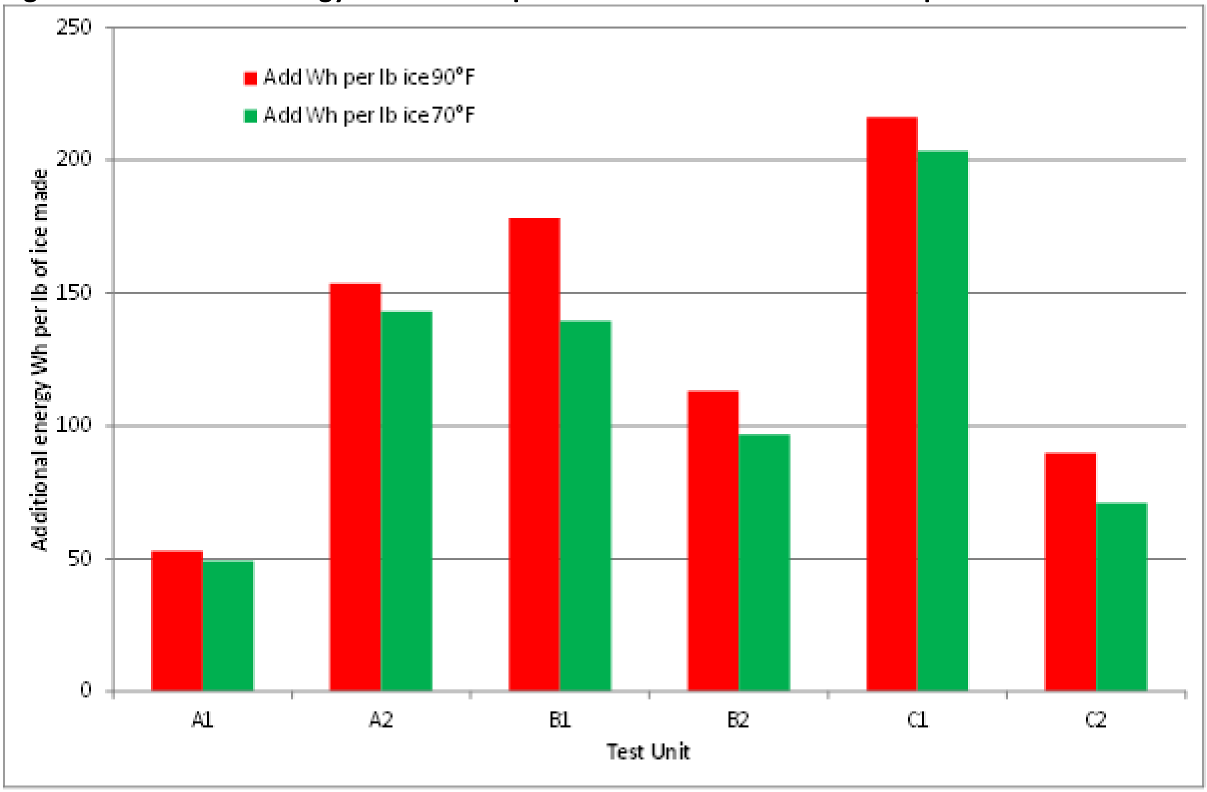
The data during icemaking was compared to a steady state period before and/or after the icemaking. No changes were made to the compartment temperatures during icemaking or afterwards. From the analysis, the following parameters were derived:

- The additional power during icemaking in watts (compared to steady state)
- The mass of ice made per hour
- Additional energy required to make a unit of ice
- Changes in compartment temperatures while making ice compared to steady state
- Any additional power consumed when the ice bin was full, compared to deactivation of the icemaker by the laboratory technician for normal tests.

## *Overview of Icemaking Results*

The headline result for icemaking is a measure of the additional energy to make a specified mass of ice. This is illustrated in Figure 16. Note that higher energy per pound of ice made is a worse result in terms of efficiency.

**Figure 16. Additional energy to make one pound of ice at both ambient temperatures**




As expected, the energy to make each pound of ice is slightly higher at an ambient of 90°F (32°C) compared to 70°F (22°C). This is because the refrigeration system is slightly less efficient at the warmer ambient, so the energy per pound of ice is higher. The most striking observation from this data is that the energy to make one pound of ice varies by a factor of four from the lowest energy to highest energy (from around 50 Wh per pound of ice made to over 200 Wh per pound of ice made).

Note that the amount of energy removed from water at the ambient temperature per pound of ice made is around 64 Wh per lb at an ambient of 90°F (32°C) and about 58 Wh per lb at an ambient of 70°F (22°C). The measured energy per pound of ice made is a function of the enthalpy change, the refrigeration system efficiency and the additional energy consumed by other auxiliaries required to make ice such as motors and heaters (required to stop water supply lines from freezing), so the measured energy per pound of ice made a complex combination of these factors.

The most interesting observation is that the measured energy per pound of ice made appears to have little or no correlation with measured load processing efficiency or steady state ambient temperature. For example, Units A1, B1 and C1 all had similar measured load processing efficiency values (refer Figure 14) but the energy per pound of ice was 53, 178 and 216 Wh per lb respectively. Units A1 and B1 had the highest steady state power while Unit C1 had the lowest steady state power. This illustrates that energy performance parameters such as load processing efficiency and icemaking efficiency need to be measured directly and cannot be accurately inferred from other measurements.

The detailed results for all units are shown in Table 5 (imperial units).

**Table 5. Summary of icemaking results – imperial units**

| Unit ID | Add W to make ice 90°F | Add W to make ice 70°F | Ice rate lb/hr 90°F | Ice rate lb/hr 70°F | Add Wh per lb ice 90°F | Add Wh per lb ice 70°F | Fresh compartment temp change °F during icemaking @ 90°F | Freezer compartment temp change °F during icemaking @ 90°F | Fresh compartment temp change °F during icemaking @ 70°F | Freezer compartment temp change °F during icemaking @ 70°F |
|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 15.5 | 14.4 | 0.293 | 0.293 | 53.0 | 49.2 | 0.0 | -0.5 | 0.0 | 0.0 |
| A2 | 34.7 | 34.0 | 0.226 | 0.238 | 153.4 | 143.0 | 3.0 | 2.0 | 0.0 | 2.5 |
| B1 | 30.0 | 21.9 | 0.168 | 0.157 | 178.1 | 139.5 | 0.0 | 2.0 | 0.0 | 1.5 |
| B2 | 16.9 | 14.8 | 0.149 | 0.153 | 113.1 | 96.7 | -1.0 | -0.5 | -0.5 | 0.0 |
| C1 | 35.4 | 27.6 | 0.164 | 0.136 | 216.4 | 203.2 | 3.4 | -15.0 | 1.0 | -14.0 |
| C2 | 19.4 | 13.8 | 0.216 | 0.195 | 89.8 | 71.0 | -0.5 | 4.0 | 0.0 | 4.0 |

Table notes: Unit A1 has two icemakers - one in the door and one in the freezer. For the Unit A1 initial test at 32°C only one of the icemakers was set up and measured, so the reading from 70°F (22°C) has been used as a proxy (estimate). All additional power measurements exclude defrost and recovery events. Large difference in incremental power between ambient temperatures for Unit B1 and C1. Shading below indicates whether the fresh and freezer were warmer or cooling during icemaking (compared to steady state).

| |
|---|
| Warmer during icemaking |
| Colder during icemaking |

The approach used for this analysis was to compare the additional power required to make ice (compared to steady state) together with the mass rate of ice made in order to calculate the additional energy per unit of ice made. While this is a robust methodology from an engineering perspective, it may be open to some potential manipulation. It is well understood that compartment temperatures impact on the energy consumption of an appliance. Analysis of triangulation test data on many hundreds of refrigeration products showed that a typical energy impact for a refrigerator-freezer was of the order of -1.5% energy per °C temperature change for the fresh food compartment and -3.5% energy per °C temperature change in the freezer compartment (Harrington and Brown, 2012). While these factors do vary somewhat in individual models, depending on their temperature control strategy, they do illustrate that an approach that some suppliers may use to reduce the apparent increase in the energy to make ice is to make compartment temperatures warmer during the icemaking process. Three of the six models appeared to have somewhat warmer freezers during icemaking, but these temperature rises were modest (2°F to 4°F) and may be, in part, the result of the additional heat load in the freezer during icemaking and associated auxiliaries. However, during a standardised test for icemaking energy, it would be wise to guard against any significant temperature rises in any compartment during icemaking to avoid potential circumvention behaviour and poor performance in the field.

One issue that became evident during testing was that the behaviour of the appliance with the icemaker "deactivated" (as per CFR 430 and/or IEC) was not always the same as the period following icemaking where the appliance ceased icemaking itself because the icemaking bin was full. This calls into question some of the approaches used to deactivate the icemaker for the energy test.

IEC 62552-3 Clause A.2.6 sets out detailed requirements regarding the configuration of icemaking bins for energy testing. Clause A.2.6.2 states:

*The intent is to make sure that, during an energy consumption test to this standard, the automatic ice-maker and its associated equipment behaves in a manner that is consistent with a value that would be obtained while the system is running but is not making new ice. In order to achieve this condition during an energy test, automatic ice-makers shall function normally but shall not produce any new ice (but should be in a state that would automatically produce new ice on demand without any user intervention if some ice were removed). Only devices or components directly associated with the production or harvesting of new ice shall be inoperative during the energy test. All components not explicitly associated with the production or harvesting of new ice shall operate normally during the energy test and shall be energized in a manner consistent with the duty cycle necessary to perform their respective functions. The cooling of the icemaker area(s) shall remain unchanged from normal ice storage conditions.*

*Other than for verification tests as specified in A.2.6.4, connection to a water supply may be omitted if it can be demonstrated that the absence or presence of a connection to a water supply will make no difference to the measured energy consumption.*

Clause A.2.6.4 goes on the say:

*For the purposes of verification of energy consumption of an appliance, the setup of the automatic icemaker should be configured in accordance with the setup specified by the manufacturer.*

*In order to detect whether there are any undeclared circumvention devices in operation during an energy test, irrespective of instructions, a test laboratory may undertake tests, including the test as set out below to assess the normal operation of the automatic ice-maker and its associated controls against the requirements of Clause 7 and the intent of A.2.6.2.*

*The purpose of this test, where undertaken, is to assess the normal operation of the automatic ice-maker against the configuration used for energy testing as set out in A.2.6.4. The ice-maker is* *connected to a water supply, the ice-making function is operated until the bin is full and ice production has automatically stopped under its own control prior to commencing an energy test. To shorten the test time, pre-made ice cubes may be used to partially fill the ice storage bin before the start of the test, but only to a level that allows the icemaker to continue producing ice to fill the bin.*

The standard clearly states that the operating state of the appliance with the icemaker deactivated for energy testing should be the same as the case where the appliance makes its own ice and stops making ice when the ice bin is full.

For the UL tests, the icemakers were activated during energy tests in accordance with the supplier's instructions. The approaches used were typically the use of a styrofoam block to hold up a lever that senses ice or to cover a photo-sensor that looks for a full ice bin. The steady state power value in this condition was compared to the steady state power when the appliance stopped making ice of its own accord when the icemaking bin was full. Five of the test units appeared to use the same overall steady state power when the test laboratory deactivated icemaking for energy tests compared to a naturally occurring full bin condition. One of the six units had a steady state power that was 3.3 W higher at 32°C ambient and 3.1 W higher at 16°C ambient when the icemaker stopped itself with the naturally occurring full bin condition. This is of some concern, and this would result in an additional 28 kWh/year of energy, which is potentially as much as 10% of annual energy in some cases.

Key lessons from the icemaking test are:

- Neither CFR 430 or IEC currently have an agreed test method for measuring the additional energy from making ice.
- CFR 430 currently uses a placeholder nominal additional energy associated with icemaking, but this does not measure likely energy associated with icemaking or reward products that make ice efficiently (nor does it penalize products that make ice inefficiently), so there is no incentive for suppliers to optimize icemaker performance.
- The measured efficiency of icemaking for the six units test varied by a factor of four, from around 50 Wh per pound of ice made to more than 200 Wh per pound of ice made.
- The measured energy per pound of ice made appears to have little or no correlation with measured load processing efficiency or steady state ambient temperature, suggesting that this can only be determined accurately via direct measurement.
- At an assumed ice consumption rate of 0.59 lb per day (DOE proposal), the additional energy to make ice would range from 29 to 120 kWh per year from the most to the least efficient unit measured.
- At an assumed ice consumption rate of 0.83 lb per day (as estimated through field data collected by NEEA), the additional energy to make ice would range from 41 to 169 kWh per year from the most to the least efficient unit measured. This could potentially make up a substantial part of the total annual energy consumption for some appliances.

- It appears that some appliances enter a different mode of operation when the icemaker is deactivated as recommended by the supplier. This may be circumvention or an unintentional change in operational state. DOE should align with IEC wording and make it clear that if there is any doubt about the state of the appliance when the icemaker is deactivated, then the default test setup should allow the icemaker to operate until it is full and then stop of its own accord for subsequent energy consumption testing.

| Brand | B | D | C | A | B | D |
|---|---|---|---|---|---|---|
| Model # | XXXXXXXXXXX01 | XXXXXXXXXXX11 | XXXXXXXXXXXXE | XXXXXXXXXXXX0 | XXXXXXXXXXXX3 | XXXXXXXXXXX01 |
| Serial # | XXXXXXXXXXX007 | XXXXXXXXXXX049 | XXXXXXXXXXX480 | XXXXXXXXXXX993 | XXXXXXXXXXX214 | XXXXXXXXXXX976 |

| Model | A1 | A2 | C1 | B1 | B2 | C2 |
|---|---|---|---|---|---|---|
| Type | French Door with Through the Door Ice. Also has ice maker in freezer compartment | French Door with Through the Door Ice | French Door without Through the Door Ice. Ice maker in freezer compartment. | Side by Side with Through the Door Ice | Side by Side with Through the Door Ice | Side by Side with through the Door Ice |
| ENERGY STAR | Yes | Yes | Yes | No | Yes | No |
| Rated Volume (cu.ft.) | 26 | 25 | 26 | 22 | 22 | 21 |
| AHAM Measured Vol (cu.ft) | 25.5 | 23.6 | 26.1 | 21.4 | 22.0 | 21.8 |
| Compressor Type | Inverter Driven | Reciprocating | Inverter Driven | Reciprocating | Inverter Driven | Reciprocating |
| Anti-Sweat Heater (ASH) | No | No | Yes | No | No | No |
| Annual Energy @ 16°C (kWh/yr) | 328 | 243 | 241 | 282 | 231 | 292 |
| LPE @ 16°C (Eff-Load W/W) | 1.969 | 1.426 | 1.856 No Valid period after LPE | 1.802 | 2.777 | 1.277 |
| Annual Energy @ 32°C (kWh/yr) | 633 | 530 | 481 | 580 | 518 | 562 |
| Annual Energy @ 32°C while making ice (kWh/yr) Normalized to 0.6 lbs/day | 635 | 572 | 546 | 614 | 544 | 586 |
| Annual Energy @ 32°C while making ice (kWh/yr) Normalized to 0.8 lbs/day | 638 | 584 | 563 | 627 | 554 | 594 |
| LPE @ 32°C | 1.590 No Valid period after LPE | 0.898 No Valid period after LPE | 1.460 No Valid period after LPE | 1.483 No Valid period after LPE | 1.659 | 1.179 No Valid period after LPE |
| Annual Energy @ 22°C (kWh/yr) | 431 | 347 | 316 | 387 | 321 | 379 |
| Annual Energy @ 22°C while making ice (kWh/yr) Normalized to 0.6 lbs/day | 431 | 378 | 361 | 417 | 344 | 398 |
| Annual Energy @ 22°C while making ice (kWh/yr) Normalized to 0.8 lbs/day | 433 | 389 | 376 | 428 | 351 | 404 |
| LPE @ 22°C | 2.017 | 1.384 | 1.717 | 1.612 | 2.623 | 1.198 |
| Annual Energy @ DOE Test 90°F (32°C) (kWh/yr) according to Appendix A | 643 | 640 | 573 Right Side amb Ave 92.4F ASH OFF | 642 | 613 Left Side amb Ave 88.4F | 677 |
| Rated Annual Energy for DOE (kWh/yr) | 686 | 685 | 620 | 672 | 639 | 660 |

| **Brand** | B | D | C | A | B | D |
|---|---|---|---|---|---|---|
| **Model #** | XXXXXXXXXXX01 | XXXXXXXXXXX11 | XXXXXXXXXXXXE | XXXXXXXXXXXX0 | XXXXXXXXXXXX3 | XXXXXXXXXXX01 |
| **Serial #** | XXXXXXXXXXX007 | XXXXXXXXXXX049 | XXXXXXXXXXX480 | XXXXXXXXXXX993 | XXXXXXXXXXX214 | XXXXXXXXXXX976 |

| **Model** | A1 | A2 | C1 | B1 | B2 | C2 |
|---|---|---|---|---|---|---|
| **Type** | French Door with Through the Door Ice. Also has ice maker in freezer compartment | French Door with Through the Door Ice | French Door without Through the Door Ice. Ice maker in freezer compartment. | Side by Side with Through the Door Ice | Side by Side with Through the Door Ice | Side by Side with through the Door Ice |
| **ENERGY STAR** | Yes | Yes | Yes | No | Yes | No |
| **Rated Volume (cu.ft.)** | 26 | 25 | 26 | 22 | 22 | 21 |
| **AHAM Measured Vol (cu.ft)** | 25.5 | 23.6 | 26.1 | 21.4 | 22.0 | 21.8 |
| **Compressor Type** | Inverter Driven | Reciprocating | Inverter Driven | Reciprocating | Inverter Driven | Reciprocating |
| **Anti-Sweat Heater (ASH)** | No | No | Yes | No | No | No |
| **Annual Energy @ DOE Test 90°F (32°C) (kWh/yr) according to AHAM HRF-1-2019** | 587 | 584 | 517 | 586 | 557 | 621 |
| **How to Deactivate Ice Machine** | Photo eye in the door. Freezer compartment has an arm that was blocked up. Both also have a switch | Block arm up | Block arm up | Wire arm moved to the up position | Switch Off | Wire arm moved to the up position |
| **Projected annual energy consumption (PAEC) AS/NZ 4474** | 512 | 463 | 435 | 454 | 383 | 486 |

# Appendix E: Test Reports

Test reports follow after References

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## 1. Client Information

| | |
|---|---|
| Customer company name: | Northwest Energy Efficiency Alliance (NEEA) |
| Contact person: | Eric Olson |
| Address: | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON 97204 |
| Telephone: | 503.688.5435 |
| Email: | EOlson@neea.org |

## 2. Test Information

| | |
|---|---|
| Title of test: | IEC 62552:2015 |
| Title of associated project: | DOE and IEC Testing on Refrigerator Brands |
| Project number: | PN9328 |
| Test conducted by: | Erick Zehr |
| Report Issue date: | 1/22/2021 |

## 3. Lab Information

| | |
|---|---|
| Testing Laboratory: | UL Verification Services Inc. |
| Testing Laboratory Address: | 3020 1st Avenue East<br>Newton IA,50208 |

## 4. Objective

The purpose for this project is to test six residential refrigerator – freezers to a series of tests including the US Department of Energy 10 CFR Part 430 Subpart B Appendix A with updates from the AHAM HRF-1-2019 and various clauses of the IEC 62552-3: 2015. These tests will evaluate the energy consumption under a range of operating conditions. The DOE and IEC residential refrigerator energy testing results will be compared in various ways by test method and type of refrigerator evaluated.

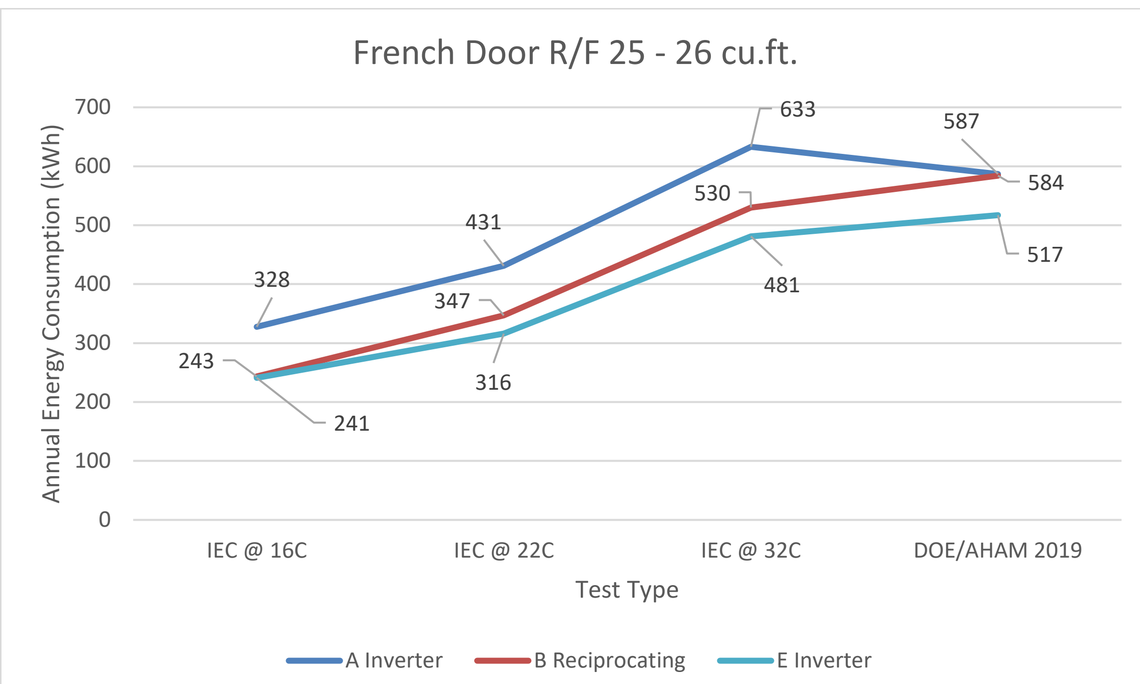
## 5. Product Information

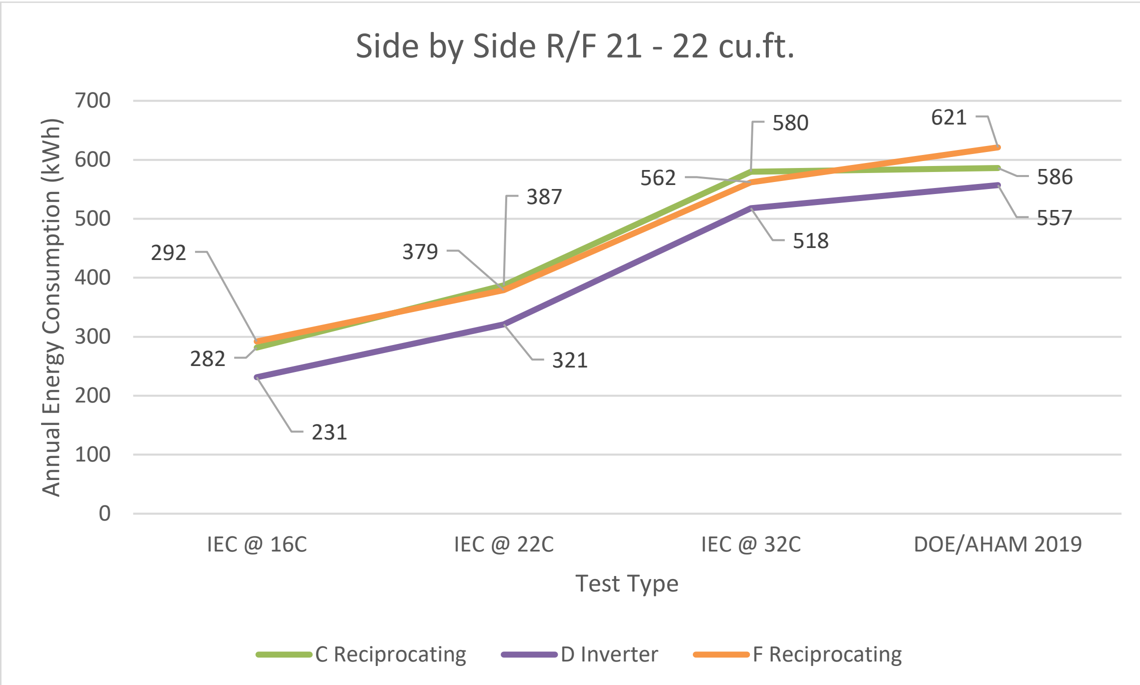
| Model | A | B | E |
|---|---|---|---|
| **Type** | French Door with Through the Door Ice. Also has ice maker in freezer compartment | French Door with Through the Door Ice | French Door without Through the Door Ice. Ice maker in freezer compartment. |
| **ENERGY STAR** | Yes | Yes | Yes |
| **Rated Volume (cu.ft.)** | 26 | 25 | 26 |
| **Compressor Type** | Inverter Driven | Reciprocating | Inverter Driven |
| **Anti-Sweat Heater (ASH)** | No | No | Yes |

| Model | C | D | F |
|---|---|---|---|
| Type | Side by Side with Through the Door Ice | Side by Side with Through the Door Ice | Side by Side with through the Door Ice |
| ENERGY STAR | No | Yes | No |
| Rated Volume (cu.ft.) | 22 | 22 | 21 |
| Compressor Type | Reciprocating | Inverter Driven | Reciprocating |
| Anti-Sweat Heater (ASH) | No | No | No |

# 6. Summary

The six test units underwent the IEC energy testing procedure at three ambient conditions of 16°C, 32°C and 22°C. Load Processing Efficiency testing was conducted at the three ambient conditions of 16°C, 32°C and 22°C. Ice making testing was conducted during the 32°C and 22°C ambient condition. Annual energy usage was also evaluated on these units using the AHAM HRF-1- 2019 test method. The following graphs show a summary of the annual energy use at the four different test conditions. Additional test comparisons are shown in the Test Results section.






## 7. Authorizing Signatures

| Report Prepared By: | Tests Reviewed By: |
|---|---|
| *Curt Tremel* | *Daryl Michael* |
| Name: Curt Tremel | Name: Daryl Michael |
| Title: Engineering Manager | Title: HVAC Lab Manager |

## 8. Test Setup and Procedure

Testing was set up and conducted according to IEC 62552:2015 Household refrigerating appliances, Parts 1 and 3. Following the IEC testing, the Units were set up according to the AHAM HRF-1-2019

i. The 6 Units were installed in the chamber according to IEC 62552-1:2015
  a) Brass thermocouples (TC's) with a nominal mass of brass 25g +/- 5%, (2.3g water equivalent heat capacity); were install in locations per Annex D. The dimension of the brass TC shall be less than 0.71 inches (18mm).
  b) One additional TC also located in Icemaker (IM) bin per TC location requirements
  c) Icemakers defeated from making new ice, but left operational
  d) Water lines connected to all units from chamber supply line
  e) Regulated 115V supplied to all testing stations

ii. The installation of the 6 Units were reconfigured according to AHAM HRF-1-2019
  a) Brass thermocouples (TC's) with an approximate mass of brass 110g; were install in locations per AHAM HRF-1-2019. The dimentions of the TC shall be 1.12+/-0.25 inches (2.9+/-0.6 cm).
  b) Icemakers defeated from making new ice, but left operational
  c) Water lines connected to all units from chamber supply line
  d) Regulated 115V supplied to all test stations.

## 9. Test Conditions

The sequence of testing was conducted in the following manner.

i. Initial Ambient = 16°C
  a) Deactivate ice making capability.
  b) Pull down units, adjust temperature settings as needed to meet requirements
  c) Establish Steady State energy usage (IEC52552-3 Annex B)
  d) Capture defrost energy increase and temperature impact (IEC52552-3 Annex C)
  e) Determine masses of water needed for Load Processing Efficiency Test (LPE) and perform test (IEC52552-3 Annex G)
    1) LPE water load allowed to stabilize at ambient temperature in the test room for several days prior to being placed into the test appliance
    2) LPE water load removed at conclusion of testing, before advancing to next ambient
  f) Ensure validity of steady state & defrost cycles and proceed to next ambient
  g) No Icemaking performed at 16°C

ii. Second Ambient = 32°C
  a) Allow temperature cycling to stabilize, adjust temperature settings as needed
  b) Establish Steady State energy usage (IEC52552-3 Annex B)
  c) Capture defrost energy increase and temperature impact (IEC52552-3 Annex C)
  d) Allow refrigerators to begin making ice.
  e) Measure the ice produced at regular intervals.
  f) Deactivate ice making capability.
  g) Perform LPE test (IEC52552-3 Annex G)

h) Ensure validity of steady state & defrost cycles and proceed to next ambient

iii. Final IEC Ambient = 22°C
  a) Allow temperature cycling to stabilize, adjust temperature settings as needed
  b) Establish Steady State energy usage (IEC52552-3 Annex B)
  c) Capture defrost energy increase and temperature impact (IEC52552-3 Annex C)
  d) Perform LPE test (IEC52552-3 Annex G)
  e) Allow refrigerators to begin making ice.
  f) Measure the ice produced at regular intervals.
  g) Allow the ice maker to operate for several hours to capture the maximum bin capacity and to allow it to stop producing ice on its own.
  h) Ensure validity of steady state & defrost cycles and proceed to DOE/AHAM testing.

iv. DOE/AHAM Testing – Ambient = 90°F (32°C)
  a) Unit setup was reconfigured according to AHAM HRF-1-2019

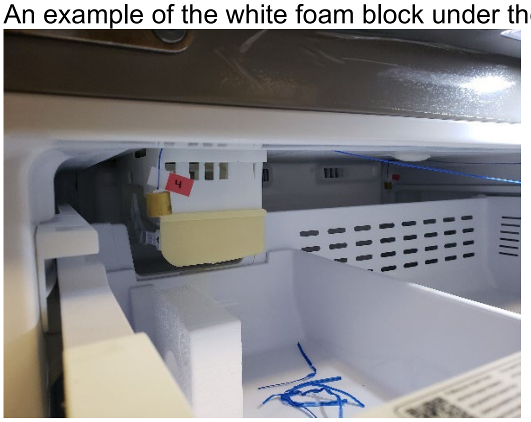
v. DOE/AHAM Mid/Mid Setting
  a) Adjust temperature control settings of the refrigerator to the “Mid” setting or “median” setpoint for both the Fresh Food and Freezer compartments for each unit
  b) Allow unit to stabilize until Steady State requirement is met (SS1 and SS2)
  c) Determine compressor cycling energy usage (T1 & EP1)
  d) Determine defrost energy usage (T2 & EP2)
    1) If unit has multiple defrost cycles (FF + FRZ, FF or FRZ only, etc.), determine second defrost energy usage also (T3 & EP3)
  e) Determine compartment temperature average for both FF and FRZ compartments
    1) If both are below Standardized Temperatures of 39°F and 0°F, respectively, 2nd test shall be performed at “Warmest” settings
    2) If either FF or FRZ compartment average (or both) are above 39°F/0°F, 2nd test shall be performed at “Coldest” settings

vi. DOE/AHAM Second Test (either Warmest or Coldest settings)
  a) Set each unit’s temperature set points to the “Warmest” setting or “Coldest” setting for both the Fresh Food and Freezer compartments, based on the results of the Mid/Mid test.
  b) Allow unit to stabilize until Steady State requirement is met (SS1 and SS2)
  c) Determine compressor cycling energy usage (T1 & EP1)
  d) Determine defrost energy usage (T2 & EP2)
    1) If unit has multiple defrost cycles (FF + FRZ, FF or FRZ only, etc.), determine second defrost energy usage also (T3 & EP3)
  e) Determine Compartment Temperature Average for both FF and FRZ compartments
    1) If second test is performed at “Coldest” settings, and temperature averages are still not below 39°F/0°F, unit fails and cannot be submitted
  f) Otherwise proceed to Energy Calculation, as outlined in AHAM HRF-1-2019
  g) One of the 6 refrigerators had an Anti-Sweat Heater (ASH) switch and therefore a subsequent DOE/AHAM test was conducted on that unit with the ASH switch in the on position.

For the process of deactivating the ice machine to conduct the energy testing, each unit had some different methods to do this.

| **Model** | **A** | **B** | **C** | **D** | **E** | **F** |
|---|---|---|---|---|---|---|
| **How to Deactivate Ice Machine** | Photo eye in the door. Freezer compartment has an arm. A block was placed under the arm. Both also have a switch | Block placed under the arm. | Wire arm moved to the up position | Switch Off | Block placed under the arm | Wire arm moved to the up position |

An example of the white foam block under the arm up and wire arm up are shown in these pictures.




## 10. Test Comments (additions, deviations, or exclusions)

For the IEC tests, a single point method was used to determine the energy usage at each ambient. The single point measurement was as close as possible to, but below the compartment target temperature. There was no interpolation of the energy results.
A couple units required defrosts to be forced.
For the IEC test, the TC's in the freezer compartment were positioned in diagonal opposite corner in the top plane and in the bottom plane. In other words, TMP 12 and TMP 13 were placed in diagonal corners instead of both being placed on the same side of the refrigerator.

# 11. Test Results

### Energy Calculation

According to the IEC62552-3, the energy was calculated by combining the steady state power consumption, the relevant defrost and recovery energy and an assumed defrost interval for each ambient temperature. For the 16°C ambient, the defrost interval was 48 hours. For the 32°C ambient, the defrost interval was 24 hours. For the 22°C ambient, the defrost interval was 39 hours.

Similarly, for the DOE/AHAM testing, the energy was calculated by combining the steady state power and the defrost power. These refrigerators being variable defrost would have associated CT (compressor run time) values to be used in the energy calculations. As an independent third-party lab, the default values of $CT_L$ and $CT_M$ of 6 and 96, respectively were used. This results in a CT value of 24.
For the DOE/AHAM test results in the following table, the ice maker adder of 0.0.0767 kWh/cycle (28 kWh/year) is included in the annual energy consumption. The 0.0767 kWh/cycle is factor in the AHAM HRF-1-2019 to account for the additional energy consumed by a refrigerator with an automatic ice maker.

| Model | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Type | French Door with Through the Door Ice. Also has ice maker in freezer compartment | French Door with Through the Door Ice | Side by Side with Through the Door Ice | Side by Side with Through the Door Ice | French Door without Through the Door Ice. Ice maker in freezer compartment. | Side by Side with through the Door Ice |
| Compressor Type | Inverter Driven | Reciprocating | Reciprocating | Inverter Driven | Inverter Driven | Reciprocating |
| Daily Energy @ 16°C (Wh) | 898 | 667 | 773 | 634 | 660 | 799 |
| Daily Energy @ 32°C (Wh) | 1735 | 1453 | 1588 | 1419 | 1319 | 1541 |
| Daily Energy @ 22C (Wh) | 1180 | 950 | 1061 | 880 | 867 | 1038 |
| Daily Energy @ DOE/AHAM Test 90°F (32°C) (Wh) | 1608 | 1600 | 1606 | 1526 | 1417 | 1701 |
| Annual Energy @ 16°C (kWh/yr) | 328 | 243 | 282 | 231 | 241 | 292 |
| Annual Energy @ 32°C (kWh/yr) | 633 | 530 | 580 | 518 | 481 | 562 |
| Annual Energy @ 22°C (kWh/yr) | 431 | 347 | 387 | 321 | 316 | 379 |
| Annual Energy @ DOE/AHAM Test 90°F (32°C) (kWh/yr) | 587 | 584 | 586 | 557 | 517 | 621 |

## Energy Comparison by Compressor Type

When setting up the test plan for this project, the hypothesis was that the inverter compressors were more energy efficient than the reciprocating compressors and thus consume less energy for each test. This did hold true for the side by side refrigerators. However, the French door refrigerators did not follow that theory. Further investigation of the results revealed that in addition to the energy consumption being different among these three French doors models, the temperature performance was also different.

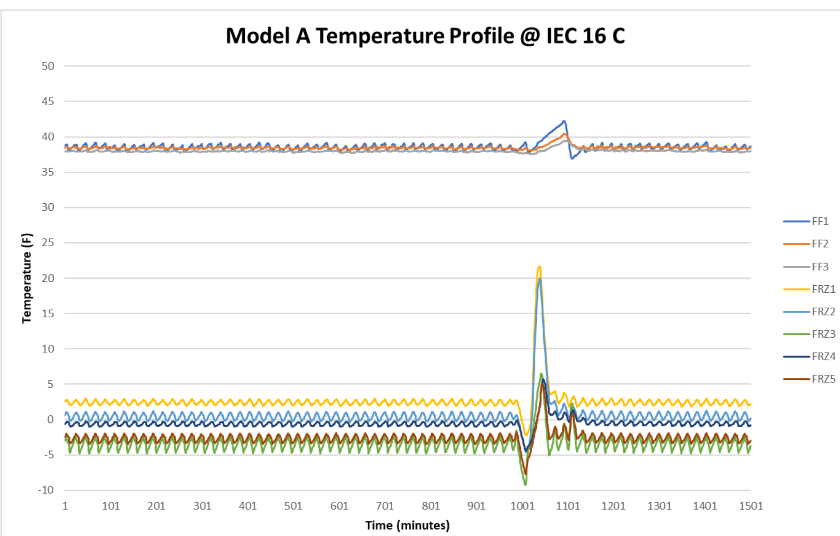
The following graphs show the cycling profile of each French door refrigerator. Each graph captures 25 hours of data showing a portion of the steady state operation and a defrost. The vertical and horizontal scales on each graph is identical for ease in comparison.

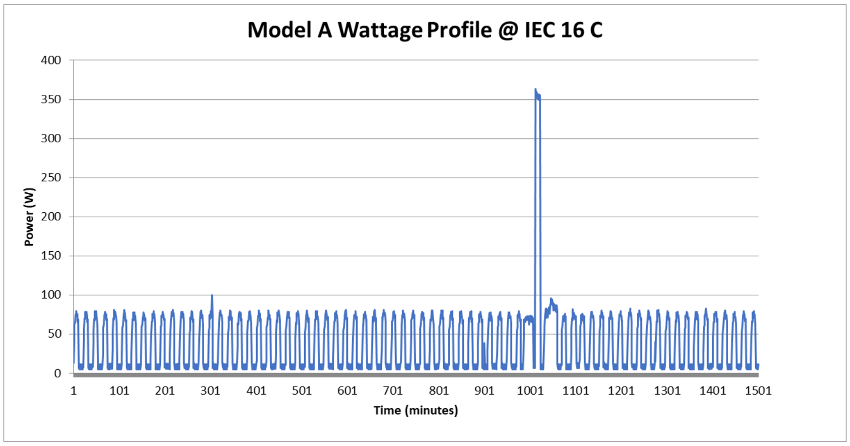
Model B with a reciprocating compressor has a good energy consumption. However, the low duty cycle of the compressor to achieve the low energy consumption is causing a wide dead band or swing in temperatures within each compartment.

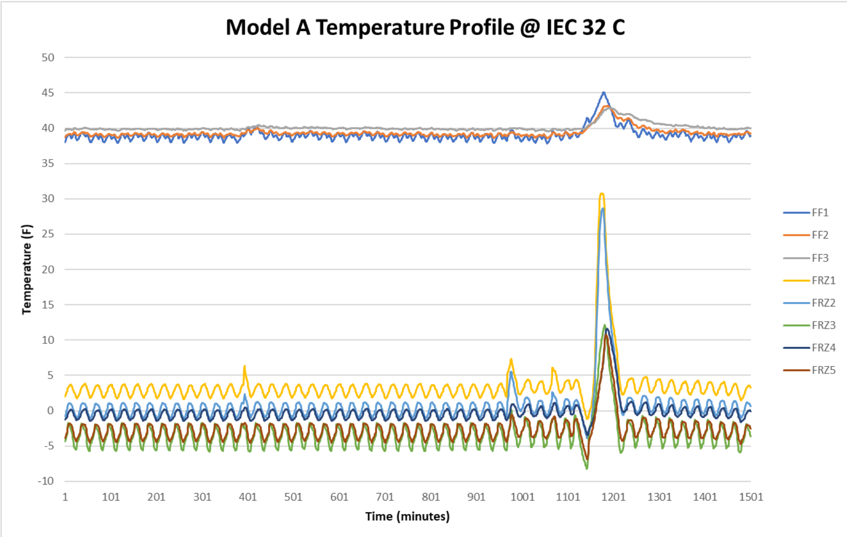
**Average Cycling Temperature Swing**

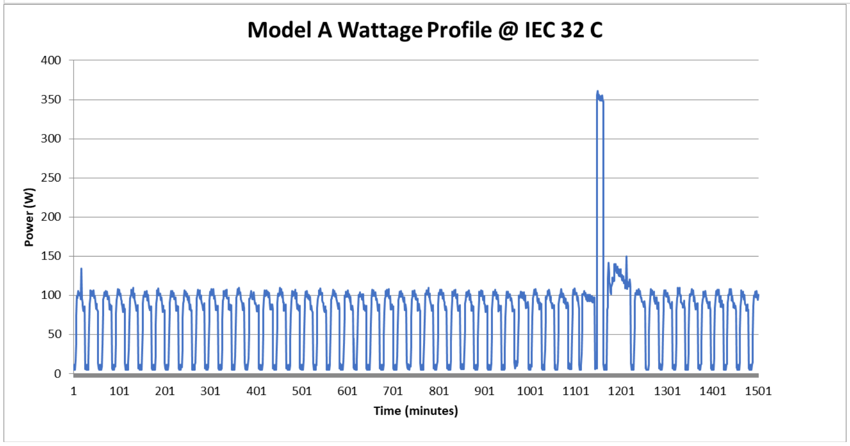
(fresh food / freezer) in degree F

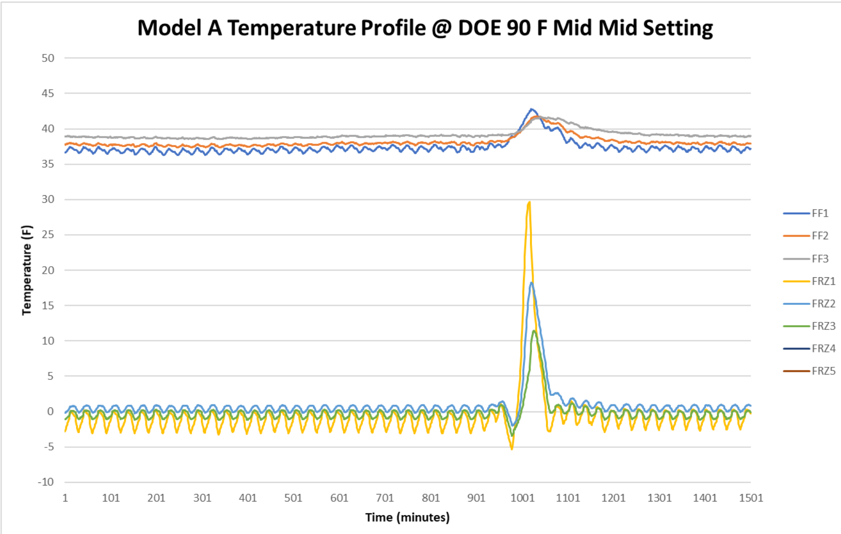
| | Model A | Model B | Model E |
|---|---|---|---|
| IEC @ 16°C | 0.77 / 1.49 | 2.20 / 8.46 | 2.35 / 3.99 |
| IEC @ 32°C | 0.95 / 2.58 | 4.47 / 7.46 | 2.93 / 3.90 |
| DOE / AHAM 2019 | 0.97 / 1.23 | 4.42 / 4.76 | 1.72 / 1.38 |

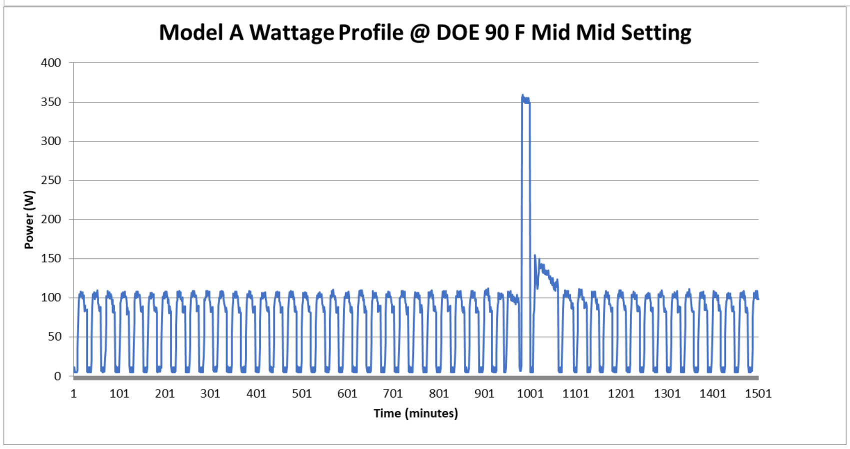


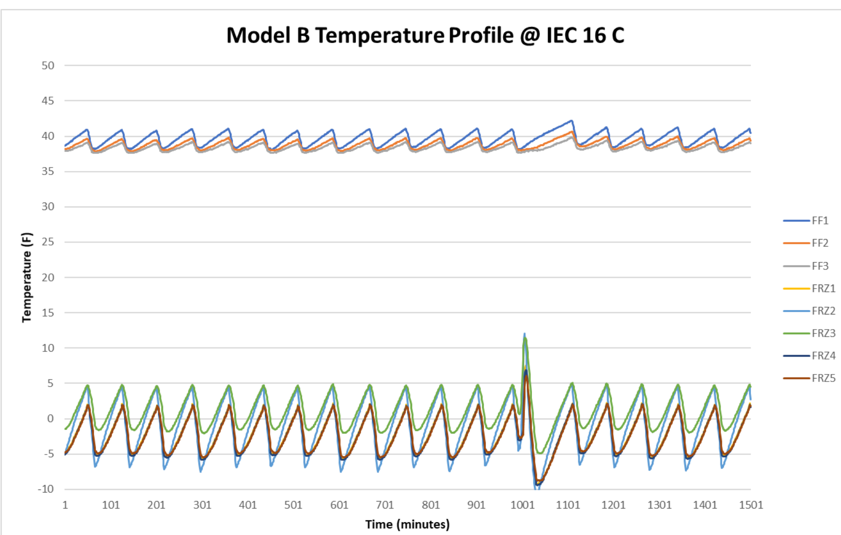

Model A Wattage Profile @ IEC 16 C
Power (W)
Time (minutes)
0
50
100
150
200
250
300
350
400
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501

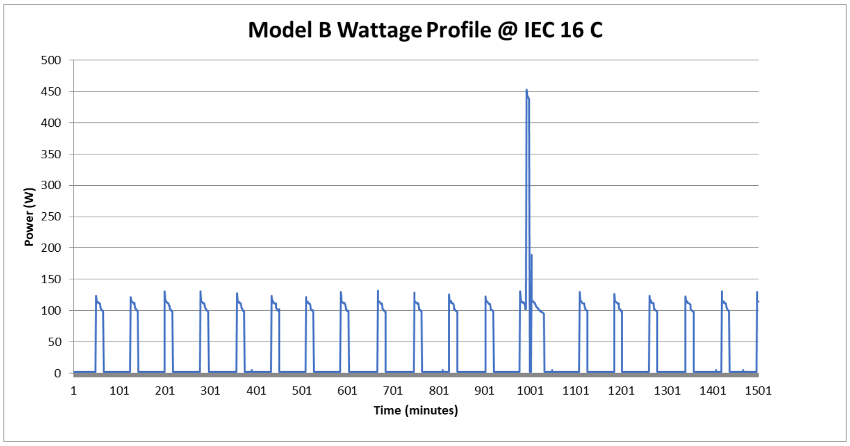

Model A Temperature Profile @ IEC 32 C
Temperature (F)
Time (minutes)
-10
-5
0
5
10
15
20
25
30
35
40
45
50
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5

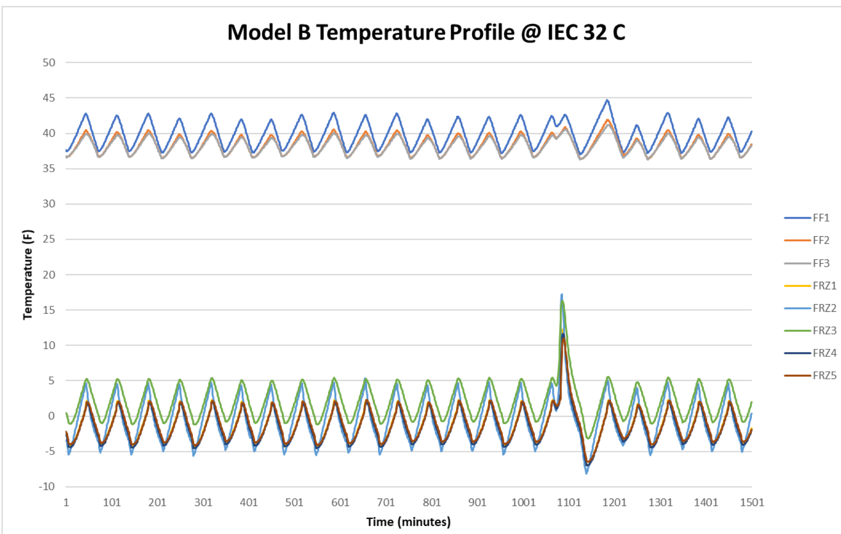

Model A Wattage Profile @ IEC 32 C
Power (W)
Time (minutes)
0
50
100
150
200
250
300
350
400
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501


Model A Temperature Profile @ DOE 90 F Mid Mid Setting
Temperature (F)
Time (minutes)
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5


Model A Wattage Profile @ DOE 90 F Mid Mid Setting
Power (W)
Time (minutes)


Model B Temperature Profile @ IEC 16 C
Temperature (F)
Time (minutes)
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5


Model B Wattage Profile @ IEC 16 C
Power (W)
Time (minutes)
500
450
400
350
300
250
200
150
100
50
0
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501


Model B Temperature Profile @ IEC 32 C
Temperature (F)
Time (minutes)
50
45
40
35
30
25
20
15
10
5
0
-5
-10
1
101
201
301
401
501
601
701
801
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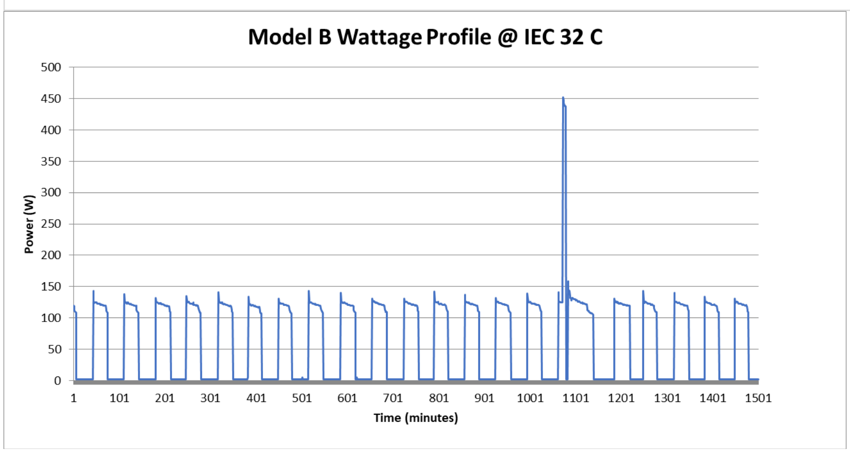
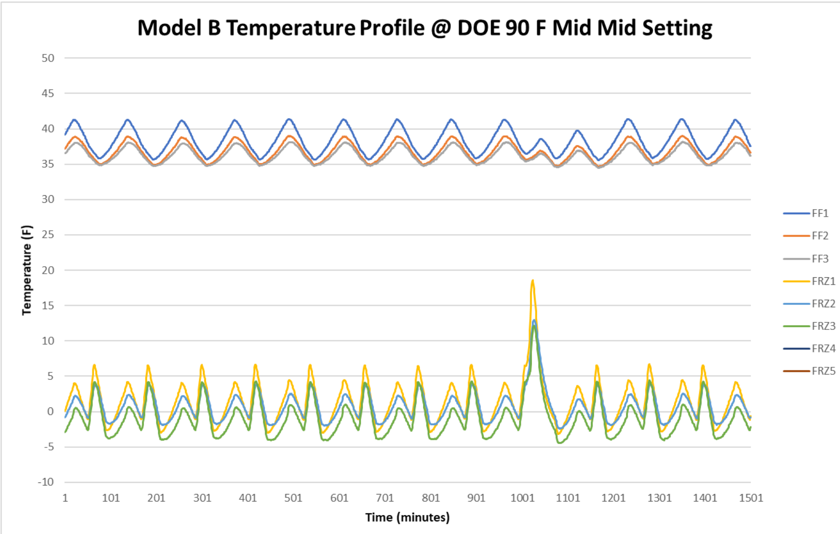
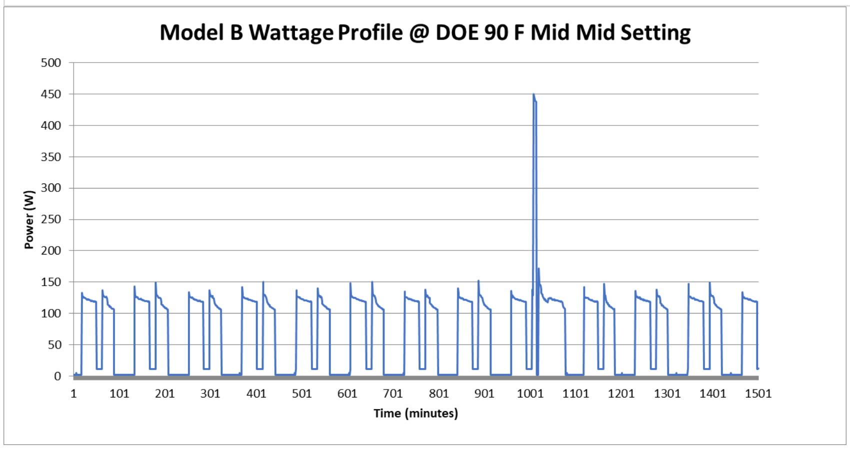
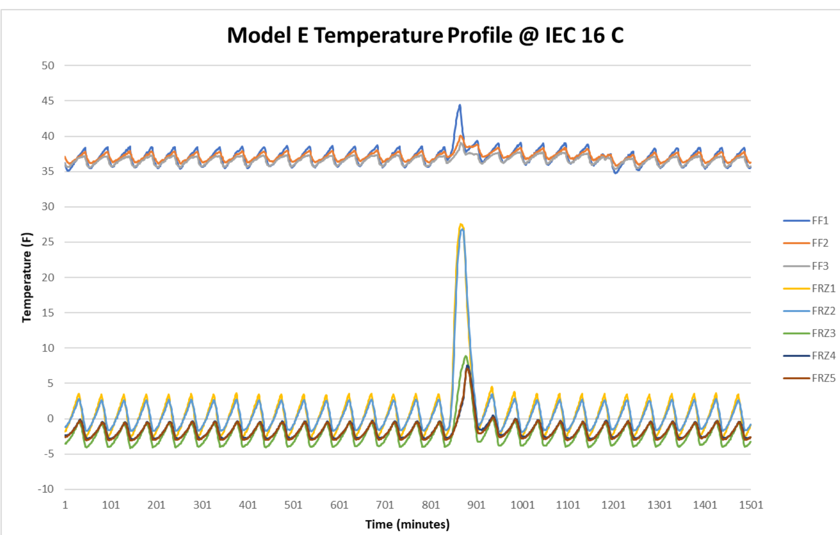
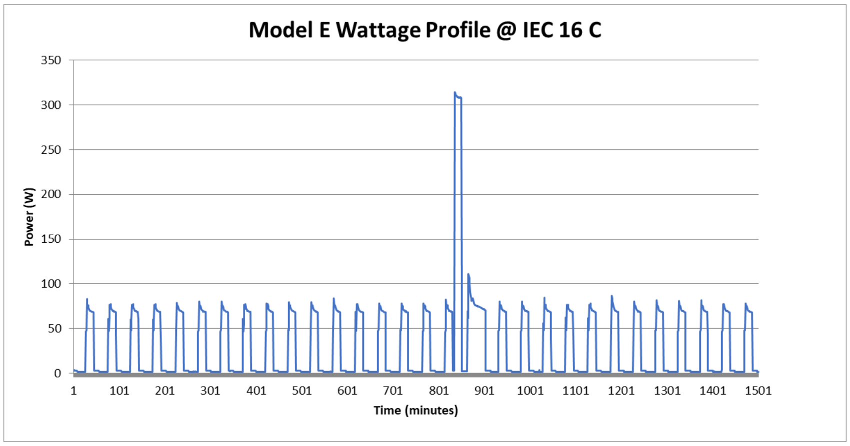
1001
1101
1201
1301
1401
1501
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5

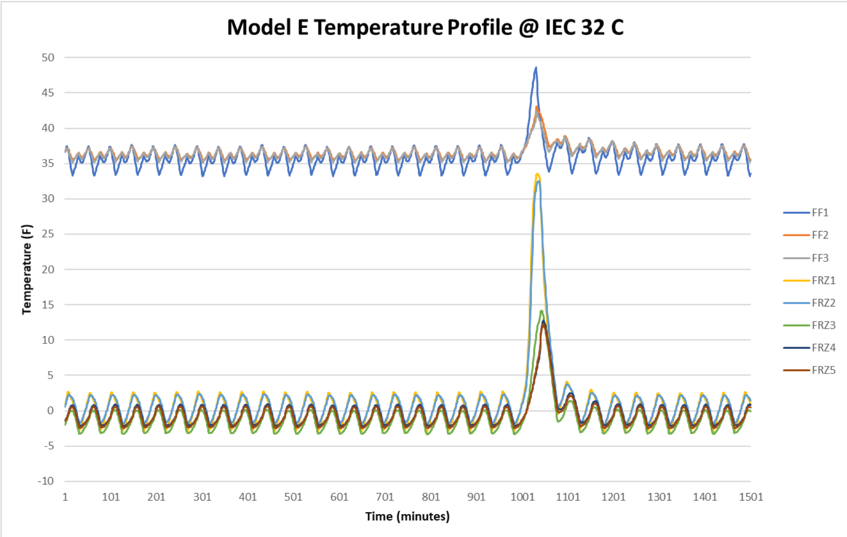

Model B Wattage Profile @ IEC 32 C
Power (W)
Time (minutes)
500
450
400
350
300
250
200
150
100
50
0
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501

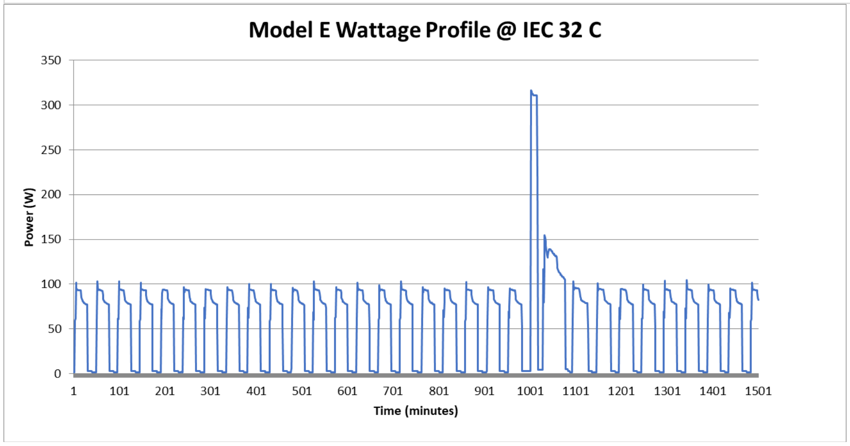

Model B Temperature Profile @ DOE 90 F Mid Mid Setting
Temperature (F)
Time (minutes)
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5

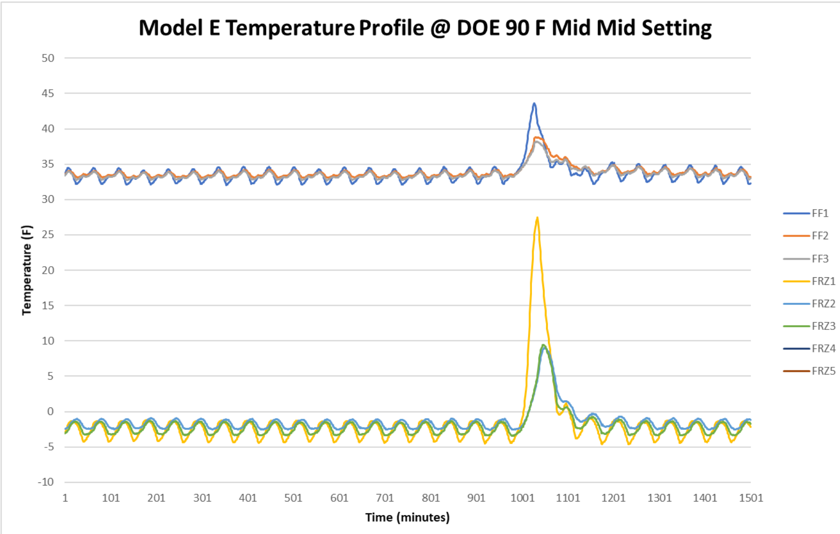

Model B Wattage Profile @ DOE 90 F Mid Mid Setting
Power (W)
Time (minutes)

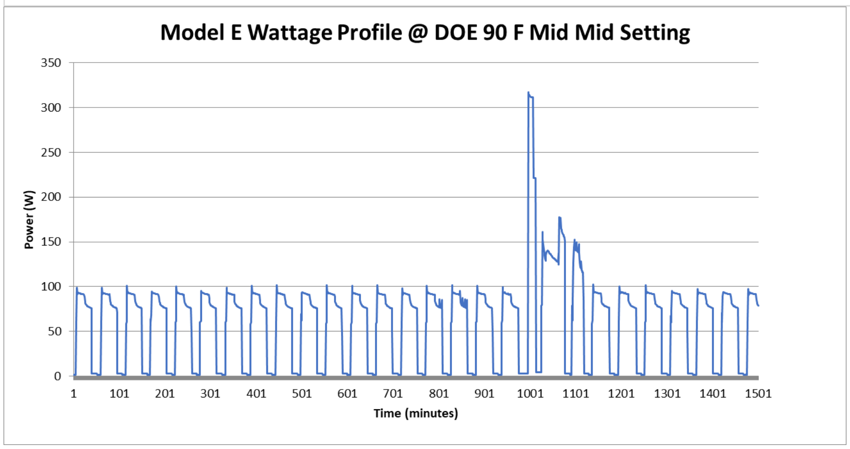

Model E Temperature Profile @ IEC 16 C
Temperature (F)
Time (minutes)
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5


Model E Wattage Profile @ IEC 16 C
Power (W)
Time (minutes)


Model E Temperature Profile @ IEC 32 C
Temperature (F)
Time (minutes)
FF1
FF2
FF3
FRZ1
FRZ2
FRZ3
FRZ4
FRZ5


Model E Wattage Profile @ IEC 32 C
Power (W)
Time (minutes)



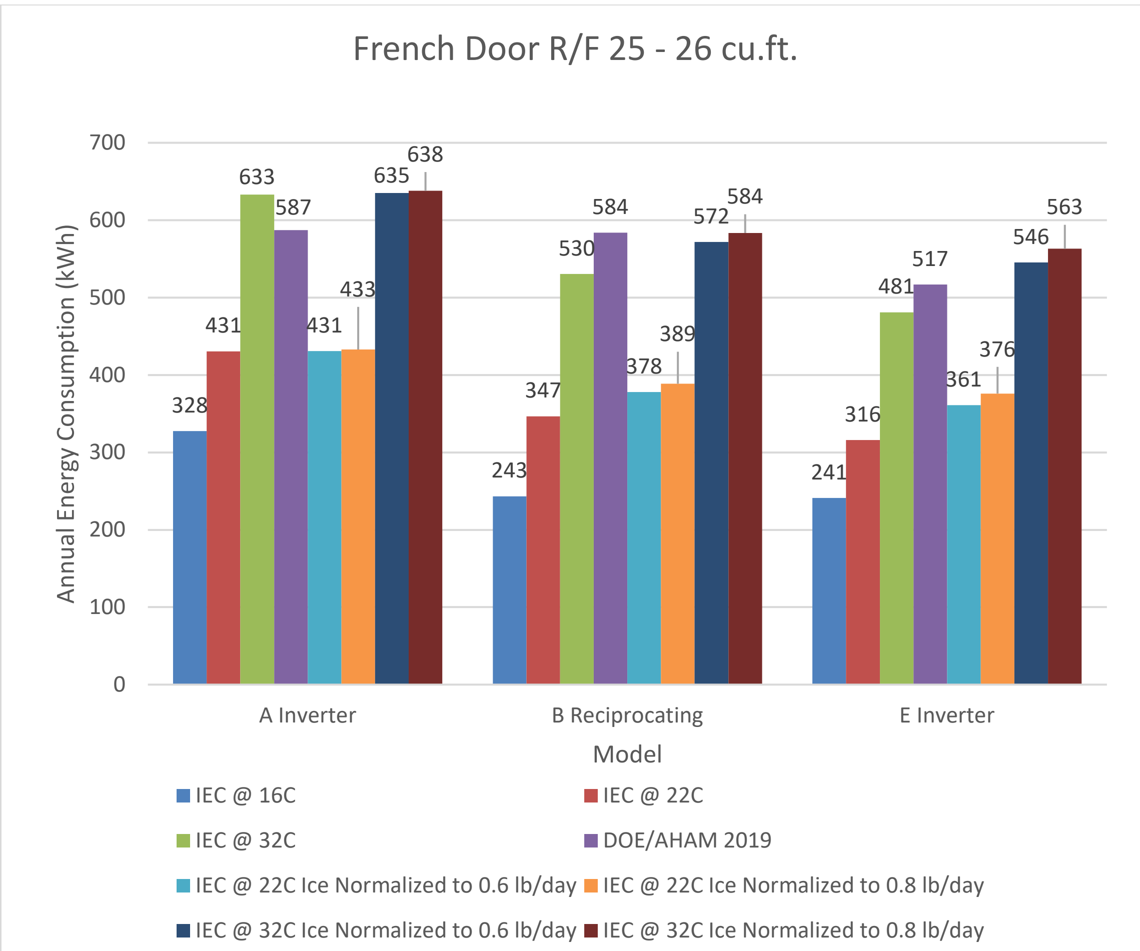



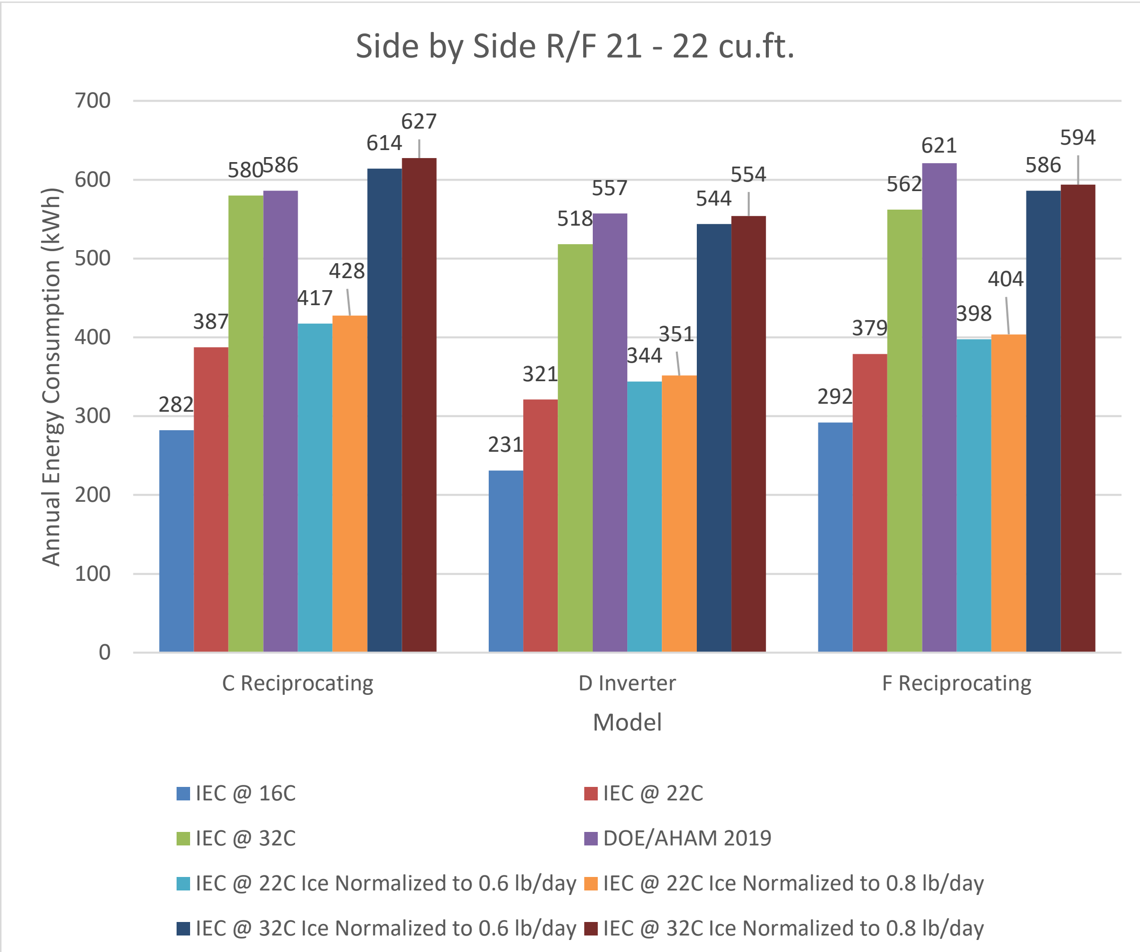

## Load Processing Efficiency

As defined in the IEC 62552-3:2015 Annex G, the Load Processing Efficiency (LPE) quantifies the additional energy consumed by the refrigerator to remove a known amount of energy contained in warm water, which is placed into the fresh food and frozen compartments. The ratio of the energy in the water to the energy consumed by the refrigerator is used to determine the LPE in units of W/W.

| Model | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Type | French Door with Through the Door Ice. Also has ice maker in freezer compartment | French Door with Through the Door Ice | Side by Side with Through the Door Ice | Side by Side with Through the Door Ice | French Door without Through the Door Ice. Ice maker in freezer compartment. | Side by Side with through the Door Ice |
| Compressor Type | Inverter Driven | Reciprocating | Reciprocating | Inverter Driven | Inverter Driven | Reciprocating |
| LPE @ 16°C (W/W) | 1.969 | 1.426 | 1.802 | 2.777 | 1.856 | 1.277 |
| LPE @ 32°C (W/W) | 1.590 | 0.898 | 1.483 | 1.659 | 1.460 | 1.179 |
| LPE @ 22°C (W/W) | 2.017 | 1.384 | 1.612 | 2.623 | 1.717 | 1.198 |

**Ice Making Test**
For the ambient IEC tests of 22°C and 32°C, the refrigerators were connected to a water supply where the water temperature was at the same ambient temperature. The ice making function was activated for each unit. The weight of ice produced over a regular interval of at least 6 hours was measured. The energy consumption during these periods was compared to the energy consumption when not making ice. This value is normalized to the standard amount of 0.6 lbs of ice / day and 0.8 lbs of ice / day. Note that Model A has an ice maker in both the French door and in the freezer drawer.



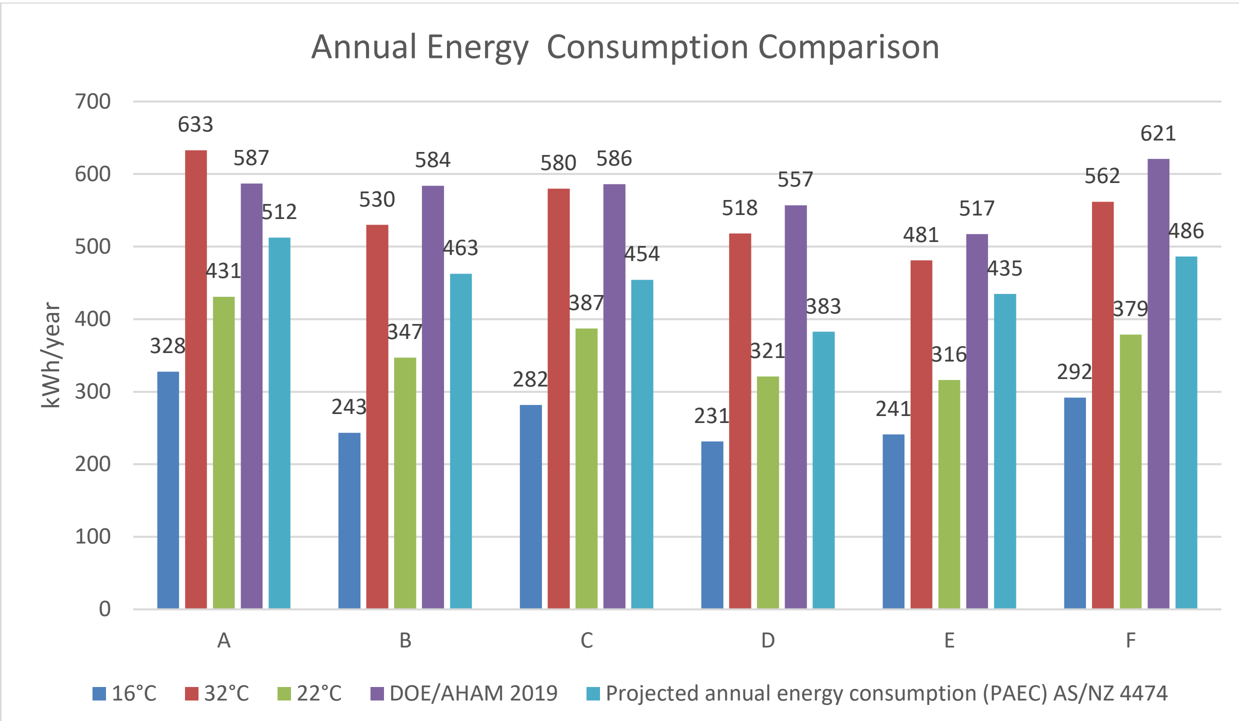



The following table shows the ice making results for each model.

| Model | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 32C Weight of ice (lbs/6 hr) | 2.341 | 1.347 | 1.007 | 0.851 | 0.915 | 1.289 |
| 32C lbs/day | 9.364 | 5.389 | 4.029 | 3.404 | 3.661 | 5.157 |
| 32C Power while making ice | 83.54 | 94.02 | 94.05 | 73.24 | 88.41 | 82.80 |
| 32C Power while not making ice | 66.59 | 57.84 | 62.73 | 53.37 | 51.83 | 60.61 |
| 32C Ice Making Energy in 6 hours | 101.68 | 217.06 | 187.90 | 119.28 | 219.50 | 133.11 |
| | | | | | | |
| 22C Weight of ice (lbs/6 hr) | 3.124 | 1.441 | 0.954 | 0.933 | 0.828 | 1.187 |
| 22C lbs/day | 12.497 | 5.764 | 3.817 | 3.733 | 3.311 | 4.750 |
| 22C Power while making ice | 59.19 | 72.42 | 64.42 | 49.12 | 61.06 | 57.69 |
| 22C Power while not making ice | 44.79 | 36.82 | 41.85 | 33.54 | 33.00 | 40.65 |
| 22C Ice Making Energy in 6 hours | 86.41 | 213.61 | 135.42 | 93.51 | 168.39 | 102.21 |

## AS/NZ 4474

The energy calculations defined in the Australian / New Zealand test method AS/NZ 4474 were utilized as another comparison requested by NEEA. This calculation combines the daily energy consumption measured in the 16°C test and the daily energy consumption measured in the 32°C test to come up with an annual energy consumption. This calculation also incorporates the Load Processing Efficiency value.



## 12. Product Photos

Model A

Model B

## Model C



## Model D



## Model E



## Model F



# 13. Equipment Used

| Instrument Type | Brand | Model # | Date of last calibration | Calibration due date |
|---|---|---|---|---|
| Power Meter (#0446) | Yokogawa | WT230 | 10/08/2019 | 10/08/2020 |
| Power Meter (#0430) | Yokogawa | WT230 | 10/08/2019 | 10/08/2020 |
| Data Acquisition (#0429) | Agilent | 34972A | 10/07/2019 | 10/07/2020 |
| Data Acquisition (#0447) | Agilent | 34972A | 10/07/2019 | 10/07/2020 |
| Data Acquisition (#0473) | Agilent | 34972A | 10/08/2019 | 10/08/2020 |

# 14. Status

| | |
|---|---|
| Testing Started: | 3/9/2020 |
| Testing Done: | 12/8/2020 |
| Report Completed: | 1/22/2021 |

# 15. Report Revision History:

| Revision | Date: | Description |
|---|---|---|
| Rev A | 3/31/2020 | IEC Report completed, reviewed & posted |
| Rev B | 6/18/2020 | Added DOE test results and comparison analysis |
| Rev C | 1/22/2021 | Updated graphs and tables |

# 16. Intended Use of This Test Report

This report is confidential and is intended for the exclusive use of the client named above.
UL Verification Services did not select the samples, determine whether the samples were representative of production samples, witness the production of the test samples, nor were we provided with information relative to the formulation or identification of component materials used in the test samples. The test results apply only to the actual samples tested. UL Verification Services has no vested interest in the results of this testing and hereby certifies the impartial manner in which the testing was performed.

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***************************END OF TEST REPORT*************************

TL-611

# TEST REPORT
# IEC 62552:2015
## Household refrigerating appliances - Characteristics and test methods
## Part 1: General requirements
## Part 2: Performance requirements
## Part 3: Energy consumption and volume

| | |
|---|---|
| **Report reference No. ....................... :** | ST137_20_V0 |
| **Project reference No....................... :** | PN9328 |
| **Tested by (name+signature).......... :** | Erick Zehr / Curt Tremel |
| **Reviewed by (name+signature).... :** | Daryl Michael |
| **Date of issue.................................. :** | 2020-12-23 |
| **Contents ......................................... :** | 20 pages (06 pages of attachements) |
| **Date of revision .............................. :** | |
| **Update due to ................................. :** | |
| **Applicant's name ........................... :** | Northwest Energy Efficiency Alliance (NEEA) |
| **Applicant's contact........................ :** | Eric Olson |
| **Address........................................... :** | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON  97204 |
| **Test specification:** | |
| **Standard ......................................... :** | IEC 62552-1:2015<br>IEC 62552-2:2015<br>IEC 62552-3:2015 |
| **Test procedure ............................... :** | Standard |
| **Non-standard test method ............ :** | N/A |
| **Test Report Form No. ..................... :** | IEC62552_A (PRO-03-25Rev.3.0) |
| **Test Report Form(s) Originator .... :** | UL International Italia S.r.l. |
| **Test item(s) description ................ :** | French door refrigerator-freezer |
| **Trademark....................................... :** | Brand B |
| **Manufacturer ................................. :** | [redacted] |
| **Country of manufacture ................ :** | - |
| **Model/Type reference.................... :** | Model A1 |
| **Product serial number................... :** | [redacted]007 |
| **UL Identification code ................... :** | ST-2020-0137  Model A |

<table>
<tr><td colspan="2">Summary of testing:</td></tr>
<tr><td rowspan="2">Tests performed (clause and name of test):<br><br>IEC 62552-1:2015<br>Clause 4 – Classification<br><br>IEC 62552-3:2015<br>Clause 6 – Determination of energy consumption<br>Clause 4.6 / Annex G – Determination of load processing efficiency</td><td>Testing laboratory:<br><br>UL Verification Services Inc.<br>3020 1st Avenue East<br>Newton IA, 50208, US<br><br>Testing location:<br>Same as above</td></tr>
<tr><td>Date of receipt of test item(s):<br>2020-03-13<br><br>Date of tests:<br>2020-03-14 to 2020-04-17</td></tr>
<tr><td colspan="2">List of attachments (including a total number of pages in each attachment):<br><br>Annex 1 - List of test equipment used (1 page)<br>Annex 2 - Graphs of energy consumption test (3 pages)<br>Annex 3 - Graphs of load processing efficiency test (3 pages)</td></tr>
</table>

| **Test item particulars......................................:** | |
|---|---|
| Type of refrigerating appliance.....................................: | ☐ refrigerator<br>☒ refrigerator-freezer<br>☐ freezer<br>☐ wine storage refrigerator |
| Type of refrigerating appliance (accessible of compartment(s) .........................................................: | ☐ top-opening ☒ upright |
| Type of mounting ..........................................................: | ☐ Built-in ☒ Free-standing ☐ Portable<br>☐ Wall-mounted |
| Cooling system ...............................................................: | ☐ Partial No-frost ☒ Total No-frost ☒ Frost-free<br>☐ Manual defrost ☒ Automatic defrost<br>☐ Cyclic defrost ☒ Variable defrost |
| Separate refrigerant circuits .........................................: | ☐ Yes ☒ No |
| Two or more motor-compressors ...............................: | ☐ Yes ☒ No |
| Electrovalve....................................................................: | ☐ Yes ☒ No |
| Compartment ..................................................................: | ☒ Fresh-food ☐ Cellar ☐ Chill ☐ 0 Star<br>☐ 1 Star ☐ 2 Star ☐ 3 Star ☒ 4 Star<br>☐ Pantry ☐ Ice-making ☐ Wine storage |
| Equipment .......................................................................: | ☒ Ice-maker ☐ Ice-dispenser<br>☐ Water-dispenser ☐ Water-tank |
| **Ratings:** | |
| Rated voltage ..................................................................: | - |
| Rated frequency.............................................................: | - |
| Rated current input ........................................................: | - |
| Climate class...................................................................: | - |
| Refrigerant type ..............................................................: | - |
| Refrigerant mass.............................................................: | - |
| Rated freezing capacity .................................................: | - |
| Rated volume ..................................................................: | Ref: 493 L Cellar: N/A Chill: N/A<br>Frz****: 249 L Frz**: N/A Frz*: N/A<br>Wine: N/A 0°C: N/A Pantry: N/A |
| **Circuit information:** | |
| Compressor.....................................................................: | Type: N/A |
| Condenser.......................................................................: | Type: N/A<br>WxH: N/A<br>No. Tubes: N/A |
| Evaporator (Refrigerator)...............................................: | Type: N/A<br>WxD: N/A<br>No. Plates: N/A |

| **Test item particulars…………………………………..:** | |
|---|---|
| | No. Tubes: N/A |
| Evaporator (Freezer) ....................................................: | Type: N/A |
| | WxD: N/A |
| | No. Plates: N/A |
| | No. Tubes: N/A |
| Thermostat setting ........................................................: | Electronic control |

**Possible test case verdicts:**

- Test object does meet the requirement ..................... : P (Passed)
- Test object does not meet the requirement ............... : F (Failed)
- Test case does not apply to the test object ............... : N/A (Not applicable)
- Test is not checked..................................................... : N/C (Not checked)

**General remarks:**

The test results presented in this test report relate only to the object tested, not selected by UL Verification Services Inc.

This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.
The test report includes only the clauses required in the reference standard.

The laboratory adopted Accuracy Method decision rule that sources of uncertainty are minimized. Therefore, measurement uncertainty does not take into account to determine the conformance with the limit or specific requirements.

The Uncertainty of Measurement (UoM) for each unit measured in this Test Report is estimated in accordance with the procedure No. 23-CL-G0851. Details of the estimation of UoM may be made available upon request.

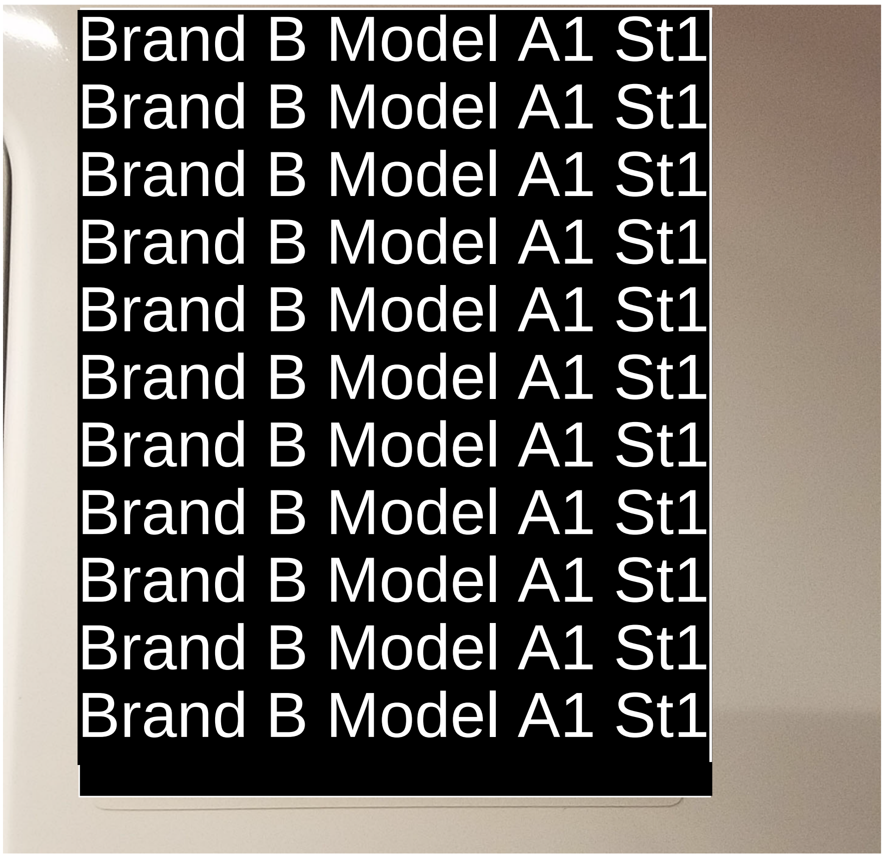
"(See appended table)" refers to a table appended to the report.

"(See appended sketch)" refers to a sketch appended to the report.

**Other product information:**

Status of sample upon receipt: ☒ New and operational ☐ Reconditioned ☐ Damaged

**Copy of marking plate:**



**Product photos:**

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| | | | |
|---|---|---|---|
| Part 1 Cl.4 | **CLASSIFICATION** | | |
| | Refrigerating appliance classified into four climate classes or into a range of classes | | - |
| | SN - Extended temperate (+10 to +32)°C...............: | | N/C |
| | N - Temperate (+16 to +32)°C................................: | | N/C |
| | ST - Subtropical (+16 to +38)°C .............................: | | N/C |
| | T - Tropical (+16 to +43)°C.....................................: | | N/C |

| | | | |
|---|---|---|---|
| Part 3 Cl.6 | **DETERMINATION OF ENERGY CONSUMPTION** | | |
| 6.2 | Objective | | - |
| | Measurement of the temperature and energy consumption for a representative period of steady state operation. | | - |
| | In the case of products with automatic defrost functions, the incremental energy during defrost and recovery is determined for a specified number of representative and valid defrost and recovery periods. | | - |
| 6.3 | Number of test runs | | P |
| | The energy consumption is determined at ambient temperatures of 16 °C and 32 °C either: | | P |
| | a) directly from the results of a single test run; | | P |
| | b) by interpolation between the results of two or more test runs. | | N/A |
| 6.4 | Steady state power consumption | See appended table | P |
| 6.5 | Defrost and recovery energy and temperature change | | P |
| | Ambient temperatures of both 16 °C and 32 °C. | | P |
| | The additional energy associated with defrost and recovery is reported in Watt-hour (Wh). | | P |
| | The temperature change associated with defrost and recovery is reported in degree Kelvin-hour (Kh). | | P |
| 6.8.2 | Daily energy consumption | | - |
| | The ambient temperature (°C)……………………..: | 16 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh)……………………………..: | $E_{daily16C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh)……………….…………………..: | $E_{daily16C}$ = 898 | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = 35.6 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………..…: | $\Delta E_{df}$ = 87.3 | P |
| | The estimated defrost interval in accordance with Annex D (h)…………………………………………..: | $\Delta t_{df}$ = 48 | P |
| | The average temperature for each compartment (°C)……………………………..…………………: | $T_{average}$ = 3.5 (Unfrozen)<br>$T_{average}$ = -18.2 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………………..……..: | $T_{ss}$ = 3.5 (Unfrozen)<br>$T_{ss}$ = -18.2 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………………..…: | $\Delta Th_{df}$ = 1.40 (Unfrozen)<br>$\Delta Th_{df}$ = 4.23 (Frozen | P |
| | The ambient temperature (°C)……………………..: | 32 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily32C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..…….…………………..: | $E_{daily32C}$ = 1735 | P |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = 66.5 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………..…: | $\Delta E_{df}$ = 136.7 | P |
| | The estimated defrost interval in accordance with Annex D (h)…………………………………………..: | $\Delta t_{df}$ = 24.0 | P |
| | The average temperature for each compartment (°C)……………………………………………………..: | $T_{average}$ = 3.09 (Unfrozen)<br>$T_{average}$ = -18.31 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………………..……..: | $T_{ss}$ = 3.09 (Unfrozen)<br>$T_{ss}$ = -18.31 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………………..…: | $\Delta Th_{df}$ = 8.17 (Unfrozen)<br>$\Delta Th_{df}$ = 9.85 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 22 °C | - |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily22C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..….…………………………..: | $E_{daily22C}$ = 1180 | P |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = 45.0 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 162.8 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 39.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 3.82 (Unfrozen)<br>$T_{average}$ = -18.03 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)……………….……..: | $T_{ss}$ = 3.82 (Unfrozen)<br>$T_{ss}$ = -18.03 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………..…: | $\Delta Th_{df}$ = 4.71 (Unfrozen)<br>$\Delta Th_{df}$ = 8.24 (Frozen) | P |
| 6.8.3 | Interpolation | | N/A |
| 6.8.4 | Specified auxiliaries | See appended table | P |
| 6.8.5 | Total energy consumption | See appended table | P |

| | | | |
|---|---|---|---|
| **Part 3 An. G** | **DETERMINATION OF LOAD PROCESING EFFICIENCY** | | |
| G.5 | Determination of load processing efficiency | | P |
| G.5.2 | Quantification of input energy | See appended table | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | **P** |
|---|---|---|

| Ambient temp.: 16°C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | |
| | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | U 1 Unfrozen comp. | °C | 3.49 | | 3.59 | | | |
| | F 1 Frozen comp. | °C | -18.22 | | -18.22 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 492.7 | |
| Frozen volume | L | 249.2 | |
| Unfrozen comp. load | kg | 5.913 | |
| Frozen comp. load | kg | 0.997 | |
| $E_{input - test}$ | Wh | 205 | |
| $\Delta E_{additional\ test}$ | Wh | 104 | |
| $Efficiency_{load}$ | Wh/Wh | 1.969 | |
| $E_{input\ nominal}$ | Wh | 204 | |
| $\Delta E_{processing}$ | Wh/d | 103.61 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | **P** |
|---|---|---|

| Ambient temp.: 32°C | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | U 1 Unfrozen comp. | °C | 3.94 | - | 4.18 | | | |
| | F 1 Frozen comp. | °C | -18.36 | - | -18.34 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 492.7 | |
| Frozen volume | L | 249.2 | |
| Unfrozen comp. load | kg | 5.913 | |
| Frozen comp. load | kg | 0.997 | |
| $E_{\text{input - test}}$ | Wh | 329 | |
| $\Delta E_{\text{additional test}}$ | Wh | 207 | |
| $\text{Efficiency}_{\text{load}}$ | Wh/Wh | 1.590 | |
| $E_{\text{input nominal}}$ | Wh | 332 | |
| $\Delta E_{\text{processing}}$ | Wh/d | 208.8 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Part 3 An. G | TABLE: Determination of load processing efficiency | P |
|---|---|---|
| Ambient temp.: 22°C | | |

| Thermostat setting | | | [Ref_Frz] N/C_N/C | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | T 1 Unfrozen comp. | °C | 3.77 | - | 3.76 | | | |
| | T 1 Frozen comp. | °C | -17.90 | - | -17.99 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 492.7 | |
| Frozen volume | L | 249.2 | |
| Unfrozen comp. load | kg | 5.913 | |
| Frozen comp. load | kg | 0.997 | |
| $E_{input-test}$ | Wh | 250 | |
| $\Delta E_{additional\ test}$ | Wh | 124 | |
| $Efficiency_{load}$ | Wh/Wh | 2.017 | |
| $E_{input\ nominal}$ | Wh | 252 | |
| $\Delta E_{processing}$ | Wh/d | 124.9 | |
| Voltage | Volt/Hz | 115/60 | |

| | TABLE: Calculation of energy consumption | - |
|---|---|---|

| | | |
|---|---|---|
| $E_{daily\ 16C}$ | 898 | Wh/d |
| $E_{daily\ 32C}$ | 1735 | Wh/d |
| $\Delta E_{processing\ 16C}$ | 103.61 | Wh/d |
| $\Delta E_{processing\ 32C}$ | 208.8 | Wh/d |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

**The following factors are as defined for the European Region**

| $E_{total} = f\{ E_{daily\ 16C}, E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **480** | **kWh/year** |

| $E_{total} = f\{ E_{daily\ 16C}, E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **537** | **kWh/year** |

**The following factors are as defined in Australian / New Zealand Region**

| $E_{total} = f\{ E_{daily\ 16C}, E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **426** | **kWh/year** |

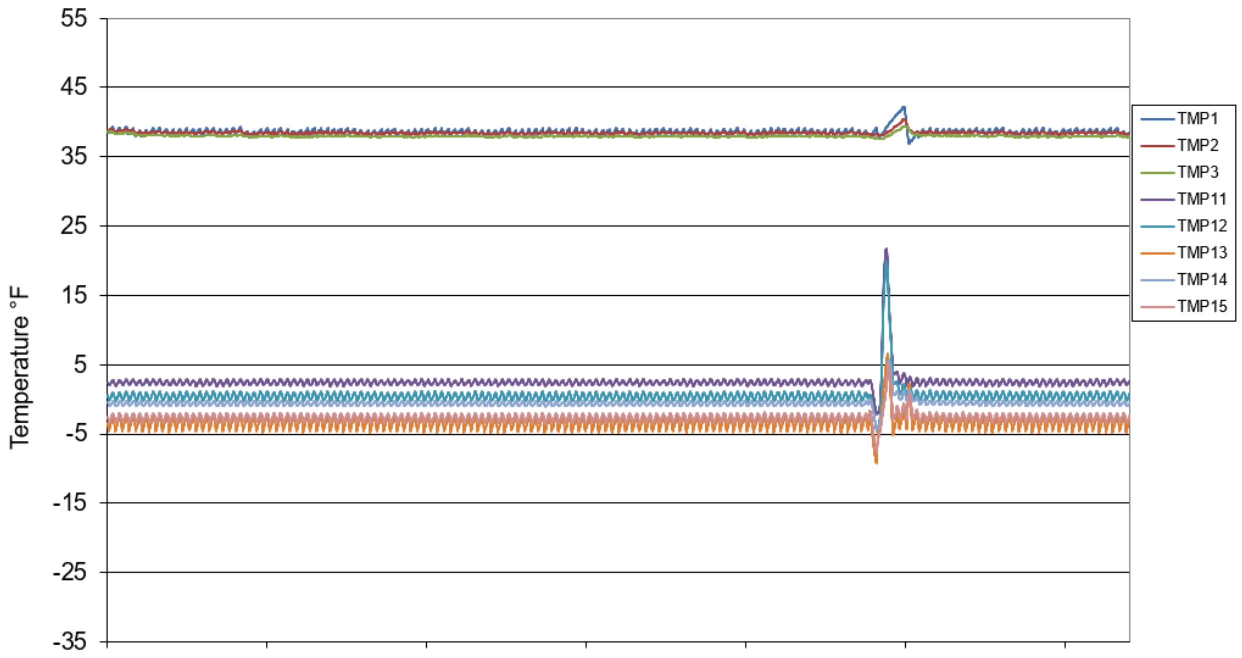
| $E_{total} = f\{ E_{daily\ 16C}, E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **512** | **kWh/year** |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

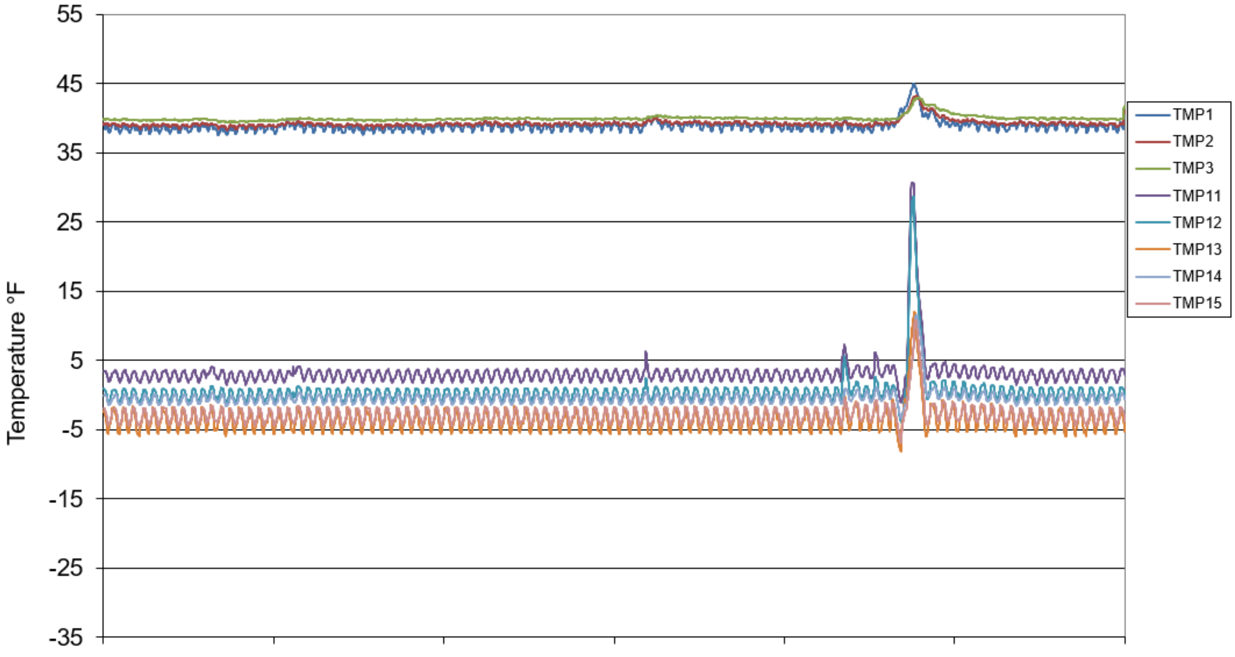
| **Annex 1** | **-** | | | | |
|---|---|---|---|---|---|
| **Clause** | **Measurement / testing** | **Testing / measuring equipment / material used** | **Instrument ID** | **Calibration** | |
| | | | | **Last** | **Expiry** |
| Part 1 An. A | Temperature | Thermocouples type T | 0429 | 10/2019 | 10/2020 |
| Part 1 An. A | Humidity | Hygrometer probe | 1182 | 9/2019 | 9/2020 |
| Part 1 An. A | Air velocity | Anemometer probe | 0550 | 11/2019 | 11/2020 |
| Part 1 An. A | Power / Energy consumption | Power analyzer / Energy meter | 0430 | 10/2019 | 10/2019 |

| **Annex 2** | **Graph of energy consumption test: 16°C** | **-** |
|---|---|---|

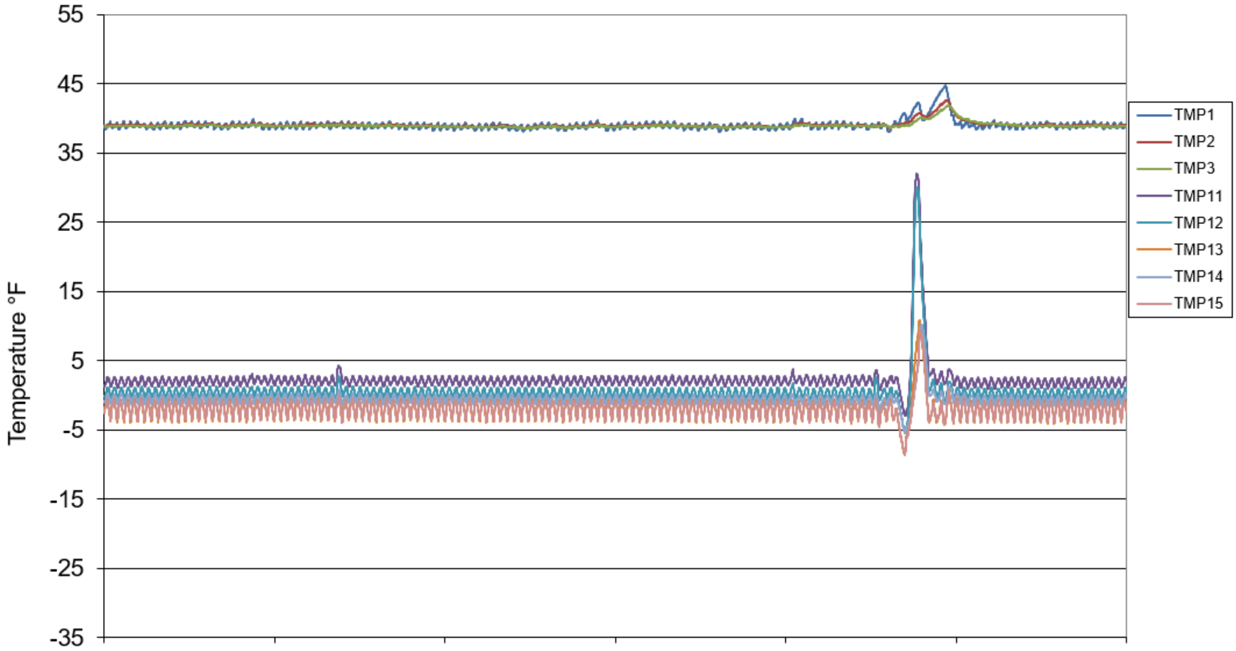


| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 2 | Graph of energy consumption test: 32°C | - |
|---|---|---|

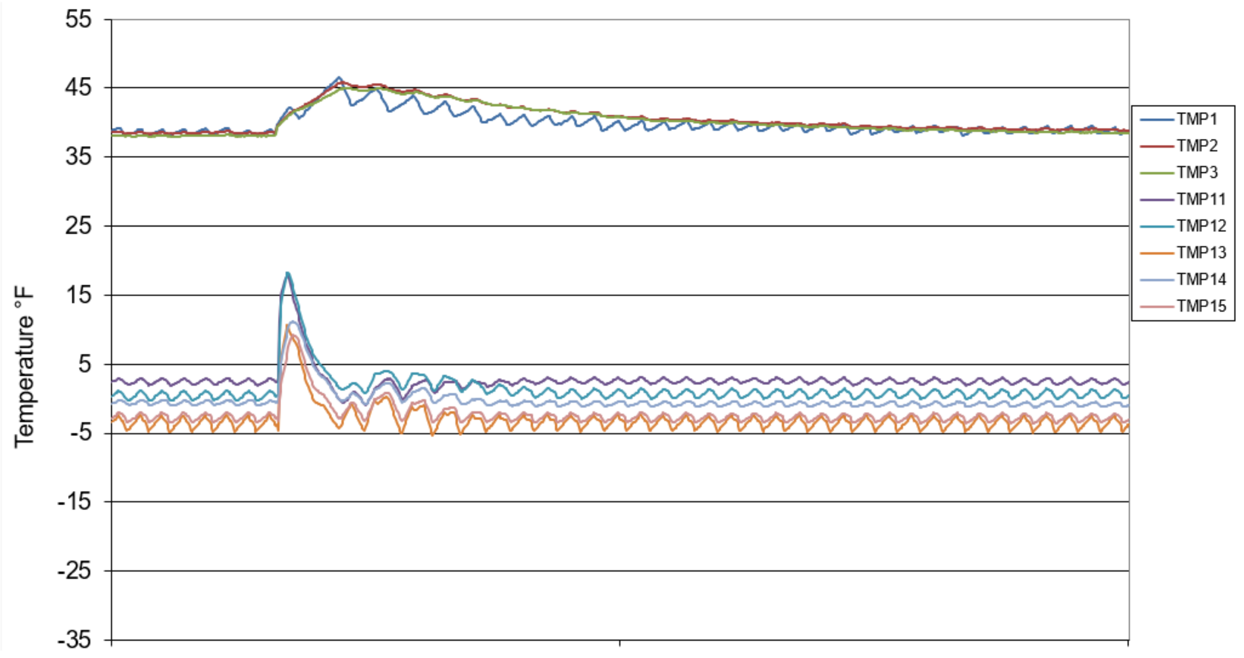


| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| **Annex 2** | **Graph of energy consumption test: 22°C** | | **-** |



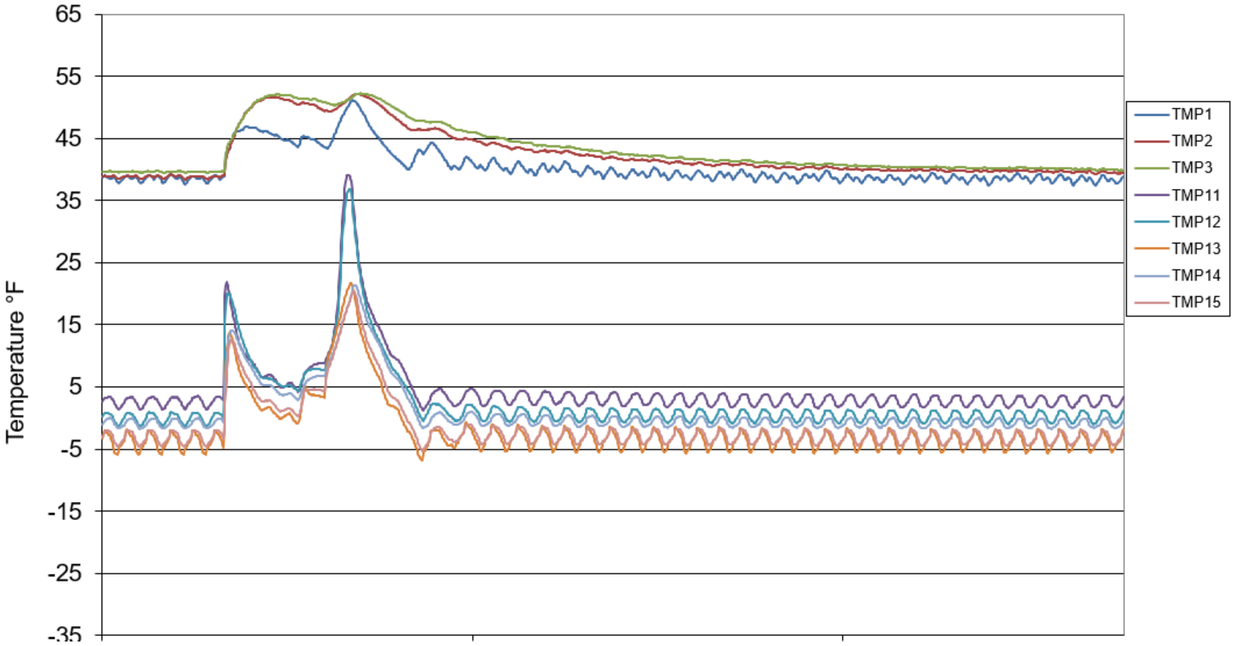
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | |
|---|---|---|
| **Annex 3** | **Graph of load processing efficiency test: 16°C** | **-** |

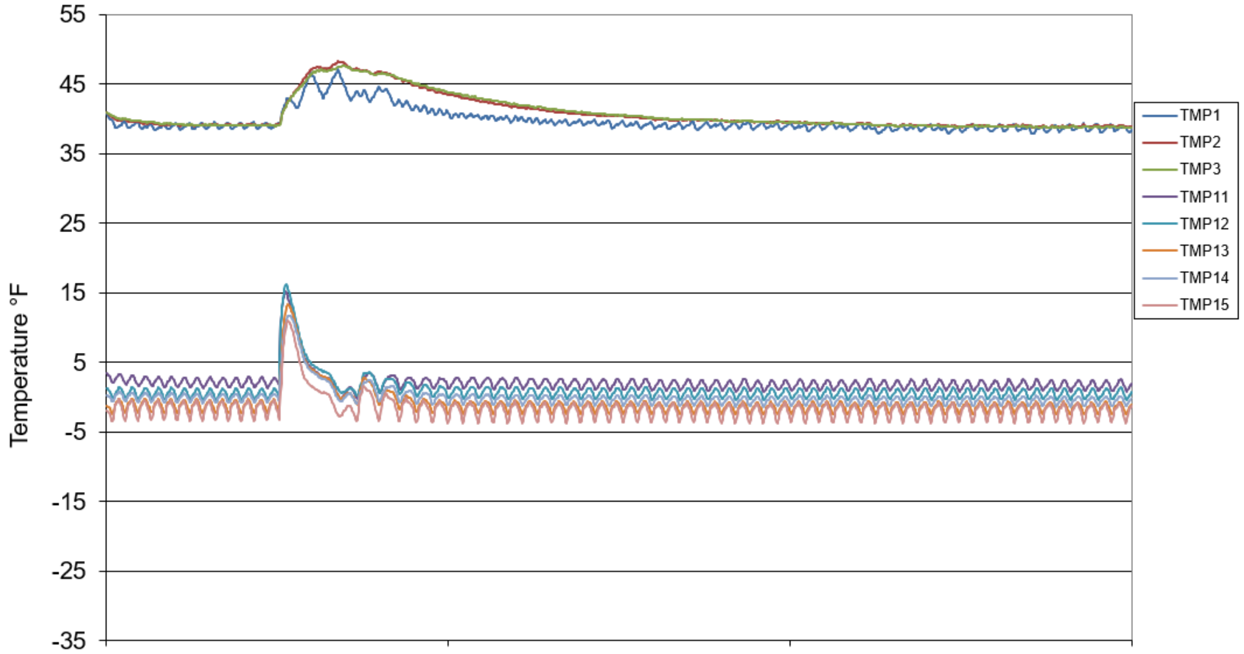


| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 3** | **Graph of load processing efficiency test: 32°C** | **-** |
|---|---|---|



| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| **Annex 3** | **Graph of load processing efficiency test: 22°C** | | **-** |




**END OF TEST REPORT**

[Back to Instructions tab]

| Title | |
|---|---|
| Test Report Template Name: | Consumer R-RF-MRef |
| Version Number: | v2.1 |
| Latest Template Revision: | 11/18/2019 |
| Tab Name: | General Info & Test Results |
| File Name: | Refrigerator Brand B Model A1St DOE Test Datasheet.xlsx |
| Test Start Date: | 4/18/2020 |
| Test Completion Date: | 5/8/2020 |

| 1. Lab Information | |
|---|---|
| Lab Name: | UL Verification Services Inc. |
| Lab Location: | Newton, Iowa |

| 2. Test Information | |
|---|---|
| Date Test Started: | 4/18/2020 |
| Date Test Finished: | 5/8/2020 |

| 3. Product Information | |
|---|---|
| Brand: | Brand B |
| Manufacturer: | [redacted] |
| Manufacturer Model Number: | Model A1 |
| Serial Number: | [redacted]007 |
| Date of Manufacture (if available): | |
| Product Class: | 5A |
| Product Type: | Refrigerator-Freezer |
| Size: | Standard-sized |
| Received Date: | 3/13/2020 |
| Received Condition: | Good |
| Anti-Sweat Heather (ASH) Switch: | No |
| Default ASH Switch Position: | |
| Number of Separate Auxiliary Compartments: | 0 |
| Variable ASH: | No |
| Demand-Response Capable: | No |
| Automatic Icemaker: | Yes |
| Number of Compressors: | 1 |
| Defrost Control Type: | Variable |
| Number of Unique Defrost Frequencies:<br>*(e.g. as described in Appendix A Sections 4.2.3 - 4.2.4)* | |
| Outer Dimensions (in.) | |
| Height: | |
| Width: | |
| Depth: | |

| 4. Explain how defrost control type was determined. |
|---|
| *Include necessary data on the raw data tabs if it is used to determine control type.* |
| |

**5. Test Results**

| Variable | Result | Units |
|---|---|---|
| **Measured Volumes** | | |
| Fresh Food | 17.40 | $ft^3$ |
| Freezer | 8.80 | $ft^3$ |
| Cooler | | $ft^3$ |
| Total Volume | 26.2 | $ft^3$ |
| Adjusted Volume | 32.9 | $ft^3$ |
| **Energy Use** | | |
| ASH Switch OFF | 643 | kWh/yr |
| ASH Switch ON* | | kWh/yr |
| Overall* | 643 | kWh/yr |
| * If necessary | | |

*NOTE: Copy only; sign off is done in the Report Sign-Off Block tab*

**6. Test Report Sign-Off Block**

**We certify that the information and data in this report: (1) were obtained from the specific test unit under test; (2) were obtained during the specific test being reported; (3) were not copied from any other source, except where instructed to do so; and (4) were not altered or modified in any way.**

| Role | Date | Entity |
|---|---|---|
| Test Completion | 5/8/2020 | UL |
| Template Completion | 12/3/2020 | UL |
| Report Review by Test Lab | | |
| Report Review by Test Lab | | |

TL-611

# TEST REPORT
# IEC 62552:2015
## Household refrigerating appliances - Characteristics and test methods
## Part 1: General requirements
## Part 2: Performance requirements
## Part 3: Energy consumption and volume

| | |
|---|---|
| **Report reference No.** ....................: | ST136_20_V0 |
| **Project reference No.**....................: | PN9328 |
| **Tested by (name+signature)**.........: | Erick Zehr / Curt Tremel |
| **Reviewed by (name+signature)**....: | Daryl Michael |
| **Date of issue**.................................: | 2021-1-06 |
| **Contents** .........................................: | 20 pages (06 pages of attachements) |
| **Date of revision** .............................: | |
| **Update due to** ................................: | |
| **Applicant's name** ...........................: | Northwest Energy Efficiency Alliance (NEEA) |
| **Applicant's contact**........................: | Eric Olson |
| **Address**..........................................: | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON 97204 |
| **Test specification:** | |
| **Standard** .........................................: | IEC 62552-1:2015<br>IEC 62552-2:2015<br>IEC 62552-3:2015 |
| **Test procedure** ...............................: | Standard |
| **Non-standard test method** ...........: | N/A |
| **Test Report Form No.** ....................: | IEC62552_A (PRO-03-25Rev.3.0) |
| **Test Report Form(s) Originator** ....: | UL International Italia S.r.l. |
| **Test item(s) description** ................: | French door refrigerator-freezer |
| **Trademark**.....................................: | Brand D |
| **Manufacturer** .................................: | [redacted] |
| **Country of manufacture** ................: | - |
| **Model/Type reference** ....................: | Model A2 |
| **Product serial number**...................: | [redacted]049 |
| **UL Identification code** ...................: | ST-2020-0136 Model B |

<table>
<tr><td colspan="2">Summary of testing:</td></tr>
<tr><td rowspan="2">Tests performed (clause and name of test):<br><br>IEC 62552-1:2015<br>Clause 4 – Classification<br><br>IEC 62552-3:2015<br>Clause 6 – Determination of energy consumption<br>Clause 4.6 / Annex G – Determination of load processing efficiency</td><td>Testing laboratory:<br><br>UL Verification Services Inc.<br>3020 1st Avenue East<br>Newton IA, 50208, US<br><br>Testing location:<br>Same as above</td></tr>
<tr><td>Date of receipt of test item(s):<br>2020-03-13<br><br>Date of tests:<br>2020-03-14 to 2020-04-17</td></tr>
<tr><td colspan="2">List of attachments (including a total number of pages in each attachment):<br><br>Annex 1 - List of test equipment used (1 page)<br>Annex 2 - Graphs of energy consumption test (3 pages)<br>Annex 3 - Graphs of load processing efficiency test (3 pages)</td></tr>
</table>

| **Test item particulars……………………………….:** | |
|---|---|
| Type of refrigerating appliance....................................: | ☐ refrigerator<br>☒ refrigerator-freezer<br>☐ freezer<br>☐ wine storage refrigerator |
| Type of refrigerating appliance (accessible of compartment(s) ............................................................: | ☐ top-opening ☒ upright |
| Type of mounting ........................................................: | ☐ Built-in ☒ Free-standing ☐ Portable<br>☐ Wall-mounted |
| Cooling system ............................................................: | ☐ Partial No-frost ☒ Total No-frost ☒ Frost-free<br>☐ Manual defrost ☒ Automatic defrost<br>☐ Cyclic defrost ☒ Variable defrost |
| Separate refrigerant circuits ........................................: | ☐ Yes ☒ No |
| Two or more motor-compressors ...............................: | ☐ Yes ☒ No |
| Electrovalve..................................................................: | ☐ Yes ☒ No |
| Compartment ...............................................................: | ☒ Fresh-food ☐ Cellar ☐ Chill ☐ 0 Star<br>☐ 1 Star ☐ 2 Star ☐ 3 Star ☒ 4 Star<br>☐ Pantry ☐ Ice-making ☐ Wine storage |
| Equipment ....................................................................: | ☒ Ice-maker ☐ Ice-dispenser<br>☐ Water-dispenser ☐ Water-tank |
| **Ratings:** | |
| Rated voltage ...............................................................: | - |
| Rated frequency...........................................................: | - |
| Rated current input .......................................................: | - |
| Climate class................................................................: | - |
| Refrigerant type ..........................................................: | - |
| Refrigerant mass..........................................................: | - |
| Rated freezing capacity ...............................................: | - |
| Rated volume ...............................................................: | Ref: 510 L  Cellar: N/A  Chill: N/A<br>Frz****: 190 L  Frz**: N/A  Frz*: N/A<br>Wine: N/A  0°C: N/A  Pantry: N/A |
| **Circuit information:** | |
| Compressor...................................................................: | Type: N/A |
| Condenser.....................................................................: | Type: N/A<br>WxH: N/A<br>No. Tubes: N/A |
| Evaporator (Refrigerator)............................................: | Type: N/A<br>WxD: N/A<br>No. Plates: N/A |

| **Test item particulars…………………………………..:** | |
|---|---|
| Evaporator (Freezer) ......................................................: | No. Tubes: N/A<br>Type: N/A<br>WxD: N/A<br>No. Plates: N/A<br>No. Tubes: N/A |
| Thermostat setting ..........................................................: | Electronic control |

**Possible test case verdicts:**

- Test object does meet the requirement .................... : P (Passed)
- Test object does not meet the requirement ............... : F (Failed)
- Test case does not apply to the test object ............... : N/A (Not applicable)
- Test is not checked.................................................... : N/C (Not checked)

**General remarks:**

The test results presented in this test report relate only to the object tested, not selected by UL Verification Services Inc.

This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.

The test report includes only the clauses required in the reference standard.

The laboratory adopted Accuracy Method decision rule that sources of uncertainty are minimized. Therefore, measurement uncertainty does not take into account to determine the conformance with the limit or specific requirements.

The Uncertainty of Measurement (UoM) for each unit measured in this Test Report is estimated in accordance with the procedure No. 23-CL-G0851. Details of the estimation of UoM may be made available upon request.

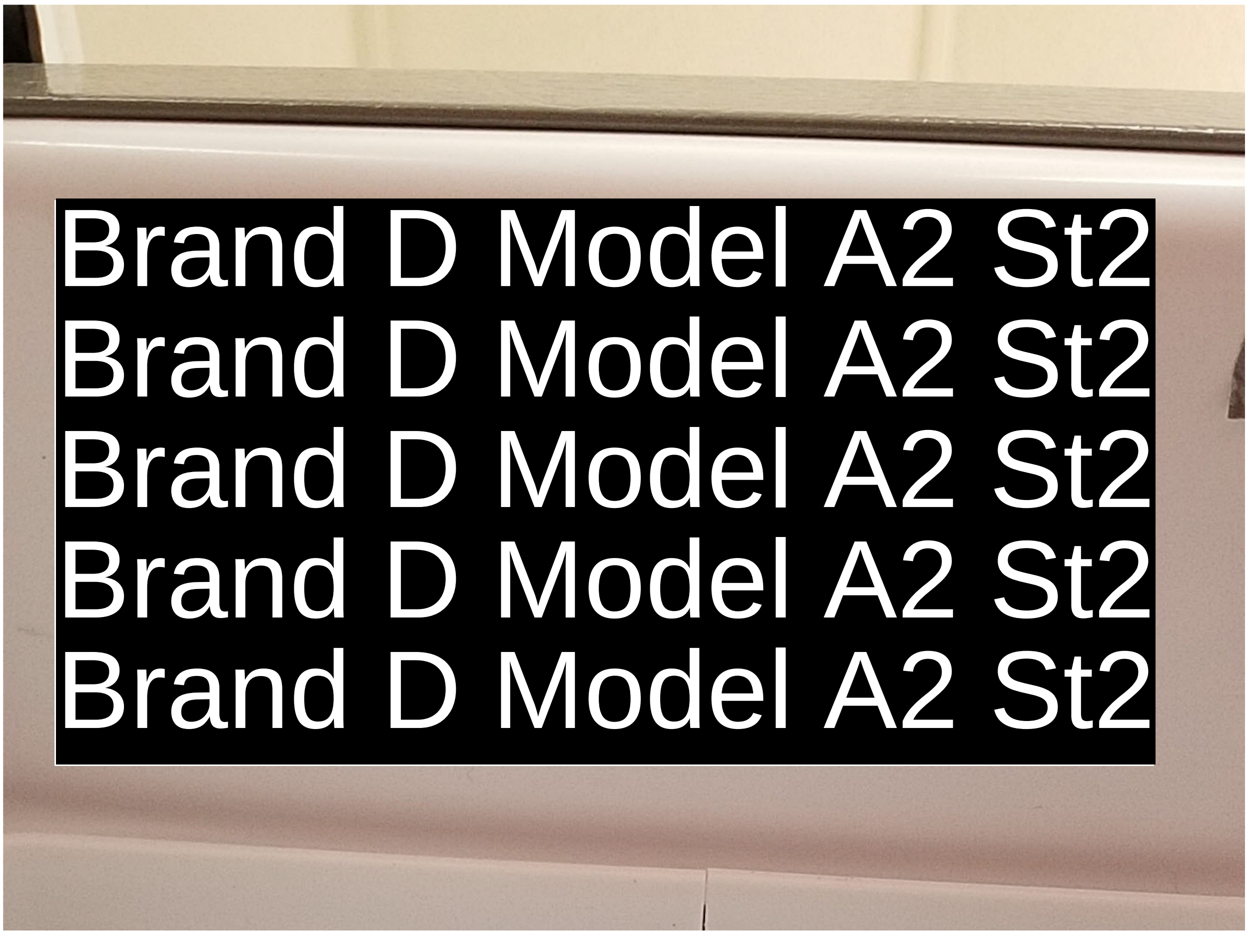
”(See appended table)” refers to a table appended to the report.

"(See appended sketch)" refers to a sketch appended to the report.

**Other product information:**

Status of sample upon receipt: ☒ New and operational ☐ Reconditioned ☐ Damaged

**Copy of marking plate:**



**Product photos:**

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | | |
|---|---|---|---|
| **Part 1 Cl.4** | **CLASSIFICATION** | | |
| | Refrigerating appliance classified into four climate classes or into a range of classes | | - |
| | SN - Extended temperate (+10 to +32)°C...............: | | N/C |
| | N - Temperate (+16 to +32)°C................................: | | N/C |
| | ST - Subtropical (+16 to +38)°C .............................: | | N/C |
| | T - Tropical (+16 to +43)°C.....................................: | | N/C |

| | | | |
|---|---|---|---|
| **Part 3 Cl.6** | **DETERMINATION OF ENERGY CONSUMPTION** | | |
| 6.2 | Objective | | - |
| | Measurement of the temperature and energy consumption for a representative period of steady state operation. | | - |
| | In the case of products with automatic defrost functions, the incremental energy during defrost and recovery is determined for a specified number of representative and valid defrost and recovery periods. | | - |
| 6.3 | Number of test runs | | P |
| | The energy consumption is determined at ambient temperatures of 16 °C and 32 °C either: | | P |
| | a) directly from the results of a single test run; | | P |
| | b) by interpolation between the results of two or more test runs. | | N/A |
| 6.4 | Steady state power consumption | See appended table | P |
| 6.5 | Defrost and recovery energy and temperature change | | P |
| | Ambient temperatures of both 16 °C and 32 °C. | | P |
| | The additional energy associated with defrost and recovery is reported in Watt-hour (Wh). | | P |
| | The temperature change associated with defrost and recovery is reported in degree Kelvin-hour (Kh). | | P |
| 6.8.2 | Daily energy consumption | | - |
| | The ambient temperature (°C)……………………..: | 16 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh)……………………………..: | $E_{daily16C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh)……………….…………………..: | $E_{daily16C}$ = 667 | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 26.3 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 71.9 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 48 | P |
| | The average temperature for each compartment (°C)……………………………..…………………: | $T_{average}$ = 3.8 (Unfrozen)<br>$T_{average}$ = -18.5 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………………….……..: | $T_{ss}$ = 3.8 (Unfrozen)<br>$T_{ss}$ = -18.5 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = 1.71 (Unfrozen)<br>$\Delta Th_{df}$ = 0.03 (Frozen | P |
| | The ambient temperature (°C)……………………..: | 32 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily32C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..…….……………………..: | $E_{daily32C}$ = 1453 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 57.9 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 63.36 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 24.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 3.8 (Unfrozen)<br>$T_{average}$ = -18.11 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………………….……..: | $T_{ss}$ = 3.8 (Unfrozen)<br>$T_{ss}$ = -18.11 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = 0.54 (Unfrozen)<br>$\Delta Th_{df}$ = 3.22 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 22 °C | - |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily22C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..….: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..….………………………..: | $E_{daily22C}$ = 950 | P |
| | The steady state power for the selected temperature control setting (W)…………………………………..: | P = 37.0 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)………………………………………………..….: | $\Delta E_{df}$ = 101.8 | P |
| | The estimated defrost interval in accordance with Annex D (h)…………………………………………..: | $\Delta t_{df}$ = 39.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 3.83 (Unfrozen)<br>$T_{average}$ = -18.62 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………….……….: | $T_{ss}$ = 3.83 (Unfrozen)<br>$T_{ss}$ = -18.62 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………..…: | $\Delta Th_{df}$ = 3.48 (Unfrozen)<br>$\Delta Th_{df}$ = 0.34 (Frozen) | P |
| 6.8.3 | Interpolation | | N/A |
| 6.8.4 | Specified auxiliaries | See appended table | P |
| 6.8.5 | Total energy consumption | See appended table | P |

| | | | |
|---|---|---|---|
| **Part 3 An. G** | **DETERMINATION OF LOAD PROCESING EFFICIENCY** | | |
| G.5 | Determination of load processing efficiency | | P |
| G.5.2 | Quantification of input energy | See appended table | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | P |
|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 16°C | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | |
| | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | U 1 Unfrozen comp. | °C | 3.82 | | 2.76 | | | |
| | F 1 Frozen comp. | °C | -18.52 | | -18.30 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 509.7 | |
| Frozen volume | L | 189.7 | |
| Unfrozen comp. load | kg | 6.116 | |
| Frozen comp. load | kg | 0.759 | |
| $E_{input - test}$ | Wh | 183 | |
| $\Delta E_{additional\ test}$ | Wh | 128 | |
| $Efficiency_{load}$ | Wh/Wh | 1.426 | |
| $E_{input\ nominal}$ | Wh | 178 | |
| $\Delta E_{processing}$ | Wh/d | 124.82 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | | P |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 32°C | | | | | | | | | |
| Thermostat setting | | | [Ref_Frz] N/C_N/C | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | U 1 Unfrozen comp. | °C | 3.65 | - | 1.34 | | | | |
| | F 1 Frozen comp. | °C | -18.05 | - | -17.84 | | | | |

| Description | Unit | Value | |
|---|---|---|---|
| Unfrozen volume | L | 509.7 | |
| Frozen volume | L | 189.7 | |
| Unfrozen comp. load | kg | 6.116 | |
| Frozen comp. load | kg | 0.759 | |
| $E_{input - test}$ | Wh | 322 | |
| $\Delta E_{additional\ test}$ | Wh | 359 | |
| $Efficiency_{load}$ | Wh/Wh | 0.898 | |
| $E_{input\ nominal}$ | Wh | 305 | |
| $\Delta E_{processing}$ | Wh/d | 339.6 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | | P |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 22°C | | | | | | | | | |
| Thermostat setting | | | [Ref_Frz] N/C_N/C | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | T 1 Unfrozen comp. | °C | 3.84 | - | 2.34 | | | | |
| | T 1 Frozen comp. | °C | -18.62 | - | -18.45 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 509.7 | |
| Frozen volume | L | 189.7 | |
| Unfrozen comp. load | kg | 6.116 | |
| Frozen comp. load | kg | 0.759 | |
| $E_{input - test}$ | Wh | 234 | |
| $\Delta E_{additional test}$ | Wh | 169 | |
| $Efficiency_{load}$ | Wh/Wh | 1.384 | |
| $E_{input nominal}$ | Wh | 226 | |
| $\Delta E_{processing}$ | Wh/d | 163.3 | |
| Voltage | Volt/Hz | 115/60 | |

| | TABLE: Calculation of energy consumption | | - |
|---|---|---|---|

| | | |
|---|---|---|
| $E_{daily 16C}$ | 667 | Wh/d |
| $E_{daily 32C}$ | 1453 | Wh/d |
| $\Delta E_{processing 16C}$ | 124.82 | Wh/d |
| $\Delta E_{processing 32C}$ | 339.6 | Wh/d |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

**The following factors are as defined for the European Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| $E_{total}$ = | 390 | kWh/year |
|---|---|---|

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| $E_{total}$ = | 475 | kWh/year |
|---|---|---|

**The following factors are as defined in Australian / New Zealand Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| $E_{total}$ = | 335 | kWh/year |
|---|---|---|

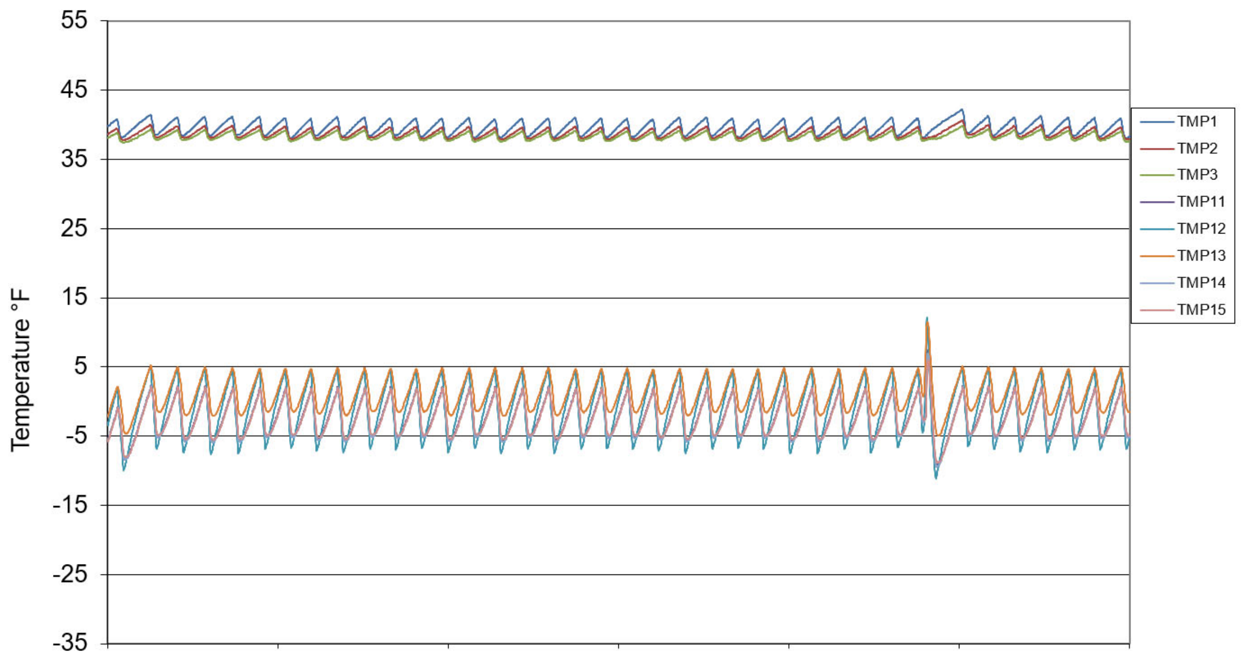
| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| $E_{total}$ = | 463 | kWh/year |
|---|---|---|

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

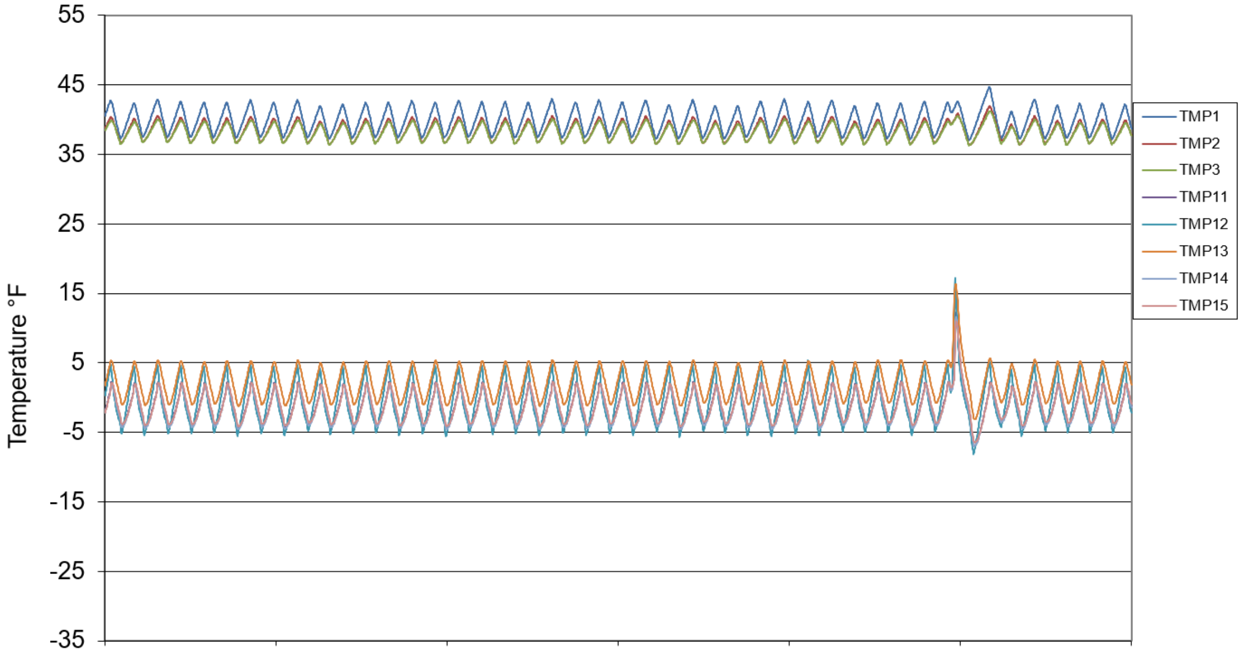
| **Annex 1** | **-** | | | | |
|---|---|---|---|---|---|
| **Clause** | **Measurement / testing** | **Testing / measuring equipment / material used** | **Instrument ID** | **Calibration** | |
| | | | | **Last** | **Expiry** |
| Part 1 An. A | Temperature | Thermocouples type T | 0429 | 10/2019 | 10/2020 |
| Part 1 An. A | Humidity | Hygrometer probe | 1182 | 9/2019 | 9/2020 |
| Part 1 An. A | Air velocity | Anemometer probe | 0550 | 11/2019 | 11/2020 |
| Part 1 An. A | Power / Energy consumption | Power analyzer / Energy meter | 0430 | 10/2019 | 10/2019 |

| **Annex 2** | **Graph of energy consumption test: 16°C** | **-** |
|---|---|---|



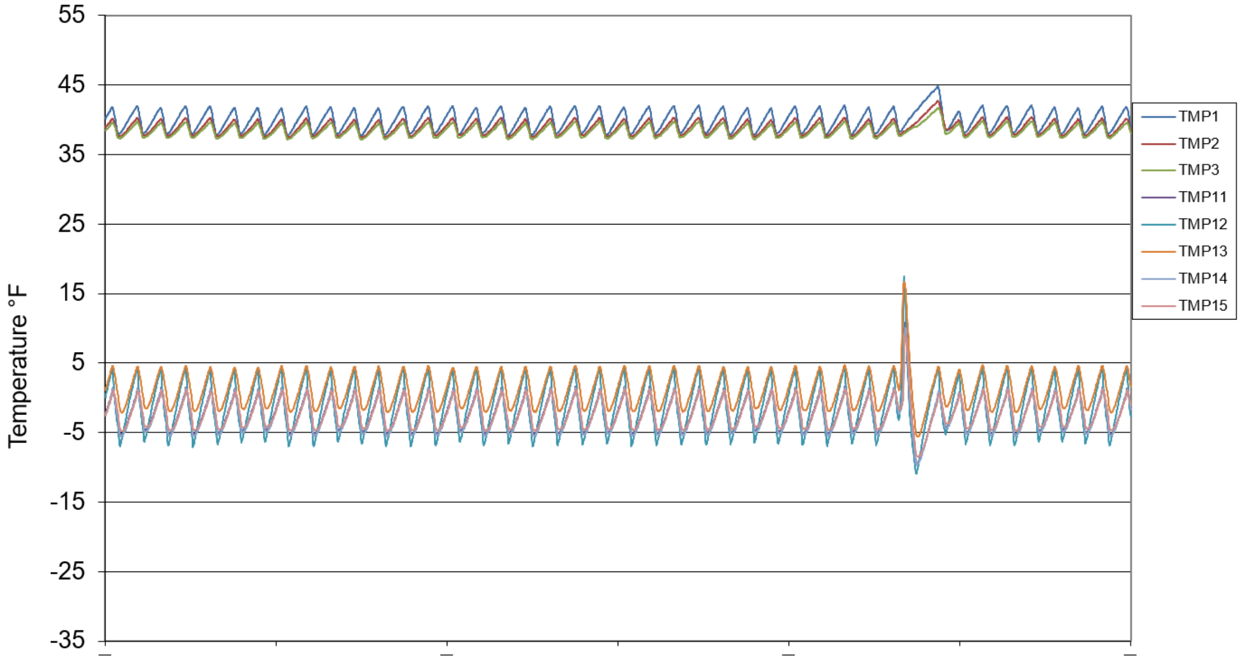
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 2** | **Graph of energy consumption test: 32°C** | **-** |
|---|---|---|



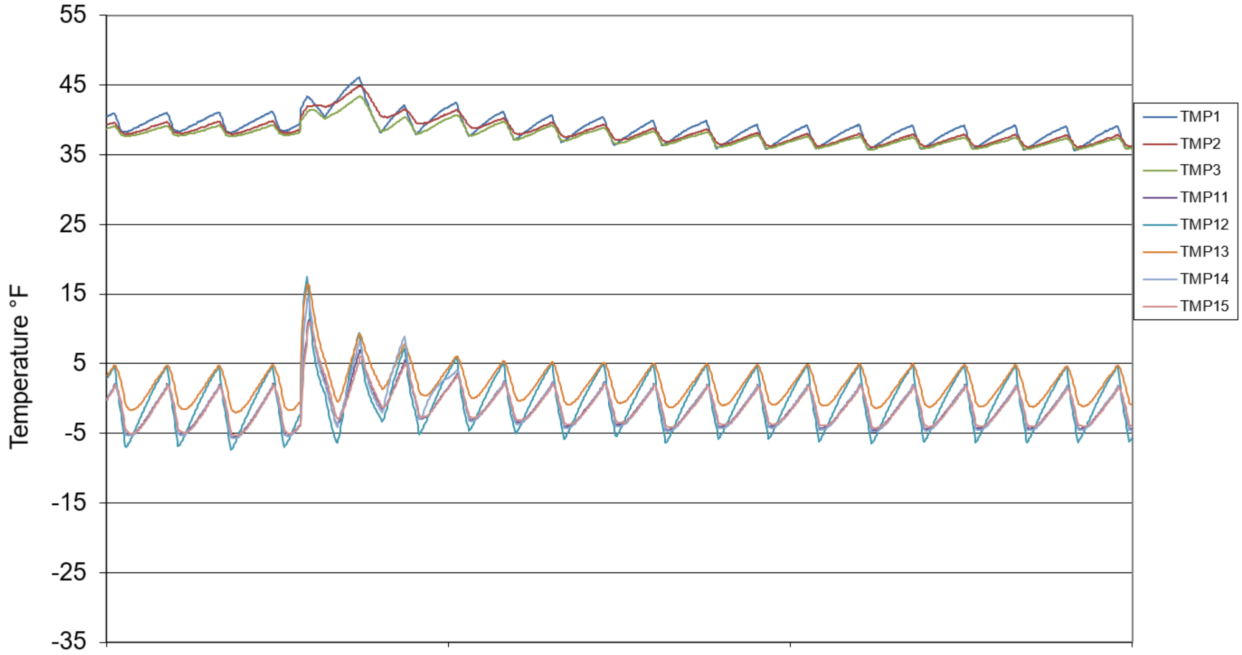
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 2 | Graph of energy consumption test: 22°C | - |
|---|---|---|



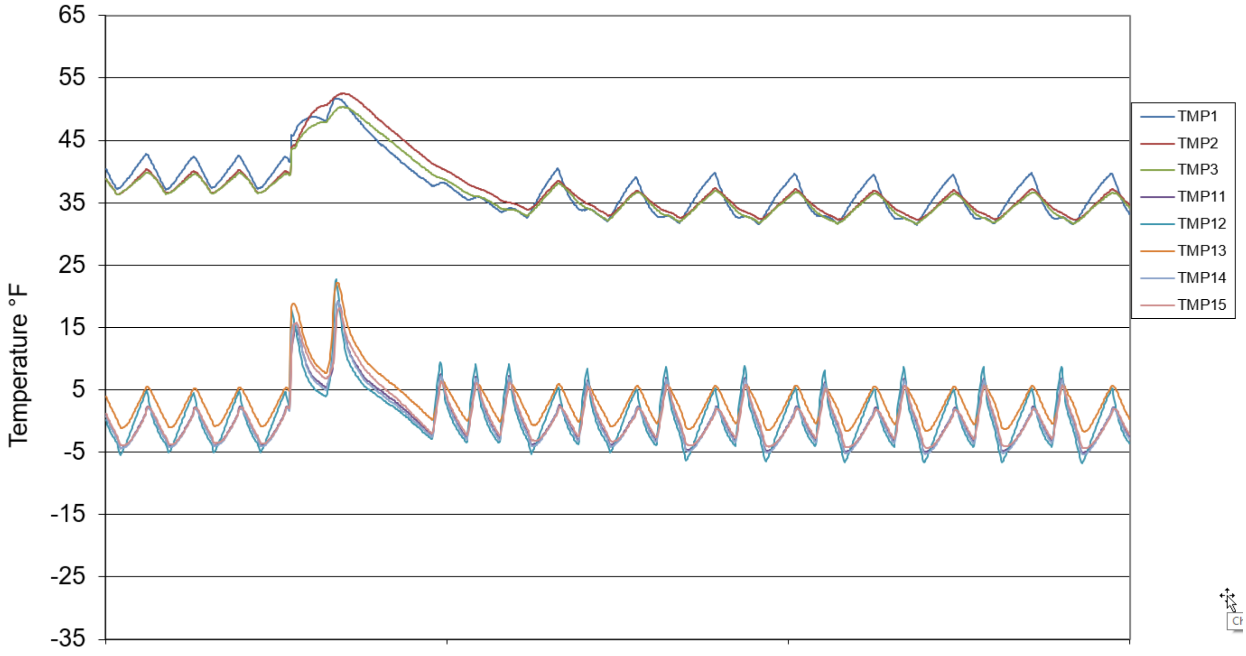
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 3 | Graph of load processing efficiency test: 16°C | - |
|---|---|---|



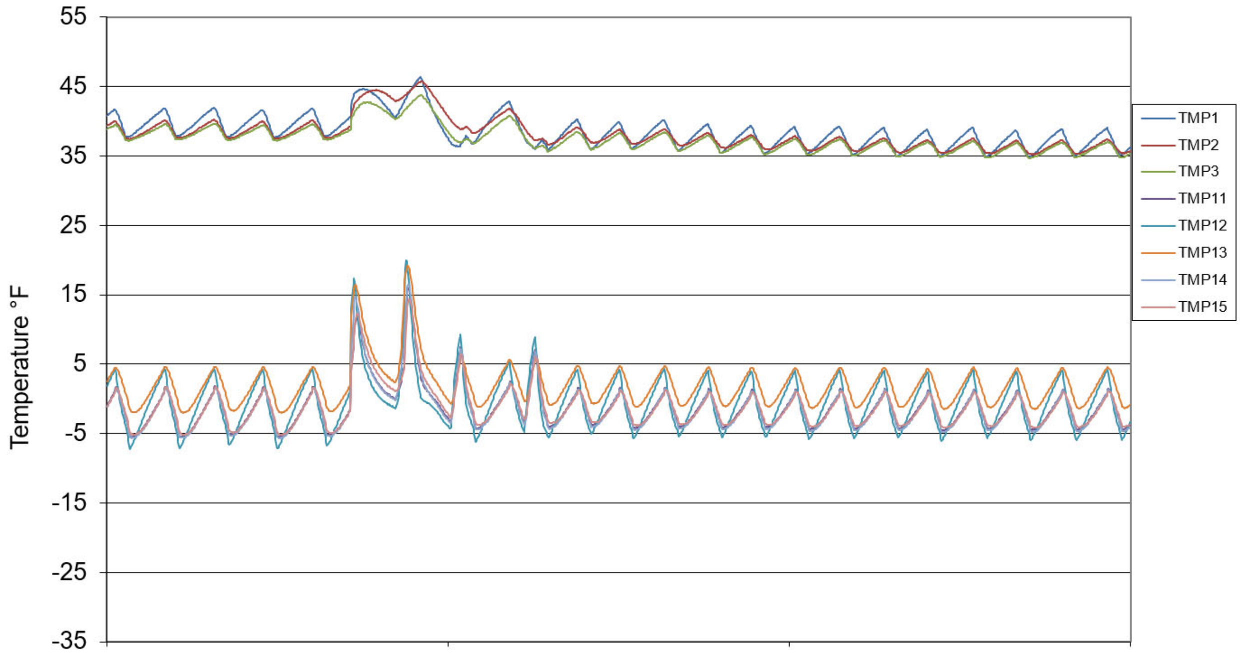
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 3 | Graph of load processing efficiency test: 32°C | - |
|---|---|---|



| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 3 | Graph of load processing efficiency test: 22°C | - |
|---|---|---|




**END OF TEST REPORT**

[Back to Instructions tab]

| Title | |
|---|---|
| Test Report Template Name: | Consumer R-RF-MRef |
| Version Number: | v2.1 |
| Latest Template Revision: | 11/18/2019 |
| Tab Name: | General Info & Test Results |
| File Name: | Refrigerator BrandDModel A2 St2 BrandDModel A2 St2 DOE Test Datasheet.xlsx |
| Test Start Date: | 4/22/2020 |
| Test Completion Date: | 5/8/2020 |

| 1. Lab Information | |
|---|---|
| Lab Name: | UL Verification Services Inc. |
| Lab Location: | Newton, Iowa |

| 2. Test Information | |
|---|---|
| Date Test Started: | 4/22/2020 |
| Date Test Finished: | 5/8/2020 |

| 3. Product Information | |
|---|---|
| Brand: | Brand D |
| Manufacturer: | [redacted] |
| Manufacturer Model Number: | Model A2 |
| Serial Number: | [redacted]049 |
| Date of Manufacture (if available): | |
| Product Class: | 5A |
| Product Type: | Refrigerator-Freezer |
| Size: | Standard-sized |
| Received Date: | 3/13/2020 |
| Received Condition: | Good |
| Anti-Sweat Heather (ASH) Switch: | No |
| Default ASH Switch Position: | |
| Number of Separate Auxiliary Compartments: | 0 |
| Variable ASH: | No |
| Demand-Response Capable: | No |
| Automatic Icemaker: | Yes |
| Number of Compressors: | 1 |
| Defrost Control Type: | Variable |
| Number of Unique Defrost Frequencies:<br>*(e.g. as described in Appendix A Sections 4.2.3 - 4.2.4)* | |
| Outer Dimensions (in.) | |
| Height: | |
| Width: | |
| Depth: | |

| 4. Explain how defrost control type was determined. |
|---|
| *Include necessary data on the raw data tabs if it is used to determine control type.* |
| |

| 5. Test Results | | |
|---|---|---|
| **Variable** | **Result** | **Units** |
| **Measured Volumes** | | |
| Fresh Food | 18.01 | $ft^3$ |
| Freezer | 6.73 | $ft^3$ |
| Cooler | | $ft^3$ |
| Total Volume | 24.7 | $ft^3$ |
| Adjusted Volume | 29.9 | $ft^3$ |
| **Energy Use** | | |
| ASH Switch OFF | 640 | kWh/yr |
| ASH Switch ON* | | kWh/yr |
| Overall* | 640 | kWh/yr |
| * If necessary | | |

*NOTE: Copy only; sign off is done in the Report Sign-Off Block tab*

| 6. Test Report Sign-Off Block | | |
|---|---|---|
| **We certify that the information and data in this report: (1) were obtained from the specific test unit under test; (2) were obtained during the specific test being reported; (3) were not copied from any other source, except where instructed to do so; and (4) were not altered or modified in any way.** | | |
| **Role** | **Date** | **Entity** |
| Test Completion | 5/8/2020 | UL |
| Template Completion | 12/3/2020 | UL |
| Report Review by Test Lab | | |
| Report Review by Test Lab | | |

TL-611

# TEST REPORT
# IEC 62552:2015
# Household refrigerating appliances - Characteristics and test methods
# Part 1: General requirements
# Part 2: Performance requirements
# Part 3: Energy consumption and volume

| | |
|---|---|
| **Report reference No. ......................:** | ST123_20_V0 |
| **Project reference No......................:** | PN9328 |
| **Tested by (name+signature).........:** | Erick Zehr / Curt Tremel |
| **Reviewed by (name+signature)....:** | Daryl Michael |
| **Date of issue..................................:** | 2020-12-23 |
| **Contents .........................................:** | 20 pages (06 pages of attachements) |
| **Date of revision ...............................:** | |
| **Update due to .................................:** | |
| **Applicant's name ...........................:** | Northwest Energy Efficiency Alliance (NEEA) |
| **Applicant's contact........................:** | Eric Olson |
| **Address...........................................:** | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON  97204 |
| **Test specification:** | |
| **Standard .........................................:** | IEC 62552-1:2015<br>IEC 62552-2:2015<br>IEC 62552-3:2015 |
| **Test procedure ...............................:** | Standard |
| **Non-standard test method ............:** | N/A |
| **Test Report Form No. ....................:** | IEC62552_A (PRO-03-25Rev.3.0) |
| **Test Report Form(s) Originator ....:** | UL International Italia S.r.l. |
| **Test item(s) description ................:** | French door refrigerator-freezer |
| **Trademark.......................................:** | Brand C |
| **Manufacturer .................................:** | [redacted] |
| **Country of manufacture ................:** | - |
| **Model/Type reference ....................:** | Model C1 |
| **Product serial number...................:** | [redacted]480 |
| **UL Identification code ...................:** | ST-2020-0123  Model E |

<table>
<tr><td colspan="2">Summary of testing:</td></tr>
<tr><td rowspan="2">Tests performed (clause and name of test):<br><br>IEC 62552-1:2015<br>Clause 4 – Classification<br><br>IEC 62552-3:2015<br>Clause 6 – Determination of energy consumption<br>Clause 4.6 / Annex G – Determination of load processing efficiency</td><td>Testing laboratory:<br><br>UL Verification Services Inc.<br>3020 1st Avenue East<br>Newton IA, 50208, US<br><br>Testing location:<br>Same as above</td></tr>
<tr><td>Date of receipt of test item(s):<br>2020-03-05<br><br>Date of tests:<br>2020-03-14 to 2020-04-17</td></tr>
<tr><td colspan="2">List of attachments (including a total number of pages in each attachment):<br><br>Annex 1 - List of test equipment used (1 page)<br>Annex 2 - Graphs of energy consumption test (3 pages)<br>Annex 3 - Graphs of load processing efficiency test (3 pages)</td></tr>
</table>

| **Test item particulars......................................:** | |
|---|---|
| Type of refrigerating appliance ..................................: | ☐ refrigerator<br>☒ refrigerator-freezer<br>☐ freezer<br>☐ wine storage refrigerator |
| Type of refrigerating appliance (accessible of compartment(s) ..........................................................: | ☐ top-opening ☒ upright |
| Type of mounting .......................................................: | ☐ Built-in ☒ Free-standing ☐ Portable<br>☐ Wall-mounted |
| Cooling system ..........................................................: | ☐ Partial No-frost ☒ Total No-frost ☒ Frost-free<br>☐ Manual defrost ☒ Automatic defrost<br>☐ Cyclic defrost ☒ Variable defrost |
| Separate refrigerant circuits ......................................: | ☐ Yes ☒ No |
| Two or more motor-compressors ...............................: | ☐ Yes ☒ No |
| Electrovalve.................................................................: | ☐ Yes ☒ No |
| Compartment ..............................................................: | ☒ Fresh-food ☐ Cellar ☐ Chill ☐ 0 Star<br>☐ 1 Star ☐ 2 Star ☐ 3 Star ☒ 4 Star<br>☐ Pantry ☐ Ice-making ☐ Wine storage |
| Equipment ....................................................................: | ☒ Ice-maker ☐ Ice-dispenser<br>☐ Water-dispenser ☐ Water-tank |
| **Ratings:** | |
| Rated voltage ..............................................................: | - |
| Rated frequency..........................................................: | - |
| Rated current input .....................................................: | - |
| Climate class...............................................................: | - |
| Refrigerant type .........................................................: | - |
| Refrigerant mass.........................................................: | - |
| Rated freezing capacity ...............................................: | - |
| Rated volume ..............................................................: | Ref: 496 L Cellar: N/A Chill: N/A<br>Frz****: 227 L Frz**: N/A Frz*: N/A<br>Wine: N/A 0°C: N/A Pantry: N/A |
| **Circuit information:** | |
| Compressor.................................................................: | Type: N/A |
| Condenser...................................................................: | Type: N/A<br>WxH: N/A<br>No. Tubes: N/A |
| Evaporator (Refrigerator)...........................................: | Type: N/A<br>WxD: N/A<br>No. Plates: N/A |

| **Test item particulars…………………………………..:** | |
|---|---|
| | No. Tubes: N/A |
| Evaporator (Freezer) ....................................................: | Type: N/A |
| | WxD: N/A |
| | No. Plates: N/A |
| | No. Tubes: N/A |
| Thermostat setting ........................................................: | Electronic control |

**Possible test case verdicts:**

- Test object does meet the requirement ..................... : P (Passed)
- Test object does not meet the requirement ............... : F (Failed)
- Test case does not apply to the test object ............... : N/A (Not applicable)
- Test is not checked ..................................................... : N/C (Not checked)

**General remarks:**

The test results presented in this test report relate only to the object tested, not selected by UL Verification Services Inc.

This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.

The test report includes only the clauses required in the reference standard.

The laboratory adopted Accuracy Method decision rule that sources of uncertainty are minimized. Therefore, measurement uncertainty does not take into account to determine the conformance with the limit or specific requirements.

The Uncertainty of Measurement (UoM) for each unit measured in this Test Report is estimated in accordance with the procedure No. 23-CL-G0851. Details of the estimation of UoM may be made available upon request.

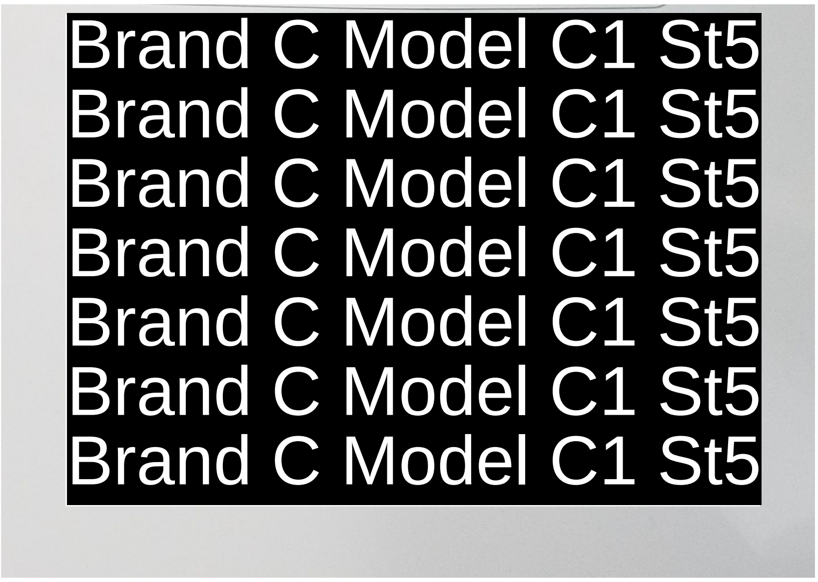
”(See appended table)” refers to a table appended to the report.

"(See appended sketch)" refers to a sketch appended to the report.

**Other product information:**

Status of sample upon receipt: ☒ New and operational ☐ Reconditioned ☐ Damaged

**Copy of marking plate:**



**Product photos:**

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | | |
|---|---|---|---|
| **Part 1 Cl.4** | **CLASSIFICATION** | | |
| | Refrigerating appliance classified into four climate classes or into a range of classes | | - |
| | SN - Extended temperate (+10 to +32)°C...............: | | N/C |
| | N - Temperate (+16 to +32)°C................................: | | N/C |
| | ST - Subtropical (+16 to +38)°C ..............................: | | N/C |
| | T - Tropical (+16 to +43)°C.....................................: | | N/C |

| | | | |
|---|---|---|---|
| **Part 3 Cl.6** | **DETERMINATION OF ENERGY CONSUMPTION** | | |
| 6.2 | Objective | | - |
| | Measurement of the temperature and energy consumption for a representative period of steady state operation. | | - |
| | In the case of products with automatic defrost functions, the incremental energy during defrost and recovery is determined for a specified number of representative and valid defrost and recovery periods. | | - |
| 6.3 | Number of test runs | | P |
| | The energy consumption is determined at ambient temperatures of 16 °C and 32 °C either: | | P |
| | a) directly from the results of a single test run; | | P |
| | b) by interpolation between the results of two or more test runs. | | N/A |
| 6.4 | Steady state power consumption | See appended table | P |
| 6.5 | Defrost and recovery energy and temperature change | | P |
| | Ambient temperatures of both 16 °C and 32 °C. | | P |
| | The additional energy associated with defrost and recovery is reported in Watt-hour (Wh). | | P |
| | The temperature change associated with defrost and recovery is reported in degree Kelvin-hour (Kh). | | P |
| 6.8.2 | Daily energy consumption | | - |
| | The ambient temperature (°C)……………………..: | 16 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh)……………………………..: | $E_{daily16C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh)……………….…………………..: | $E_{daily16C}$ = 660 | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 25.6 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………….…: | $\Delta E_{df}$ = 38.9 (1st defrost)<br>$\Delta E_{df}$ = 98.2 (2nd defrost) | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 96.0 | P |
| | The average temperature for each compartment (°C)……………………………..…………………: | $T_{average}$ = 2.8 (Unfrozen)<br>$T_{average}$ = -18.2 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)……………….……….: | $T_{ss}$ = 2.7 (Unfrozen)<br>$T_{ss}$ = -18.2 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………………….: | $\Delta Th_{df}$ = 3.4 (Unfr.–1st defrost)<br>$\Delta Th_{df}$ = 2.9 (Froz.–1st defrost)<br>$\Delta Th_{df}$ = 2.4 (Unfr.–2nd defrost)<br>$\Delta Th_{df}$ = 9.6 (Froz.–2nd defrost) | P |
| | The ambient temperature (°C)……………………..: | 32 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)…….…………………..: | $E_{daily32C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)….....…: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..…….…………………………..: | $E_{daily32C}$ = 1319 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 51.6 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………….…: | $\Delta E_{df}$ = 35.4 (1st defrost)<br>$\Delta E_{df}$ = 124.7 (2nd defrost) | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 48.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 2.5 (Unfrozen)<br>$T_{average}$ = -18.0 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)……………….……….: | $T_{ss}$ = 2.2 (Unfrozen)<br>$T_{ss}$ = -18.0 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………………….: | $\Delta Th_{df}$ = 6.5 (Unfr.–1st defrost)<br>$\Delta Th_{df}$ = 6.1 (Froz.–1st defrost)<br>$\Delta Th_{df}$ = 7.4 (Unfr.–2nd defrost)<br>$\Delta Th_{df}$ =18.5(Froz.–2nd defrost) | P |
| | The ambient temperature (°C)……………………..: | 22 °C | - |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily22C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..….: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..…………………………..: | $E_{daily22C}$ = 867 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 33.3 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………….…: | $\Delta E_{df}$ = 47.6 (1st defrost)<br>$\Delta E_{df}$ = 122.9 (2nd defrost) | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 78.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 2.5 (Unfrozen)<br>$T_{average}$ = -18.1 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)………………..……..: | $T_{ss}$ = 2.5 (Unfrozen)<br>$T_{ss}$ = -18.4 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………………..…: | $\Delta Th_{df}$ = 3.6 (Unfr.–1st defrost)<br>$\Delta Th_{df}$ = 3.9 (Froz.–1st defrost)<br>$\Delta Th_{df}$ = 4.0 (Unfr.–2nd defrost)<br>$\Delta Th_{df}$ =15.4(Froz.–2nd defrost) | P |
| 6.8.3 | Interpolation | | N/A |
| 6.8.4 | Specified auxiliaries | See appended table | P |
| 6.8.5 | Total energy consumption | See appended table | P |

| Part 3 An. G | **DETERMINATION OF LOAD PROCESING EFFICIENCY** | | |
|---|---|---|---|
| G.5 | Determination of load processing efficiency | | P |
| G.5.2 | Quantification of input energy | See appended table | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 16°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | U 1 Unfrozen comp. | °C | 2.73 | | 2.66 | | | | |
| | F 1 Frozen comp. | °C | -18.4 | | -18.4 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 495.5 | |
| Frozen volume | L | 226.5 | |
| Unfrozen comp. load | kg | 5.946 | |
| Frozen comp. load | kg | 0.906 | |
| $E_{\text{input - test}}$ | Wh | 200 | |
| $\Delta E_{\text{additional test}}$ | Wh | 108 | |
| $\text{Efficiency}_{\text{load}}$ | Wh/Wh | 1.856 | |
| $E_{\text{input nominal}}$ | Wh | 193 | |
| $\Delta E_{\text{processing}}$ | Wh/d | 103.99 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | | P |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 32°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | U 1 Unfrozen comp. | °C | 2.18 | - | 2.41 | | | | |
| | F 1 Frozen comp. | °C | -17.78 | - | -17.98 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 495.5 | |
| Frozen volume | L | 226.5 | |
| Unfrozen comp. load | kg | 5.947 | |
| Frozen comp. load | kg | 0.906 | |
| $E_{\text{input - test}}$ | Wh | 329 | |
| $\Delta E_{\text{additional test}}$ | Wh | 225 | |
| $\text{Efficiency}_{\text{load}}$ | Wh/Wh | 1.460 | |
| $E_{\text{input nominal}}$ | Wh | 321 | |
| $\Delta E_{\text{processing}}$ | Wh/d | 219.86 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 22°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | T 1 Unfrozen comp. | °C | 2.18 | - | 2.41 | | | | |
| | T 1 Frozen comp. | °C | -17.78 | - | -17.98 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 495.5 | |
| Frozen volume | L | 226.5 | |
| Unfrozen comp. load | kg | 5.947 | |
| Frozen comp. load | kg | 0.906 | |
| $E_{\text{input - test}}$ | Wh | 248 | |
| $\Delta E_{\text{additional test}}$ | Wh | 145 | |
| $\text{Efficiency}_{\text{load}}$ | Wh/Wh | 1.717 | |
| $E_{\text{input nominal}}$ | Wh | 241 | |
| $\Delta E_{\text{processing}}$ | Wh/d | 140.36 | |
| Voltage | Volt/Hz | 115/60 | |

| | **TABLE: Calculation of energy consumption** | **-** |
|---|---|---|

| | | |
|---|---|---|
| $E_{\text{daily 16C}}$ | 660 | Wh/d |
| $E_{\text{daily 32C}}$ | 1319 | Wh/d |
| $\Delta E_{\text{processing 16C}}$ | 103.99 | Wh/d |
| $\Delta E_{\text{processing 32C}}$ | 219.86 | Wh/d |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

**The following factors are as defined for the European Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| **$E_{total}$ =** | **361** | **kWh/year** |
|---|---|---|

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| **$E_{total}$ =** | **420** | **kWh/year** |
|---|---|---|

**The following factors are as defined in Australian / New Zealand Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| **$E_{total}$ =** | **318** | **kWh/year** |
|---|---|---|

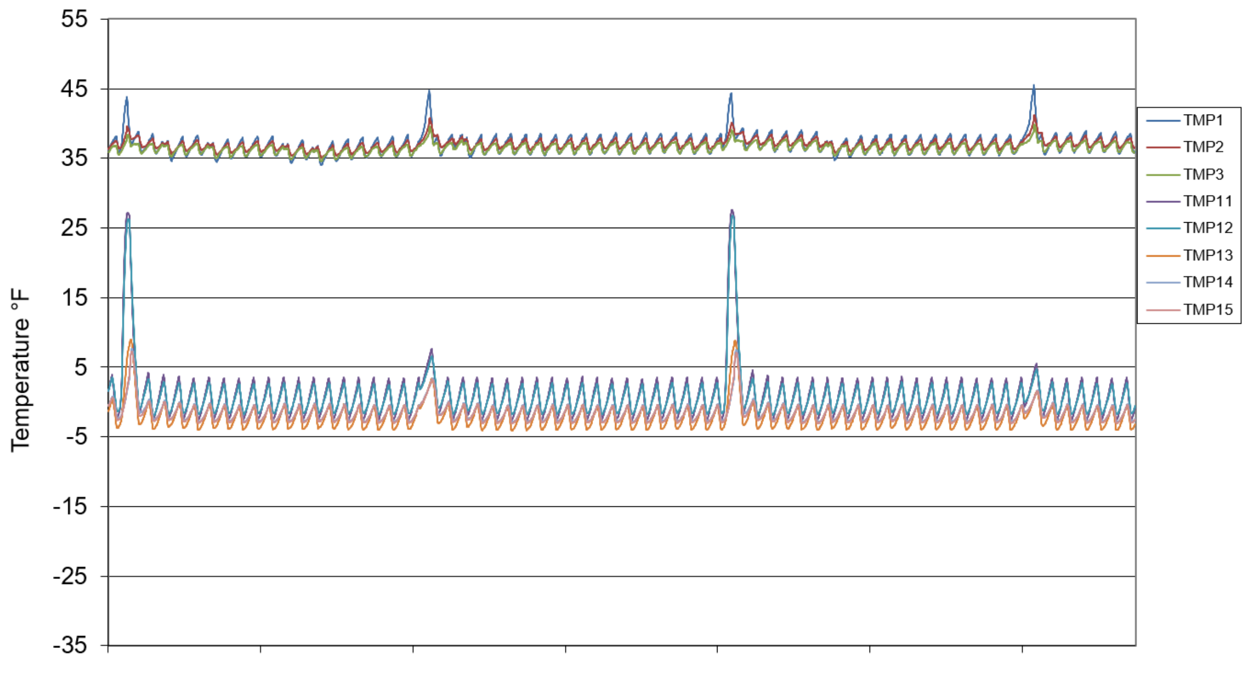
| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ + Anti-Sweat Heater | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| **$E_{total}$ =** | **435** | **kWh/year** |
|---|---|---|

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

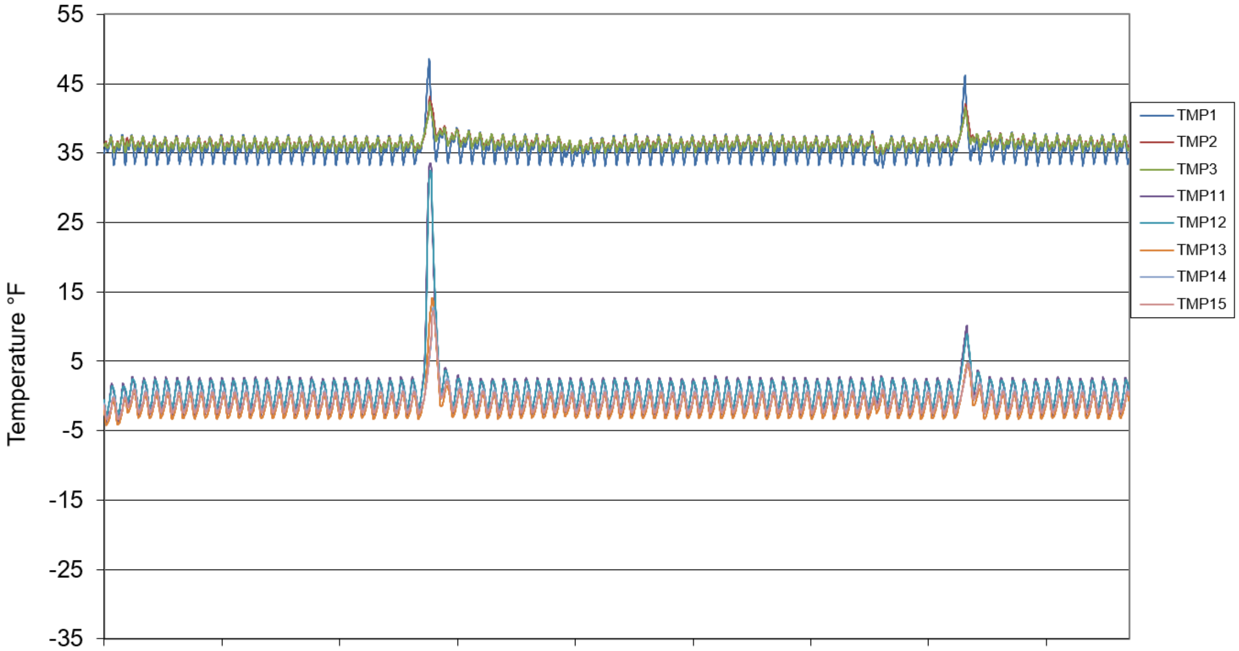
| **Annex 1** | **-** | | | | |
|---|---|---|---|---|---|
| **Clause** | **Measurement / testing** | **Testing / measuring equipment / material used** | **Instrument ID** | **Calibration** | |
| | | | | **Last** | **Expiry** |
| Part 1 An. A | Temperature | Thermocouples type T | 0429 | 10/2019 | 10/2020 |
| Part 1 An. A | Humidity | Hygrometer probe | 1182 | 9/2019 | 9/2020 |
| Part 1 An. A | Air velocity | Anemometer probe | 0550 | 11/2019 | 11/2020 |
| Part 1 An. A | Power / Energy consumption | Power analyzer / Energy meter | 0430 | 10/2019 | 10/2019 |

| **Annex 2** | **Graph of energy consumption test: 16°C** | **-** |
|---|---|---|



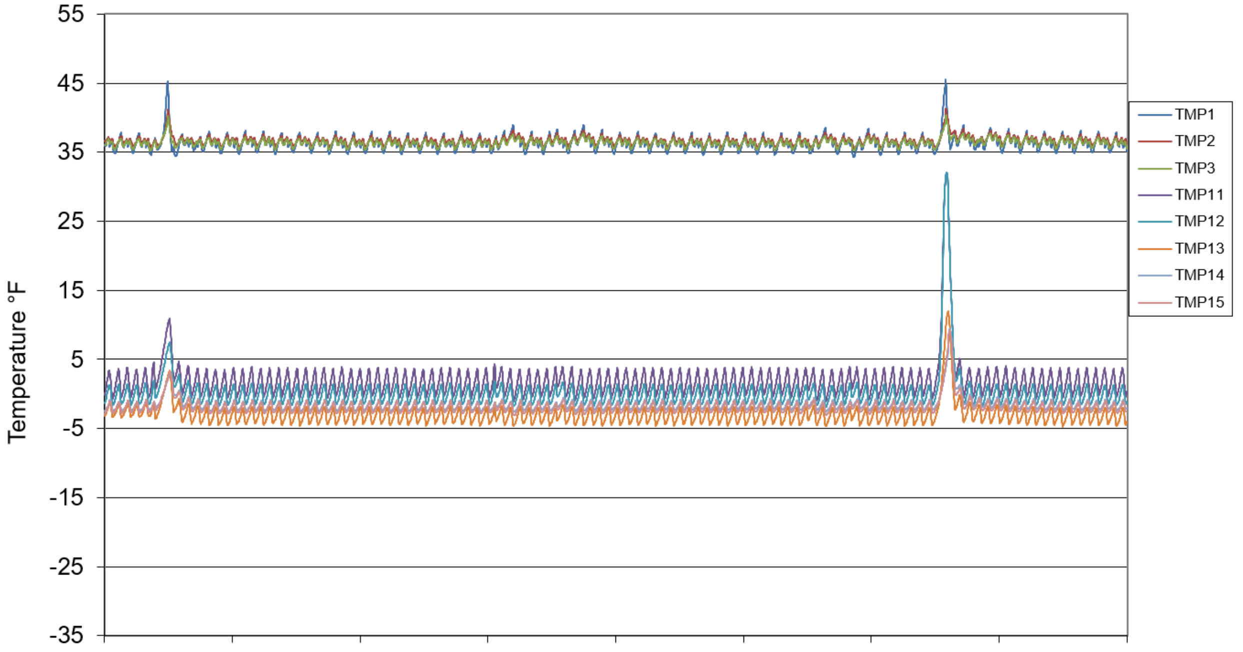
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 2** | **Graph of energy consumption test: 32°C** | **-** |
|---|---|---|



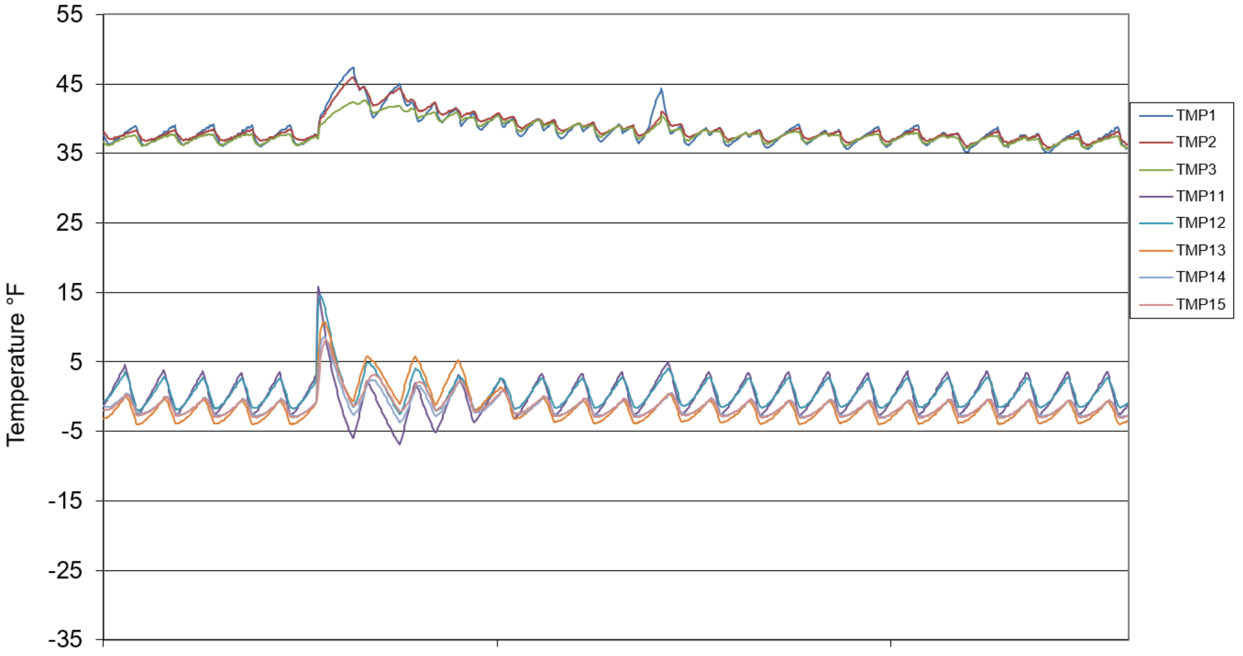
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 2** | **Graph of energy consumption test: 22°C** | **-** |
|---|---|---|



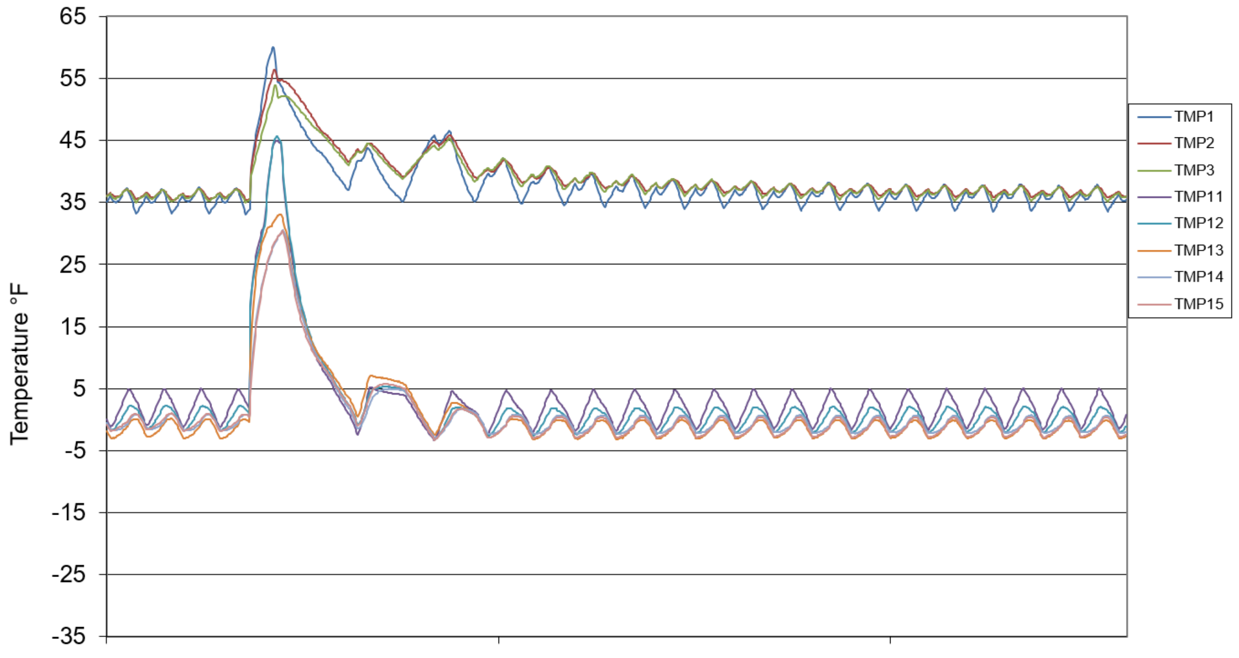
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 3** | **Graph of load processing efficiency test: 16°C** | **-** |
|---|---|---|



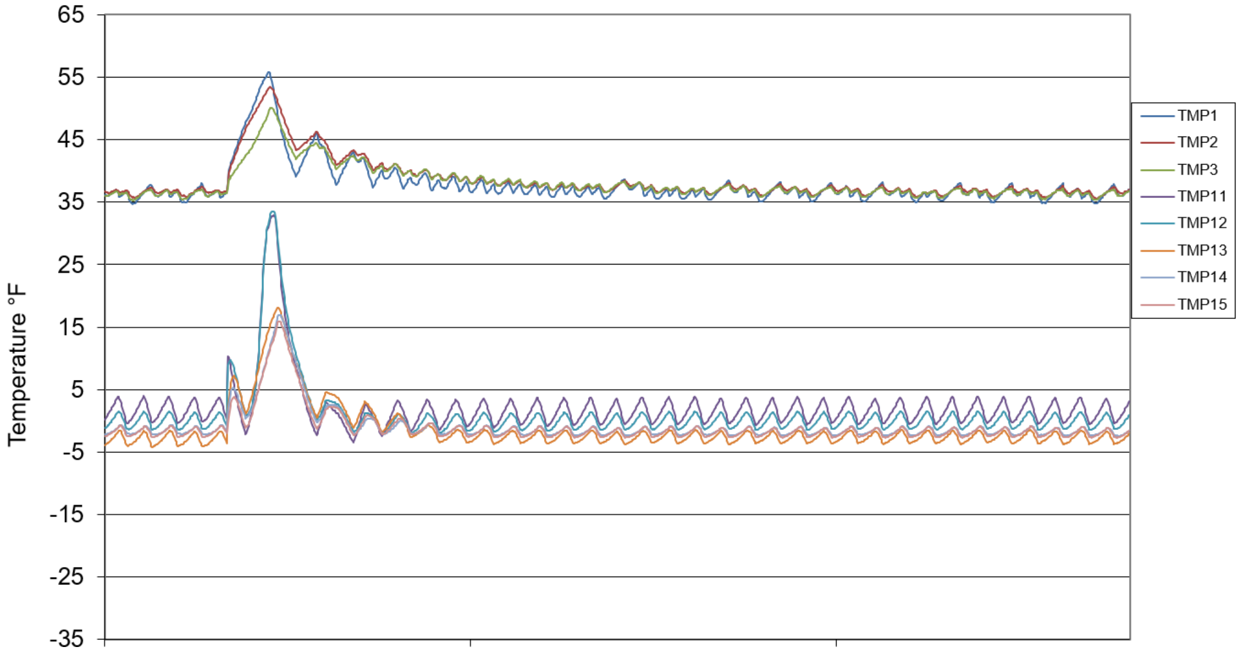
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 3** | **Graph of load processing efficiency test: 32°C** | **-** |
|---|---|---|



| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 3 | Graph of load processing efficiency test: 22°C | - |
|---|---|---|




**END OF TEST REPORT**

Back to Instructions tab

| Title | |
|---|---|
| Test Report Template Name: | Consumer R-RF-MRef |
| Version Number: | v2.1 |
| Latest Template Revision: | 11/18/2019 |
| Tab Name: | General Info & Test Results |
| File Name: | Refrigerator Brand C Model C1 St DOE Test Datasheet.xlsx |
| Test Start Date: | 4/18/2020 |
| Test Completion Date: | 8/28/2020 |

| 1. Lab Information | |
|---|---|
| Lab Name: | UL Verification Services Inc. |
| Lab Location: | Newton, Iowa |

| 2. Test Information | |
|---|---|
| Date Test Started: | 4/18/2020 |
| Date Test Finished: | 8/28/2020 |

| 3. Product Information | |
|---|---|
| Brand: | Brand C |
| Manufacturer: | |
| Manufacturer Model Number: | Model C1 |
| Serial Number: | [redacted]480 |
| Date of Manufacture (if available): | |
| Product Class: | 5I |
| Product Type: | Refrigerator-Freezer |
| Size: | Standard-sized |
| Received Date: | 3/5/2020 |
| Received Condition: | Good |
| Anti-Sweat Heather (ASH) Switch: | Yes |
| Default ASH Switch Position: | - |
| Number of Separate Auxiliary Compartments: | 0 |
| Variable ASH: | No |
| Demand-Response Capable: | No |
| Automatic Icemaker: | Yes |
| Number of Compressors: | 1 |
| Defrost Control Type: | Variable |
| Number of Unique Defrost Frequencies: *(e.g. as described in Appendix A Sections 4.2.3 - 4.2.4)* | 1 |
| Outer Dimensions (in.) | |
| Height: | |
| Width: | |
| Depth: | |

**4. Explain how defrost control type was determined.**

*Include necessary data on the raw data tabs if it is used to determine control type.*

| 5. Test Results | | |
|---|---|---|
| **Variable** | **Result** | **Units** |
| **Measured Volumes** | | |
| Fresh Food | 17.50 | $ft^3$ |
| Freezer | 8.00 | $ft^3$ |
| Cooler | | $ft^3$ |
| Total Volume | 25.5 | $ft^3$ |
| Adjusted Volume | 31.6 | $ft^3$ |
| **Energy Use** | | |
| ASH Switch OFF | 564 | kWh/yr |
| ASH Switch ON* | 582 | kWh/yr |
| Overall* | 573 | kWh/yr |
| * If necessary | | |

*NOTE: Copy only; sign off is done in the Report Sign-Off Block tab*

**6. Test Report Sign-Off Block**

**We certify that the information and data in this report: (1) were obtained from the specific test unit under test; (2) were obtained during the specific test being reported; (3) were not copied from any other source, except where instructed to do so; and (4) were not altered or modified in any way.**

| Role | Date | Entity |
|---|---|---|
| Test Completion | 8/28/2020 | UL |
| Template Completion | 12/3/2020 | UL |
| Report Review by Test Lab | | |
| Report Review by Test Lab | | |

TEST REPORT
IEC 62552:2015
Household refrigerating appliances - Characteristics and test methods
Part 1: General requirements
Part 2: Performance requirements
Part 3: Energy consumption and volume

| | |
|---|---|
| **Report reference No. ......................:** | ST133_20_V0 |
| **Project reference No......................:** | PN9328 |
| **Tested by (name+signature).........:** | Erick Zehr / Curt Tremel |
| **Reviewed by (name+signature)....:** | Daryl Michael |
| **Date of issue....................................:** | 2021-1-06 |
| **Contents ..........................................:** | 20 pages (06 pages of attachements) |
| **Date of revision ..............................:** | |
| **Update due to .................................:** | |
| **Applicant's name ...........................:** | Northwest Energy Efficiency Alliance (NEEA) |
| **Applicant's contact........................:** | Eric Olson |
| **Address...........................................:** | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON 97204 |
| **Test specification:** | |
| **Standard ..........................................:** | IEC 62552-1:2015<br>IEC 62552-2:2015<br>IEC 62552-3:2015 |
| **Test procedure ...............................:** | Standard |
| **Non-standard test method ............:** | N/A |
| **Test Report Form No. ....................:** | IEC62552_A (PRO-03-25Rev.3.0) |
| **Test Report Form(s) Originator ....:** | UL International Italia S.r.l. |
| **Test item(s) description ................:** | Side by Side refrigerator-freezer |
| **Trademark.......................................:** | Brand A |
| **Manufacturer .................................:** | [redacted] |
| **Country of manufacture ................:** | - |
| **Model/Type reference ....................:** | Model B1 [redacted] |
| **Product serial number...................:** | [redacted]993 |
| **UL Identification code ...................:** | ST-2020-0133 Model C |

<table>
<tr><td colspan="2">Summary of testing:</td></tr>
<tr><td rowspan="2">Tests performed (clause and name of test):<br><br>IEC 62552-1:2015<br>Clause 4 – Classification<br><br><br>IEC 62552-3:2015<br>Clause 6 – Determination of energy consumption<br>Clause 4.6 / Annex G – Determination of load processing efficiency</td><td>Testing laboratory:<br><br>UL Verification Services Inc.<br>3020 1st Avenue East<br>Newton IA, 50208, US<br><br><br>Testing location:<br>Same as above</td></tr>
<tr><td>Date of receipt of test item(s):<br>2020-03-10<br><br>Date of tests:<br>2020-03-14 to 2020-04-17</td></tr>
<tr><td colspan="2">List of attachments (including a total number of pages in each attachment):<br><br>Annex 1 - List of test equipment used (1 page)<br>Annex 2 - Graphs of energy consumption test (3 pages)<br>Annex 3 - Graphs of load processing efficiency test (3 pages)</td></tr>
</table>

| **Test item particulars……………………………………..:** | |
|---|---|
| Type of refrigerating appliance.....................................: | ☐ refrigerator<br>☒ refrigerator-freezer<br>☐ freezer<br>☐ wine storage refrigerator |
| Type of refrigerating appliance (accessible of compartment(s) ...............................................................: | ☐ top-opening ☒ upright |
| Type of mounting ............................................................: | ☐ Built-in ☒ Free-standing ☐ Portable<br>☐ Wall-mounted |
| Cooling system ................................................................: | ☐ Partial No-frost ☒ Total No-frost ☒ Frost-free<br>☐ Manual defrost ☒ Automatic defrost<br>☐ Cyclic defrost ☒ Variable defrost |
| Separate refrigerant circuits .........................................: | ☐ Yes ☒ No |
| Two or more motor-compressors ...............................: | ☐ Yes ☒ No |
| Electrovalve.....................................................................: | ☐ Yes ☒ No |
| Compartment ..................................................................: | ☒ Fresh-food ☐ Cellar ☐ Chill ☐ 0 Star<br>☐ 1 Star ☐ 2 Star ☐ 3 Star ☒ 4 Star<br>☐ Pantry ☐ Ice-making ☐ Wine storage |
| Equipment .......................................................................: | ☒ Ice-maker ☐ Ice-dispenser<br>☐ Water-dispenser ☐ Water-tank |
| **Ratings:** | |
| Rated voltage ..................................................................: | - |
| Rated frequency..............................................................: | - |
| Rated current input .........................................................: | - |
| Climate class....................................................................: | - |
| Refrigerant type ..............................................................: | - |
| Refrigerant mass..............................................................: | - |
| Rated freezing capacity ...................................................: | - |
| Rated volume ..................................................................: | Ref: 399 L Cellar: N/A Chill: N/A<br>Frz****: 224 L Frz**: N/A Frz*: N/A<br>Wine: N/A 0°C: N/A Pantry: N/A |
| **Circuit information:** | |
| Compressor......................................................................: | Type: N/A |
| Condenser........................................................................: | Type: N/A<br>WxH: N/A<br>No. Tubes: N/A |
| Evaporator (Refrigerator)...............................................: | Type: N/A<br>WxD: N/A<br>No. Plates: N/A |

| **Test item particulars……………………………………..:** | |
|---|---|
| Evaporator (Freezer) ......................................................: | No. Tubes: N/A<br>Type: N/A<br>WxD: N/A<br>No. Plates: N/A<br>No. Tubes: N/A |
| Thermostat setting ..........................................................: | Electronic control |

**Possible test case verdicts:**

- Test object does meet the requirement ..................... : P (Passed)
- Test object does not meet the requirement ............... : F (Failed)
- Test case does not apply to the test object ............... : N/A (Not applicable)
- Test is not checked..................................................... : N/C (Not checked)

**General remarks:**

The test results presented in this test report relate only to the object tested, not selected by UL Verification Services Inc.

This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.
The test report includes only the clauses required in the reference standard.

The laboratory adopted Accuracy Method decision rule that sources of uncertainty are minimized. Therefore, measurement uncertainty does not take into account to determine the conformance with the limit or specific requirements.

The Uncertainty of Measurement (UoM) for each unit measured in this Test Report is estimated in accordance with the procedure No. 23-CL-G0851. Details of the estimation of UoM may be made available upon request.

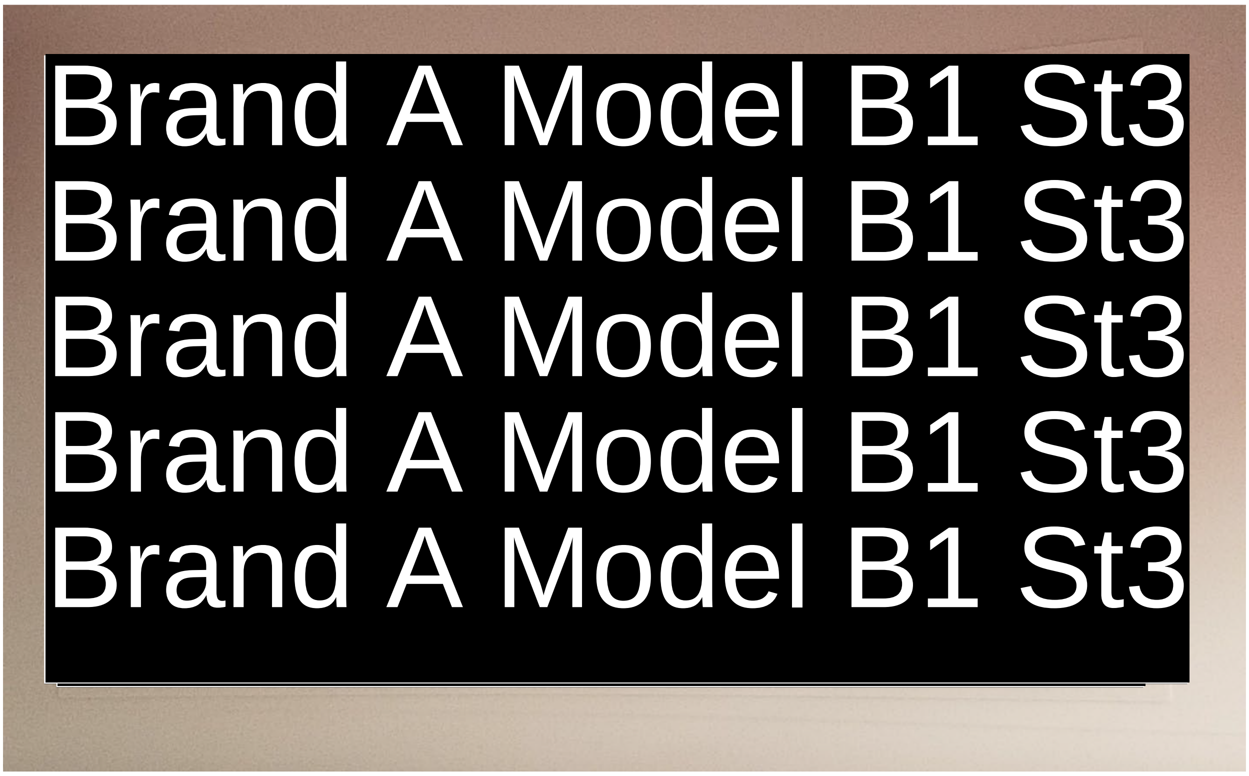
”(See appended table)” refers to a table appended to the report.

"(See appended sketch)" refers to a sketch appended to the report.

**Other product information:**

Status of sample upon receipt: ☒ New and operational ☐ Reconditioned ☐ Damaged

**Copy of marking plate:**




**Product photos:**

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | | |
|---|---|---|---|
| **Part 1 Cl.4** | **CLASSIFICATION** | | |
| | Refrigerating appliance classified into four climate classes or into a range of classes | | - |
| | SN - Extended temperate (+10 to +32)°C...............: | | N/C |
| | N - Temperate (+16 to +32)°C................................: | | N/C |
| | ST - Subtropical (+16 to +38)°C ..............................: | | N/C |
| | T - Tropical (+16 to +43)°C.....................................: | | N/C |

| | | | |
|---|---|---|---|
| **Part 3 Cl.6** | **DETERMINATION OF ENERGY CONSUMPTION** | | |
| 6.2 | Objective | | - |
| | Measurement of the temperature and energy consumption for a representative period of steady state operation. | | - |
| | In the case of products with automatic defrost functions, the incremental energy during defrost and recovery is determined for a specified number of representative and valid defrost and recovery periods. | | - |
| 6.3 | Number of test runs | | P |
| | The energy consumption is determined at ambient temperatures of 16 °C and 32 °C either: | | P |
| | a) directly from the results of a single test run; | | P |
| | b) by interpolation between the results of two or more test runs. | | N/A |
| 6.4 | Steady state power consumption | See appended table | P |
| 6.5 | Defrost and recovery energy and temperature change | | P |
| | Ambient temperatures of both 16 °C and 32 °C. | | P |
| | The additional energy associated with defrost and recovery is reported in Watt-hour (Wh). | | P |
| | The temperature change associated with defrost and recovery is reported in degree Kelvin-hour (Kh). | | P |
| 6.8.2 | Daily energy consumption | | - |
| | The ambient temperature (°C)……………………..: | 16 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh)……………………………..: | $E_{daily16C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh)……………….……………………..: | $E_{daily16C}$ = 773 | P |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 30.7 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………….….: | $\Delta E_{df}$ = 72.5 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 48 | P |
| | The average temperature for each compartment (°C)……………………………..…………………: | $T_{average}$ = 3.5 (Unfrozen)<br>$T_{average}$ = -18.1 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………………….……..: | $T_{ss}$ = 3.5 (Unfrozen)<br>$T_{ss}$ = -18.1 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = -0.44 (Unfrozen)<br>$\Delta Th_{df}$ = 6.162 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 32 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily32C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..………………………….: | $E_{daily32C}$ = 1588.4 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 62.74 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………….….: | $\Delta E_{df}$ = 82.73 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 24.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 3.5 (Unfrozen)<br>$T_{average}$ = -18.5 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)…………………….……..: | $T_{ss}$ = 3.5 (Unfrozen)<br>$T_{ss}$ = -18.5 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = 1.97 (Unfrozen)<br>$\Delta Th_{df}$ = 7.45 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 22 °C | - |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..……………………..: | $E_{daily22C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..….…: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..….…………………………..: | $E_{daily22C}$ = 1061.4 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 42.0 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………………..….: | $\Delta E_{df}$ = 87.1 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 39.0 | P |
| | The average temperature for each compartment (°C)……………………………………………………...: | $T_{average}$ = 3.44 (Unfrozen)<br>$T_{average}$ = -18.83 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)………………..……….: | $T_{ss}$ = 3.44 (Unfrozen)<br>$T_{ss}$ = -18.83 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….….: | $\Delta Th_{df}$ = 0.97 (Unfrozen)<br>$\Delta Th_{df}$ = 6.59 (Frozen) | P |
| 6.8.3 | Interpolation | | N/A |
| 6.8.4 | Specified auxiliaries | See appended table | P |
| 6.8.5 | Total energy consumption | See appended table | P |

| | | | |
|---|---|---|---|
| Part 3 An. G | **DETERMINATION OF LOAD PROCESING EFFICIENCY** | | |
| G.5 | Determination of load processing efficiency | | P |
| G.5.2 | Quantification of input energy | See appended table | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | P |
|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 16°C | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | |
| | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | U 1 Unfrozen comp. | °C | 3.53 | | 3.97 | | | |
| | F 1 Frozen comp. | °C | -18.10 | | -18.01 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 399.3 | |
| Frozen volume | L | 223.7 | |
| Unfrozen comp. load | kg | 4.792 | |
| Frozen comp. load | kg | 0.895 | |
| $E_{input - test}$ | Wh | 175 | |
| $\Delta E_{additional\ test}$ | Wh | 97 | |
| $Efficiency_{load}$ | Wh/Wh | 1.802 | |
| $E_{input\ nominal}$ | Wh | 176 | |
| $\Delta E_{processing}$ | Wh/d | 97.67 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 32°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | U 1 Unfrozen comp. | °C | 3.47 | - | 3.73 | | | | |
| | F 1 Frozen comp. | °C | -18.50 | - | -18.53 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 399.3 | |
| Frozen volume | L | 223.7 | |
| Unfrozen comp. load | kg | 4.792 | |
| Frozen comp. load | kg | 0.895 | |
| $E_{input - test}$ | Wh | 283 | |
| $\Delta E_{additional\ test}$ | Wh | 191 | |
| $Efficiency_{load}$ | Wh/Wh | 1.483 | |
| $E_{input\ nominal}$ | Wh | 176 | |
| $\Delta E_{processing}$ | Wh/d | 118.68 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 22°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | T 1 Unfrozen comp. | °C | 3.45 | - | 3.38 | | | | |
| | T 1 Frozen comp. | °C | -18.84 | - | -18.82 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 399.3 | |
| Frozen volume | L | 223.7 | |
| Unfrozen comp. load | kg | 4.792 | |
| Frozen comp. load | kg | 0.895 | |
| $E_{\text{input - test}}$ | Wh | 218 | |
| $\Delta E_{\text{additional test}}$ | Wh | 135 | |
| $\text{Efficiency}_{\text{load}}$ | Wh/Wh | 1.612 | |
| $E_{\text{input nominal}}$ | Wh | 215 | |
| $\Delta E_{\text{processing}}$ | Wh/d | 133.37 | |
| Voltage | Volt/Hz | 115/60 | |

| | **TABLE: Calculation of energy consumption** | | **-** |
|---|---|---|---|

| | | |
|---|---|---|
| $E_{\text{daily 16C}}$ | 773 | Wh/d |
| $E_{\text{daily 32C}}$ | 1588 | Wh/d |
| $\Delta E_{\text{processing 16C}}$ | 97.67 | Wh/d |
| $\Delta E_{\text{processing 32C}}$ | 118.68 | Wh/d |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

**The following factors are as defined for the European Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **431** | **kWh/year** |

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **470** | **kWh/year** |

**The following factors are as defined in Australian / New Zealand Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **378** | **kWh/year** |

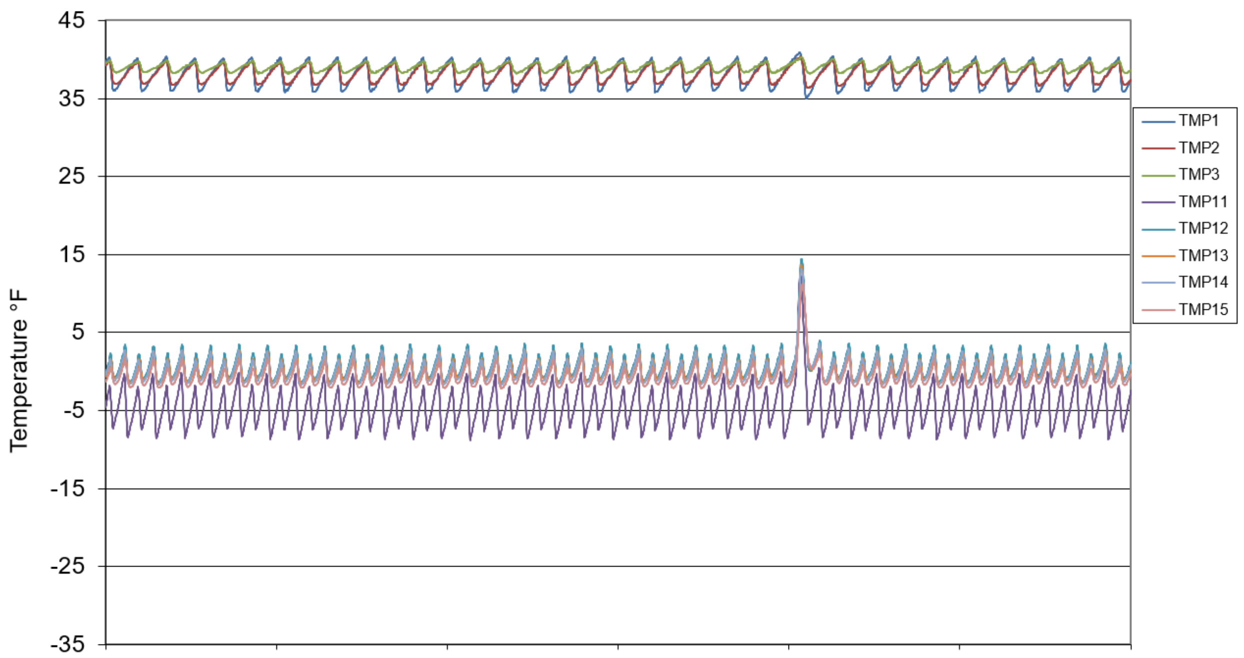
| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| | | |
|---|---|---|
| **$E_{total}$ =** | **454** | **kWh/year** |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

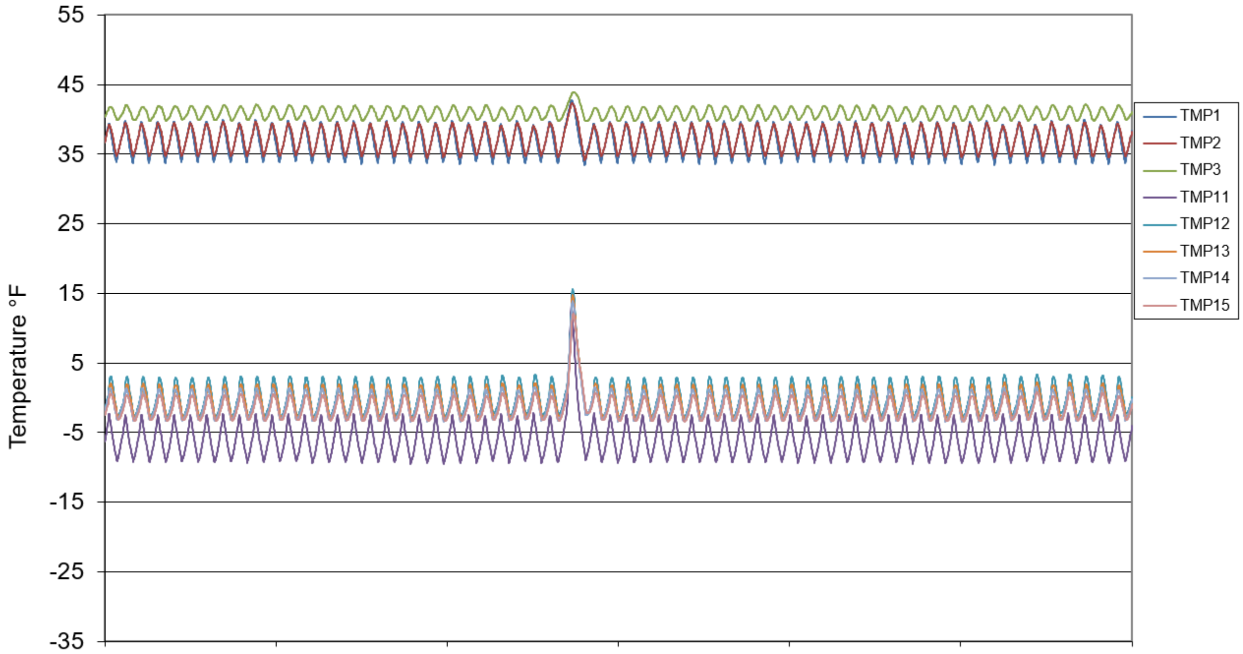
| **Annex 1** | **-** | | | | |
|---|---|---|---|---|---|
| **Clause** | **Measurement / testing** | **Testing / measuring equipment / material used** | **Instrument ID** | **Calibration** | |
| | | | | **Last** | **Expiry** |
| Part 1 An. A | Temperature | Thermocouples type T | 0429 | 10/2019 | 10/2020 |
| Part 1 An. A | Humidity | Hygrometer probe | 1182 | 9/2019 | 9/2020 |
| Part 1 An. A | Air velocity | Anemometer probe | 0550 | 11/2019 | 11/2020 |
| Part 1 An. A | Power / Energy consumption | Power analyzer / Energy meter | 0430 | 10/2019 | 10/2019 |

| **Annex 2** | **Graph of energy consumption test: 16°C** | **-** |
|---|---|---|



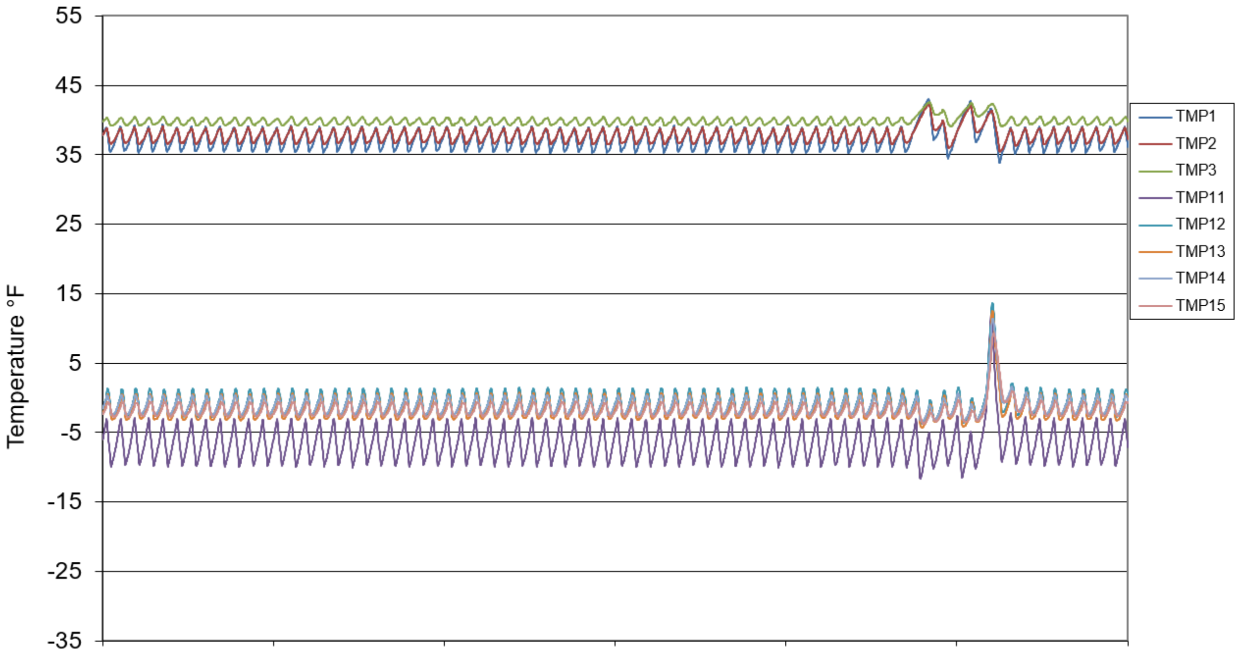
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 2** | **Graph of energy consumption test: 32°C** | **-** |
|---|---|---|

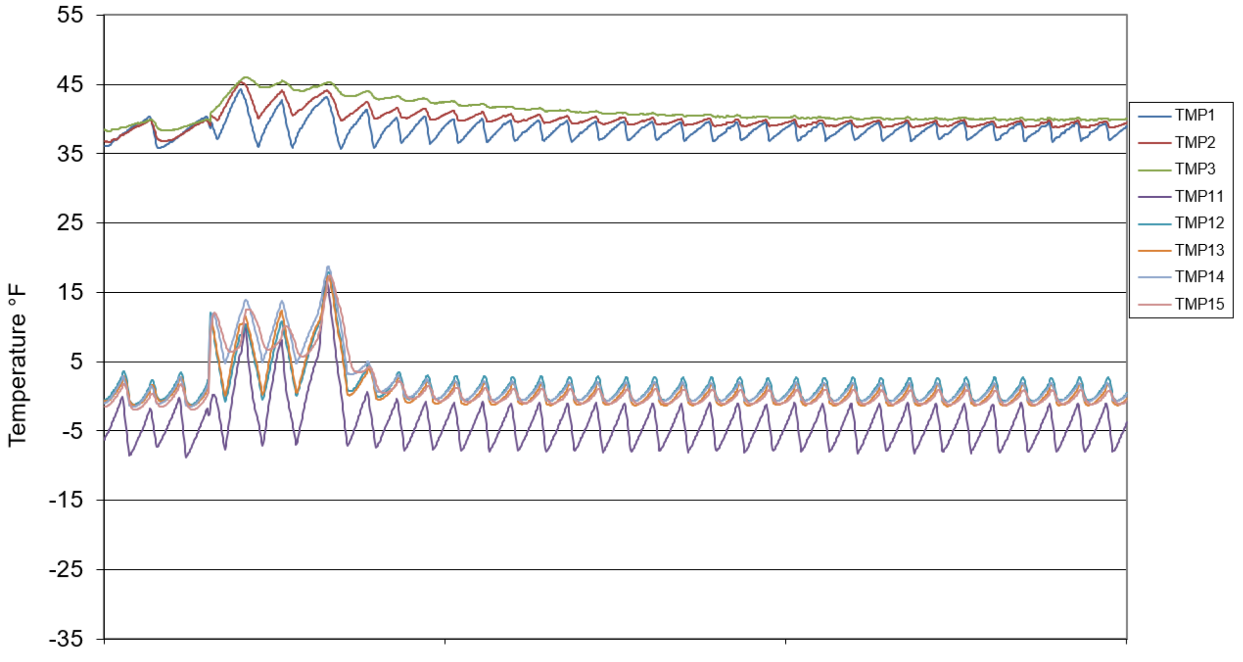


| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 2 | Graph of energy consumption test: 22°C | - |
|---|---|---|

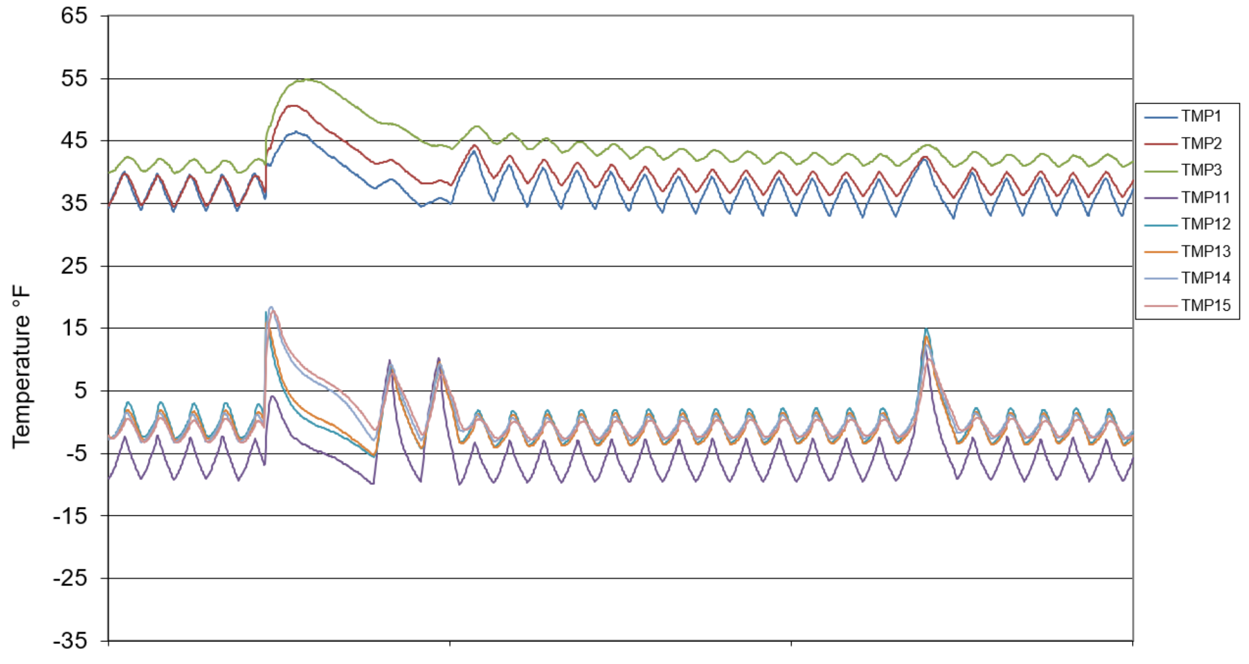


| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| **Annex 3** | **Graph of load processing efficiency test: 16°C** | | **-** |

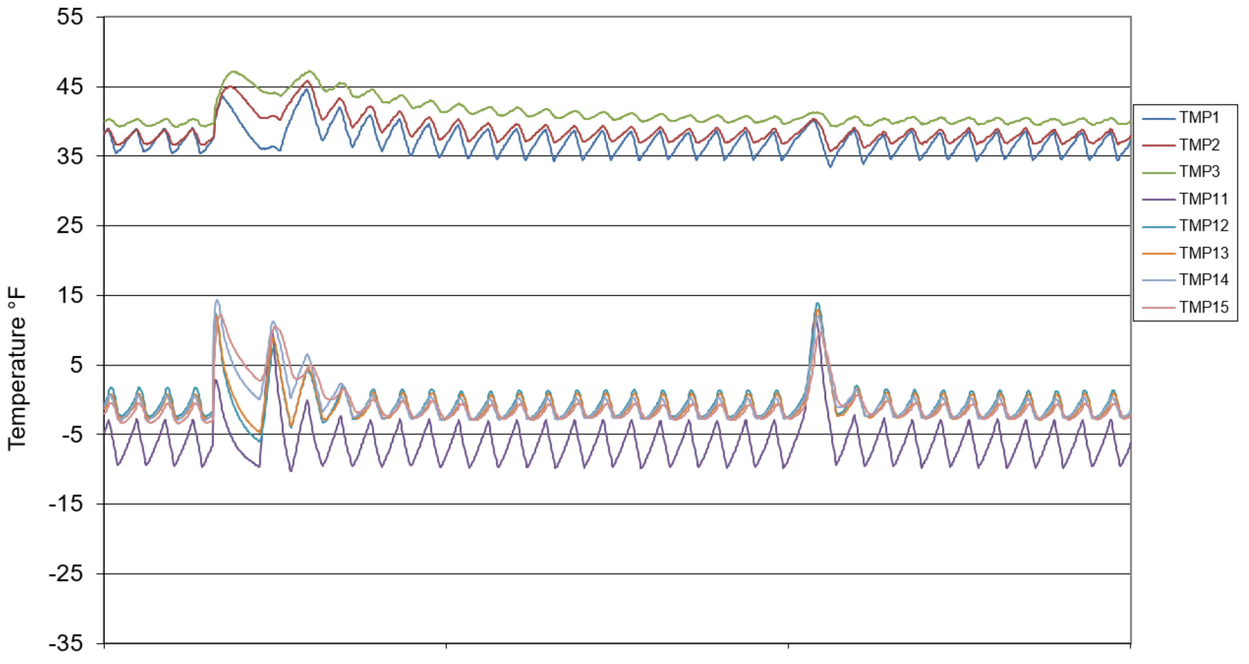


| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | |
|---|---|---|
| **Annex 3** | **Graph of load processing efficiency test: 32°C** | **-** |



| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| **Annex 3** | **Graph of load processing efficiency test: 22°C** | | **-** |




## END OF TEST REPORT

Back to Instructions tab

| Title | |
|---|---|
| Test Report Template Name: | Consumer R-RF-MRef |
| Version Number: | v2.1 |
| Latest Template Revision: | 11/18/2019 |
| Tab Name: | General Info & Test Results |
| File Name: | Refrigerator Brand A Model B1 St3 DOE Test Datasheet.xlsx |
| Test Start Date: | 4/18/2020 |
| Test Completion Date: | 5/8/2020 |

| 1. Lab Information | |
|---|---|
| Lab Name: | UL Verification Services Inc. |
| Lab Location: | Newton, Iowa |

| 2. Test Information | |
|---|---|
| Date Test Started: | 4/18/2020 |
| Date Test Finished: | 5/8/2020 |

| 3. Product Information | |
|---|---|
| Brand: | Brand A |
| Manufacturer: | |
| Manufacturer Model Number: | Model B1 |
| Serial Number: | [redacted]993 |
| Date of Manufacture (if available): | |
| Product Class: | 7 |
| Product Type: | Refrigerator-Freezer |
| Size: | Standard-sized |
| Received Date: | 3/10/2020 |
| Received Condition: | Good |
| Anti-Sweat Heather (ASH) Switch: | No |
| Default ASH Switch Position: | |
| Number of Separate Auxiliary Compartments: | 0 |
| Variable ASH: | No |
| Demand-Response Capable: | No |
| Automatic Icemaker: | Yes |
| Number of Compressors: | 1 |
| Defrost Control Type: | Variable |
| Number of Unique Defrost Frequencies:<br>*(e.g. as described in Appendix A Sections 4.2.3 - 4.2.4)* | |
| Outer Dimensions (in.) | |
| Height: | |
| Width: | |
| Depth: | |

| 4. Explain how defrost control type was determined. |
|---|
| *Include necessary data on the raw data tabs if it is used to determine control type.* |
| |

| 5. Test Results | | |
|---|---|---|
| **Variable** | **Result** | **Units** |
| **Measured Volumes** | | |
| Fresh Food | 14.17 | $ft^3$ |
| Freezer | 7.90 | $ft^3$ |
| Cooler | | $ft^3$ |
| Total Volume | 22.1 | $ft^3$ |
| Adjusted Volume | 28.1 | $ft^3$ |
| **Energy Use** | | |
| ASH Switch OFF | 642 | kWh/yr |
| ASH Switch ON* | | kWh/yr |
| Overall* | 642 | kWh/yr |
| * If necessary | | |

*NOTE: Copy only; sign off is done in the Report Sign-Off Block tab*

| 6. Test Report Sign-Off Block | | |
|---|---|---|
| **We certify that the information and data in this report: (1) were obtained from the specific test unit under test; (2) were obtained during the specific test being reported; (3) were not copied from any other source, except where instructed to do so; and (4) were not altered or modified in any way.** | | |
| **Role** | **Date** | **Entity** |
| Test Completion | 5/8/2020 | UL |
| Template Completion | 12/3/2020 | UL |
| Report Review by Test Lab | | |
| Report Review by Test Lab | | |

TL-611

# TEST REPORT
# IEC 62552:2015
# Household refrigerating appliances - Characteristics and test methods
# Part 1: General requirements
# Part 2: Performance requirements
# Part 3: Energy consumption and volume

| | |
|---|---|
| **Report reference No. ..................... :** | ST128_20_V0 |
| **Project reference No...................... :** | PN9328 |
| **Tested by (name+signature)......... :** | Erick Zehr / Curt Tremel |
| **Reviewed by (name+signature).... :** | Daryl Michael |
| **Date of issue.................................. :** | 2021-1-06 |
| **Contents ........................................ :** | 20 pages (06 pages of attachements) |
| **Date of revision .............................. :** | |
| **Update due to ................................. :** | |
| **Applicant's name ........................... :** | Northwest Energy Efficiency Alliance (NEEA) |
| **Applicant's contact........................ :** | Eric Olson |
| **Address.......................................... :** | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON  97204 |
| **Test specification:** | |
| **Standard ........................................ :** | IEC 62552-1:2015<br>IEC 62552-2:2015<br>IEC 62552-3:2015 |
| **Test procedure ............................... :** | Standard |
| **Non-standard test method ........... :** | N/A |
| **Test Report Form No. .................... :** | IEC62552_A (PRO-03-25Rev.3.0) |
| **Test Report Form(s) Originator .... :** | UL International Italia S.r.l. |
| **Test item(s) description ................ :** | Side by Side refrigerator-freezer |
| **Trademark....................................... :** | Brand B |
| **Manufacturer ................................. :** | [redacted] |
| **Country of manufacture ................ :** | - |
| **Model/Type reference .................... :** | Model B2 |
| **Product serial number................... :** | [redacted]214 |
| **UL Identification code ................... :** | ST-2020-0128  Model D |

| Summary of testing: | |
|---|---|
| **Tests performed (clause and name of test):**<br><br>**IEC 62552-1:2015**<br>Clause 4 – Classification<br><br>**IEC 62552-3:2015**<br>Clause 6 – Determination of energy consumption<br>Clause 4.6 / Annex G – Determination of load processing efficiency | **Testing laboratory:**<br><br>UL Verification Services Inc.<br>3020 1st Avenue East<br>Newton IA, 50208, US<br><br>**Testing location:**<br>Same as above |
| | **Date of receipt of test item(s):**<br>2020-03-06<br><br>**Date of tests:**<br>2020-03-14 to 2020-04-17 |
| **List of attachments (including a total number of pages in each attachment):**<br><br>Annex 1 - List of test equipment used (1 page)<br>Annex 2 - Graphs of energy consumption test (3 pages)<br>Annex 3 - Graphs of load processing efficiency test (3 pages) | |

| **Test item particulars....................................:** | |
|---|---|
| Type of refrigerating appliance....................................: | ☐ refrigerator<br>☒ refrigerator-freezer<br>☐ freezer<br>☐ wine storage refrigerator |
| Type of refrigerating appliance (accessible of compartment(s) .........................................................: | ☐ top-opening ☒ upright |
| Type of mounting ........................................................: | ☐ Built-in ☒ Free-standing ☐ Portable<br>☐ Wall-mounted |
| Cooling system ...........................................................: | ☐ Partial No-frost ☒ Total No-frost ☒ Frost-free<br>☐ Manual defrost ☒ Automatic defrost<br>☐ Cyclic defrost ☒ Variable defrost |
| Separate refrigerant circuits ........................................: | ☐ Yes ☒ No |
| Two or more motor-compressors ...............................: | ☐ Yes ☒ No |
| Electrovalve..................................................................: | ☐ Yes ☒ No |
| Compartment ................................................................: | ☒ Fresh-food ☐ Cellar ☐ Chill ☐ 0 Star<br>☐ 1 Star ☐ 2 Star ☐ 3 Star ☒ 4 Star<br>☐ Pantry ☐ Ice-making ☐ Wine storage |
| Equipment .....................................................................: | ☒ Ice-maker ☐ Ice-dispenser<br>☐ Water-dispenser ☐ Water-tank |
| **Ratings:** | |
| Rated voltage ................................................................: | - |
| Rated frequency...........................................................: | - |
| Rated current input .......................................................: | - |
| Climate class.................................................................: | - |
| Refrigerant type ...........................................................: | - |
| Refrigerant mass...........................................................: | - |
| Rated freezing capacity ................................................: | - |
| Rated volume ................................................................: | Ref: 411 L Cellar: N/A Chill: N/A<br>Frz****: 210 L Frz**: N/A Frz*: N/A<br>Wine: N/A 0°C: N/A Pantry: N/A |
| **Circuit information:** | |
| Compressor....................................................................: | Type: N/A |
| Condenser.....................................................................: | Type: N/A<br>WxH: N/A<br>No. Tubes: N/A |
| Evaporator (Refrigerator)............................................: | Type: N/A<br>WxD: N/A<br>No. Plates: N/A |

| **Test item particulars………………………………..:** | |
|---|---|
| | No. Tubes: N/A |
| Evaporator (Freezer) ....................................................: | Type: N/A |
| | WxD: N/A |
| | No. Plates: N/A |
| | No. Tubes: N/A |
| Thermostat setting ........................................................: | Electronic control |

**Possible test case verdicts:**

- Test object does meet the requirement ..................... : P (Passed)
- Test object does not meet the requirement ............... : F (Failed)
- Test case does not apply to the test object ............... : N/A (Not applicable)
- Test is not checked..................................................... : N/C (Not checked)

**General remarks:**

The test results presented in this test report relate only to the object tested, not selected by UL Verification Services Inc.

This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.
The test report includes only the clauses required in the reference standard.

The laboratory adopted Accuracy Method decision rule that sources of uncertainty are minimized. Therefore, measurement uncertainty does not take into account to determine the conformance with the limit or specific requirements.

The Uncertainty of Measurement (UoM) for each unit measured in this Test Report is estimated in accordance with the procedure No. 23-CL-G0851. Details of the estimation of UoM may be made available upon request.

"(See appended table)" refers to a table appended to the report.

"(See appended sketch)" refers to a sketch appended to the report.

**Other product information:**

Status of sample upon receipt: ☒ New and operational ☐ Reconditioned ☐ Damaged

**Copy of marking plate:**

**Product photos:**

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 1 Cl.4** | **CLASSIFICATION** | | |
|---|---|---|---|
| | Refrigerating appliance classified into four climate classes or into a range of classes | | - |
| | SN - Extended temperate (+10 to +32)°C...............: | | N/C |
| | N - Temperate (+16 to +32)°C................................: | | N/C |
| | ST - Subtropical (+16 to +38)°C ..............................: | | N/C |
| | T - Tropical (+16 to +43)°C.....................................: | | N/C |

| **Part 3 Cl.6** | **DETERMINATION OF ENERGY CONSUMPTION** | | |
|---|---|---|---|
| 6.2 | Objective | | - |
| | Measurement of the temperature and energy consumption for a representative period of steady state operation. | | - |
| | In the case of products with automatic defrost functions, the incremental energy during defrost and recovery is determined for a specified number of representative and valid defrost and recovery periods. | | - |
| 6.3 | Number of test runs | | P |
| | The energy consumption is determined at ambient temperatures of 16 °C and 32 °C either: | | P |
| | a) directly from the results of a single test run; | | P |
| | b) by interpolation between the results of two or more test runs. | | N/A |
| 6.4 | Steady state power consumption | See appended table | P |
| 6.5 | Defrost and recovery energy and temperature change | | P |
| | Ambient temperatures of both 16 °C and 32 °C. | | P |
| | The additional energy associated with defrost and recovery is reported in Watt-hour (Wh). | | P |
| | The temperature change associated with defrost and recovery is reported in degree Kelvin-hour (Kh). | | P |
| 6.8.2 | Daily energy consumption | | - |
| | The ambient temperature (°C)……………………..: | 16 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh)……………………………..: | $E_{daily16C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh)……………….…………………..: | $E_{daily16C}$ = 634 | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 24.1 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 113.1 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 48 | P |
| | The average temperature for each compartment (°C)……………………………..…………………: | $T_{average}$ = 3.9 (Unfrozen)<br>$T_{average}$ = -18.5 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)……………….……..: | $T_{ss}$ = 3.9 (Unfrozen)<br>$T_{ss}$ = -18.5 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = 3.44 (Unfrozen)<br>$\Delta Th_{df}$ = 2.78 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 32 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)…….……………………..: | $E_{daily32C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..………………………..: | $E_{daily32C}$ = 1419 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 53.37 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 138.5 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 24.0 | P |
| | The average temperature for each compartment (°C)……………………………………………………..: | $T_{average}$ = 3.67 (Unfrozen)<br>$T_{average}$ = -18.5 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)……………….……..: | $T_{ss}$ = 3.67 (Unfrozen)<br>$T_{ss}$ = -18.5 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = 0.55 (Unfrozen)<br>$\Delta Th_{df}$ = 2.66 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 22 °C | - |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..……………………..: | $E_{daily22C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…...….: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..…..………………………..: | $E_{daily22C}$ = 879.6 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 33.54 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)…………………………………………………..….: | $\Delta E_{df}$ = 121.3 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 39.0 | P |
| | The average temperature for each compartment (°C)……………………………………………………...: | $T_{average}$ = 3.68 (Unfrozen)<br>$T_{average}$ = -19.23 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)………………..……….: | $T_{ss}$ = 3.68 (Unfrozen)<br>$T_{ss}$ = -19.23 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………….……: | $\Delta Th_{df}$ = 1.51 (Unfrozen)<br>$\Delta Th_{df}$ = 5.27 (Frozen) | P |
| 6.8.3 | Interpolation | | N/A |
| 6.8.4 | Specified auxiliaries | See appended table | P |
| 6.8.5 | Total energy consumption | See appended table | P |

| | | | |
|---|---|---|---|
| **Part 3 An. G** | **DETERMINATION OF LOAD PROCESING EFFICIENCY** | | |
| G.5 | Determination of load processing efficiency | | P |
| G.5.2 | Quantification of input energy | See appended table | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 16°C | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | |
| | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | U 1 Unfrozen comp. | °C | 3.25 | | 3.33 | | | |
| | F 1 Frozen comp. | °C | -18.93 | | -18.94 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 410.6 | |
| Frozen volume | L | 209.5 | |
| Unfrozen comp. load | kg | 4.928 | |
| Frozen comp. load | kg | 0.838 | |
| $E_{input - test}$ | Wh | 174 | |
| $\Delta E_{additional\ test}$ | Wh | 62.8 | |
| $Efficiency_{load}$ | Wh/Wh | 2.777 | |
| $E_{input\ nominal}$ | Wh | 170.6 | |
| $\Delta E_{processing}$ | Wh/d | 61.43 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 32°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | U 1 Unfrozen comp. | °C | 3.32 | - | 3.45 | | | | |
| | F 1 Frozen comp. | °C | -18.16 | - | -19.17 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 410.6 | |
| Frozen volume | L | 209.5 | |
| Unfrozen comp. load | kg | 4.928 | |
| Frozen comp. load | kg | 0.838 | |
| $E_{input - test}$ | Wh | 283 | |
| $\Delta E_{additional\ test}$ | Wh | 171 | |
| $Efficiency_{load}$ | Wh/Wh | 1.659 | |
| $E_{input\ nominal}$ | Wh | 278 | |
| $\Delta E_{processing}$ | Wh/d | 167.6 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | | | | | | | | **P** |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 22°C | | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | T 1 Unfrozen comp. | °C | 3.45 | - | 3.38 | | | | |
| | T 1 Frozen comp. | °C | -18.84 | - | -18.82 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 410.6 | |
| Frozen volume | L | 209.5 | |
| Unfrozen comp. load | kg | 4.928 | |
| Frozen comp. load | kg | 0.838 | |
| $E_{input - test}$ | Wh | 215 | |
| $\Delta E_{additional\ test}$ | Wh | 82 | |
| $Efficiency_{load}$ | Wh/Wh | 2.623 | |
| $E_{input\ nominal}$ | Wh | 211 | |
| $\Delta E_{processing}$ | Wh/d | 80.44 | |
| Voltage | Volt/Hz | 115/60 | |

| | **TABLE: Calculation of energy consumption** | | **-** |
|---|---|---|---|
| | $E_{daily\ 16C}$ | 634 | Wh/d |
| | $E_{daily\ 32C}$ | 1419 | Wh/d |
| | $\Delta E_{processing\ 16C}$ | 61.43 | Wh/d |
| | $\Delta E_{processing\ 32C}$ | 167.6 | Wh/d |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

**The following factors are as defined for the European Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| $E_{total}$ = | 375 | kWh/year |
|---|---|---|

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| $E_{total}$ = | 417 | kWh/year |
|---|---|---|

**The following factors are as defined in Australian / New Zealand Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| $E_{total}$ = | 323 | kWh/year |
|---|---|---|

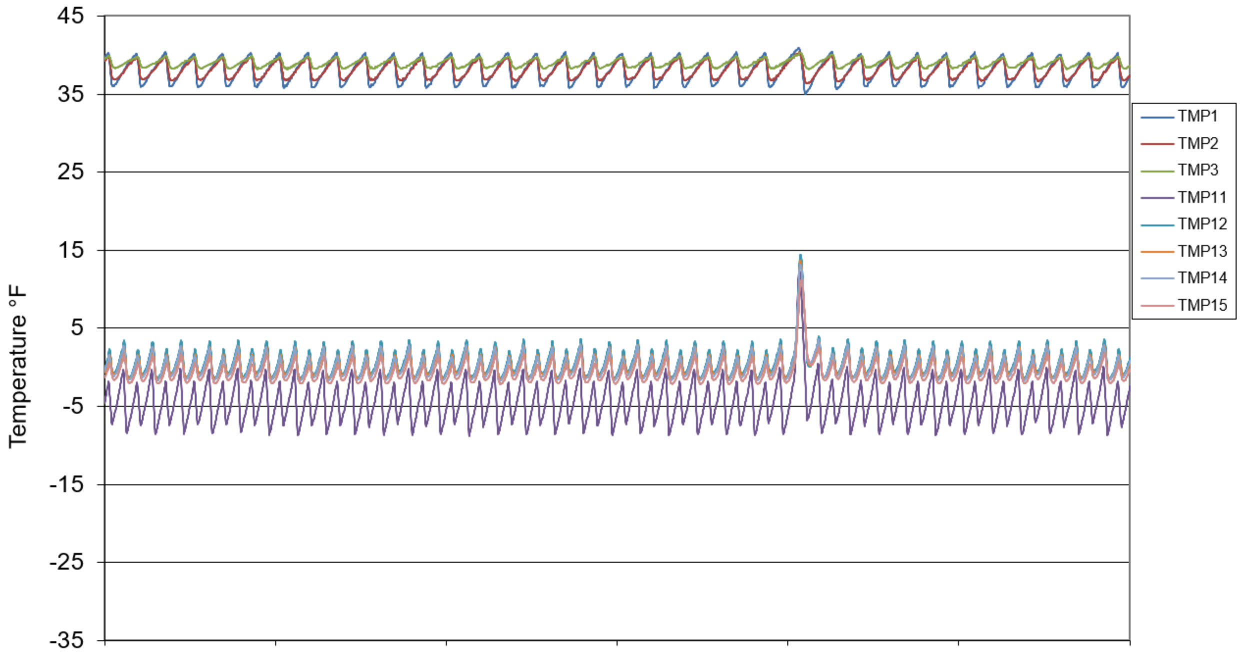
| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| $E_{total}$ = | 383 | kWh/year |
|---|---|---|

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

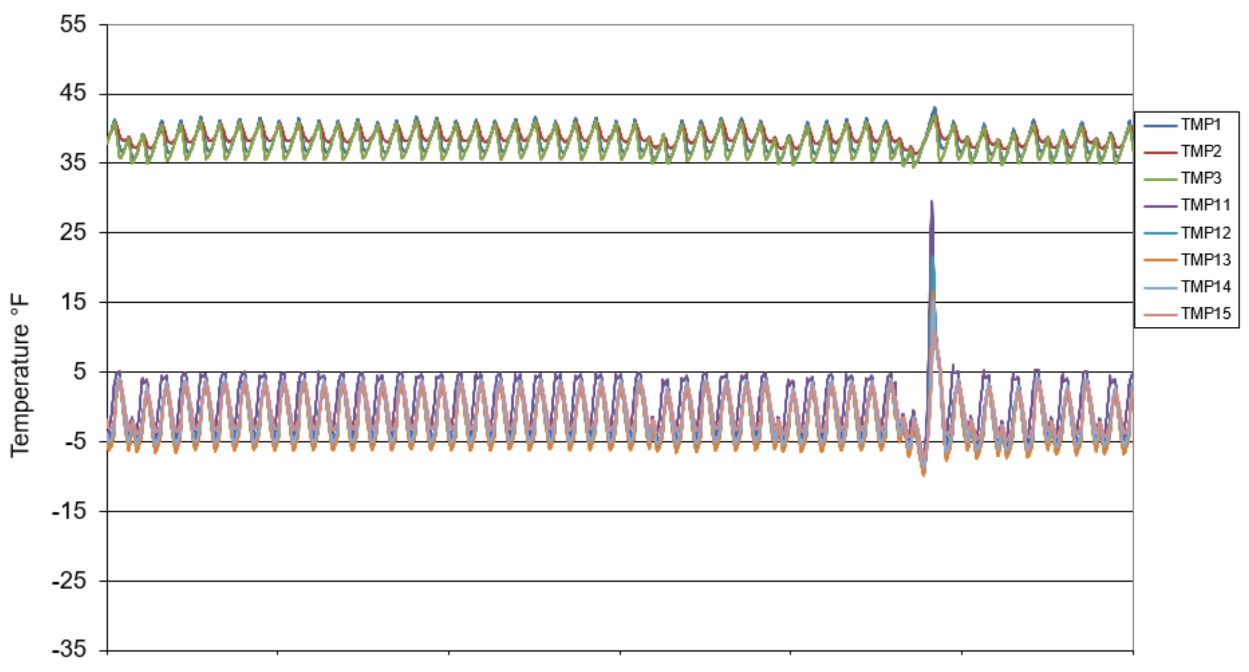
| **Annex 1** | - | | | | |
|---|---|---|---|---|---|
| **Clause** | **Measurement / testing** | **Testing / measuring equipment / material used** | **Instrument ID** | **Calibration** | |
| | | | | **Last** | **Expiry** |
| Part 1 An. A | Temperature | Thermocouples type T | 0429 | 10/2019 | 10/2020 |
| Part 1 An. A | Humidity | Hygrometer probe | 1182 | 9/2019 | 9/2020 |
| Part 1 An. A | Air velocity | Anemometer probe | 0550 | 11/2019 | 11/2020 |
| Part 1 An. A | Power / Energy consumption | Power analyzer / Energy meter | 0430 | 10/2019 | 10/2019 |

| **Annex 2** | **Graph of energy consumption test: 16°C** | **-** |
|---|---|---|



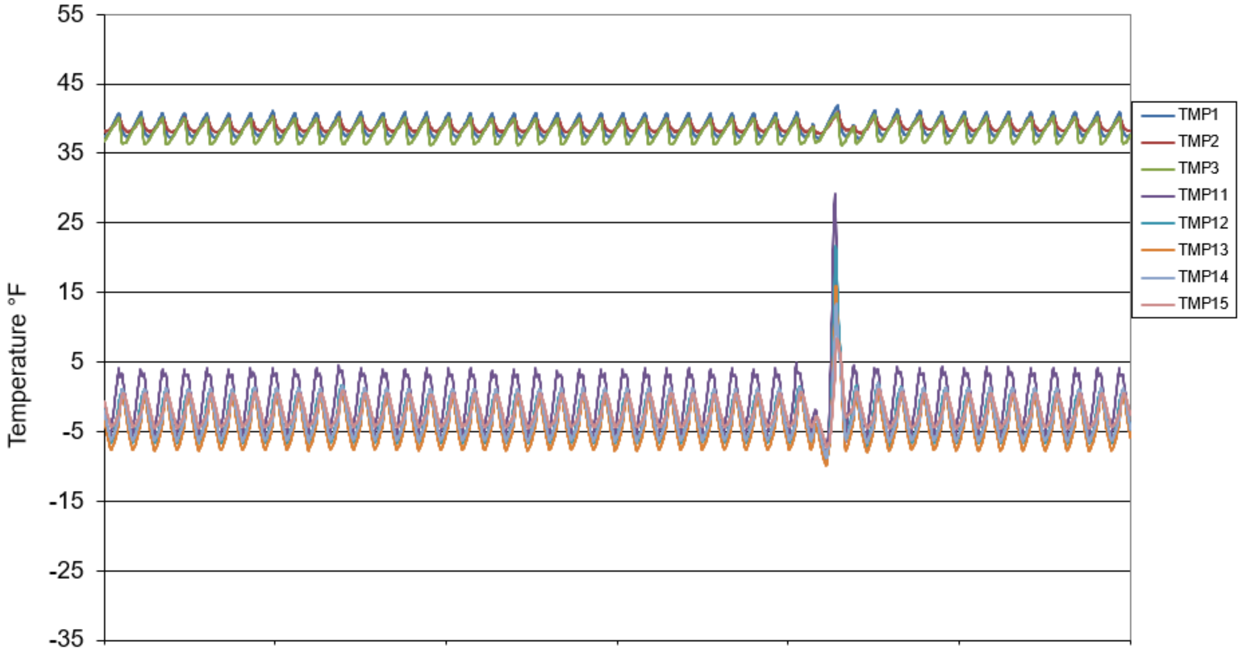
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | |
|---|---|---|
| **Annex 2** | **Graph of energy consumption test: 32°C** | **-** |



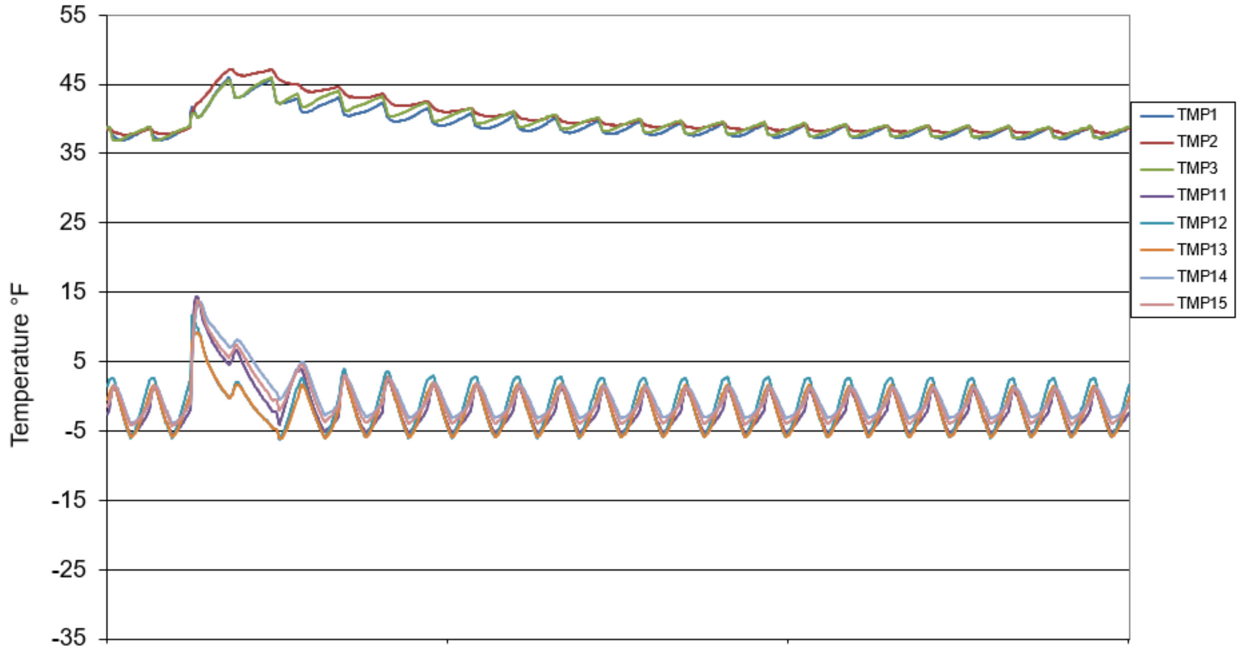
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 2 | Graph of energy consumption test: 22°C | - |
|---|---|---|



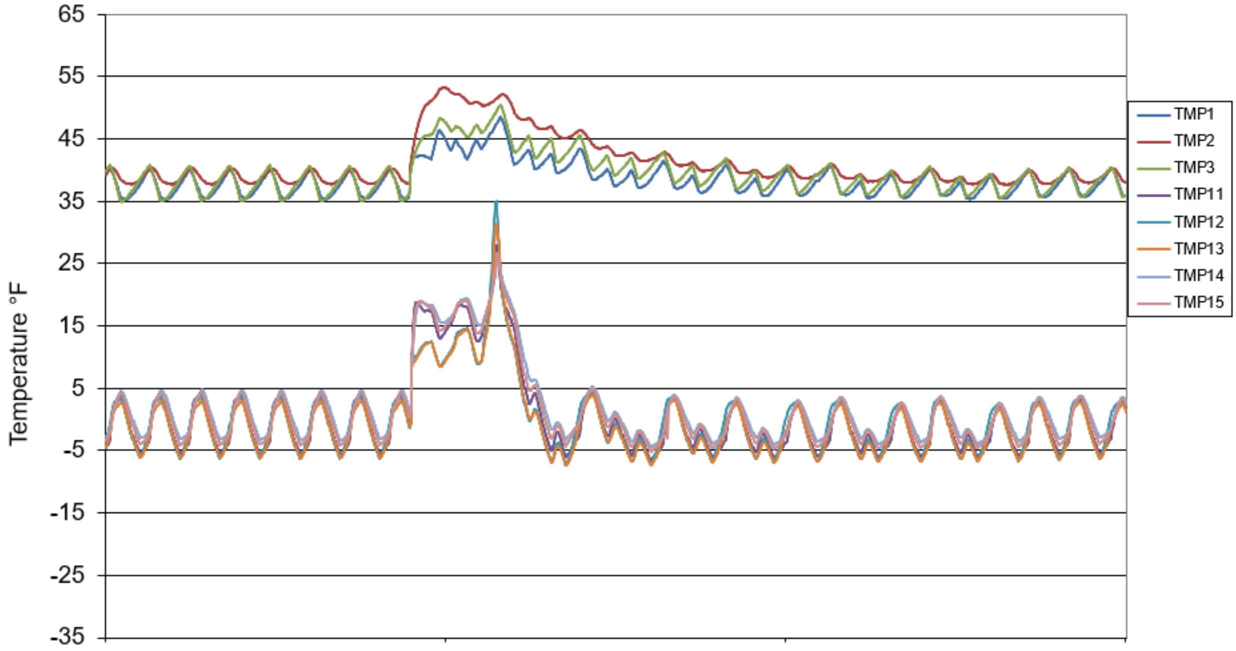
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 3** | **Graph of load processing efficiency test: 16°C** | **-** |
|---|---|---|



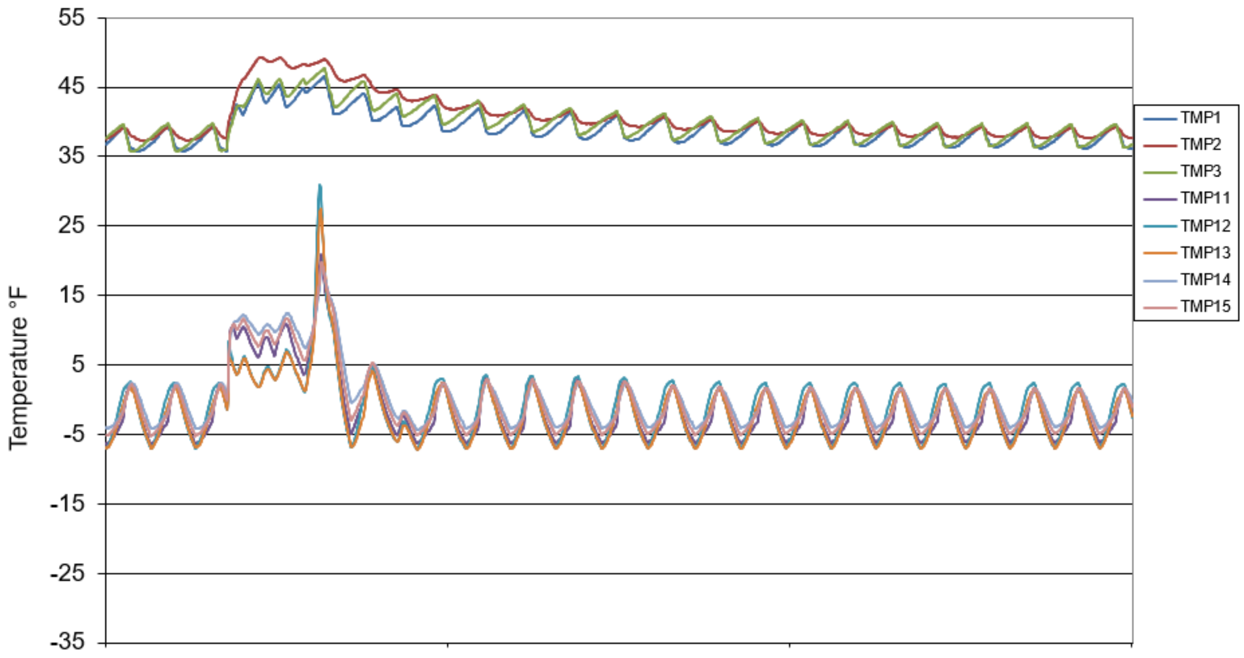
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 3** | **Graph of load processing efficiency test: 32°C** | **-** |
|---|---|---|



| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 3 | Graph of load processing efficiency test: 22°C | - |
|---|---|---|




**END OF TEST REPORT**

Back to Instructions tab

| Title | |
|---|---|
| Test Report Template Name: | Consumer R-RF-MRef |
| Version Number: | v2.1 |
| Latest Template Revision: | 11/18/2019 |
| Tab Name: | General Info & Test Results |
| File Name: | Refrigerator Brand B Model B2 St DOE Test Datasheet.xlsx |
| Test Start Date: | 4/18/2020 |
| Test Completion Date: | 5/8/2020 |

| 1. Lab Information | |
|---|---|
| Lab Name: | UL Verification Services Inc. |
| Lab Location: | Newton, Iowa |

| 2. Test Information | |
|---|---|
| Date Test Started: | 4/18/2020 |
| Date Test Finished: | 5/8/2020 |

| 3. Product Information | |
|---|---|
| Brand: | Brand B |
| Manufacturer: | |
| Manufacturer Model Number: | Model B2 |
| Serial Number: | [redacted]214 |
| Date of Manufacture (if available): | |
| Product Class: | 7 |
| Product Type: | Refrigerator-Freezer |
| Size: | Standard-sized |
| Received Date: | 3/6/2020 |
| Received Condition: | Good |
| Anti-Sweat Heather (ASH) Switch: | No |
| Default ASH Switch Position: | - |
| Number of Separate Auxiliary Compartments: | 0 |
| Variable ASH: | No |
| Demand-Response Capable: | No |
| Automatic Icemaker: | Yes |
| Number of Compressors: | 1 |
| Defrost Control Type: | Variable |
| Number of Unique Defrost Frequencies:<br>*(e.g. as described in Appendix A Sections 4.2.3 - 4.2.4)* | |
| Outer Dimensions (in.) | |
| Height: | |
| Width: | |
| Depth: | |

| 4. Explain how defrost control type was determined. |
|---|
| *Include necessary data on the raw data tabs if it is used to determine control type.* |
| |

| 5. Test Results | | |
|---|---|---|
| **Variable** | **Result** | **Units** |
| **Measured Volumes** | | |
| Fresh Food | 14.50 | $ft^3$ |
| Freezer | 7.40 | $ft^3$ |
| Cooler | | $ft^3$ |
| Total Volume | 21.9 | $ft^3$ |
| Adjusted Volume | 27.5 | $ft^3$ |
| **Energy Use** | | |
| ASH Switch OFF | 613 | kWh/yr |
| ASH Switch ON* | | kWh/yr |
| Overall* | 613 | kWh/yr |
| * If necessary | | |

*NOTE: Copy only; sign off is done in the Report Sign-Off Block tab*

| 6. Test Report Sign-Off Block | | |
|---|---|---|
| **We certify that the information and data in this report: (1) were obtained from the specific test unit under test; (2) were obtained during the specific test being reported; (3) were not copied from any other source, except where instructed to do so; and (4) were not altered or modified in any way.** | | |
| **Role** | **Date** | **Entity** |
| Test Completion | 5/8/2020 | UL |
| Template Completion | 12/3/2020 | UL |
| Report Review by Test Lab | | |
| Report Review by Test Lab | | |

TL-611

# TEST REPORT
# IEC 62552:2015
## Household refrigerating appliances - Characteristics and test methods
## Part 1: General requirements
## Part 2: Performance requirements
## Part 3: Energy consumption and volume

| | |
|---|---|
| **Report reference No.** ..................... : | ST122_20_V0 |
| **Project reference No.**..................... : | PN9328 |
| **Tested by (name+signature)**......... : | Erick Zehr / Curt Tremel |
| **Reviewed by (name+signature)**.... : | Daryl Michael |
| **Date of issue**.................................. : | 2021-1-06 |
| **Contents** ......................................... : | 20 pages (06 pages of attachements) |
| **Date of revision** .............................. : | |
| **Update due to** ................................. : | |
| **Applicant's name** ........................... : | Northwest Energy Efficiency Alliance (NEEA) |
| **Applicant's contact**........................ : | Eric Olson |
| **Address**.......................................... : | 421 SW Sixth Avenue Suite 600<br>Portland, OREGON  97204 |
| **Test specification:** | |
| **Standard** ......................................... : | IEC 62552-1:2015<br>IEC 62552-2:2015<br>IEC 62552-3:2015 |
| **Test procedure** ............................... : | Standard |
| **Non-standard test method** ........... : | N/A |
| **Test Report Form No.** .................... : | IEC62552_A (PRO-03-25Rev.3.0) |
| **Test Report Form(s) Originator**.... : | UL International Italia S.r.l. |
| **Test item(s) description** ................ : | Side by Side refrigerator-freezer |
| **Trademark**...................................... : | Brand D |
| **Manufacturer** ................................. : | Brand D |
| **Country of manufacture** ................ : | - |
| **Model/Type reference**.................... : | Model C2 |
| **Product serial number**................... : | [redacted]976 |
| **UL Identification code** ................... : | ST-2020-0122  Model F |

<table>
<tr><td colspan="2">Summary of testing:</td></tr>
<tr><td rowspan="2">Tests performed (clause and name of test):<br><br>IEC 62552-1:2015<br>Clause 4 – Classification<br><br>IEC 62552-3:2015<br>Clause 6 – Determination of energy consumption<br>Clause 4.6 / Annex G – Determination of load processing efficiency</td><td>Testing laboratory:<br><br>UL Verification Services Inc.<br>3020 1st Avenue East<br>Newton IA, 50208, US<br><br>Testing location:<br>Same as above</td></tr>
<tr><td>Date of receipt of test item(s):<br>2020-03-05<br><br>Date of tests:<br>2020-03-14 to 2020-04-17</td></tr>
<tr><td colspan="2">List of attachments (including a total number of pages in each attachment):<br><br>Annex 1 - List of test equipment used (1 page)<br>Annex 2 - Graphs of energy consumption test (3 pages)<br>Annex 3 - Graphs of load processing efficiency test (3 pages)</td></tr>
</table>

| **Test item particulars**......................................: | |
|---|---|
| Type of refrigerating appliance ......................................: | ☐ refrigerator<br>☒ refrigerator-freezer<br>☐ freezer<br>☐ wine storage refrigerator |
| Type of refrigerating appliance (accessible of compartment(s) ......................................: | ☐ top-opening ☒ upright |
| Type of mounting ......................................: | ☐ Built-in ☒ Free-standing ☐ Portable<br>☐ Wall-mounted |
| Cooling system ......................................: | ☐ Partial No-frost ☒ Total No-frost ☒ Frost-free<br>☐ Manual defrost ☒ Automatic defrost<br>☐ Cyclic defrost ☒ Variable defrost |
| Separate refrigerant circuits ......................................: | ☐ Yes ☒ No |
| Two or more motor-compressors ......................................: | ☐ Yes ☒ No |
| Electrovalve......................................: | ☐ Yes ☒ No |
| Compartment ......................................: | ☒ Fresh-food ☐ Cellar ☐ Chill ☐ 0 Star<br>☐ 1 Star ☐ 2 Star ☐ 3 Star ☒ 4 Star<br>☐ Pantry ☐ Ice-making ☐ Wine storage |
| Equipment ......................................: | ☒ Ice-maker ☐ Ice-dispenser<br>☐ Water-dispenser ☐ Water-tank |
| **Ratings:** | |
| Rated voltage ......................................: | - |
| Rated frequency......................................: | - |
| Rated current input ......................................: | - |
| Climate class......................................: | - |
| Refrigerant type ......................................: | - |
| Refrigerant mass......................................: | - |
| Rated freezing capacity ......................................: | - |
| Rated volume ......................................: | Ref: 413 L Cellar: N/A Chill: N/A<br>Frz****: 193 L Frz**: N/A Frz*: N/A<br>Wine: N/A 0°C: N/A Pantry: N/A |
| **Circuit information:** | |
| Compressor......................................: | Type: N/A |
| Condenser......................................: | Type: N/A<br>WxH: N/A<br>No. Tubes: N/A |
| Evaporator (Refrigerator)......................................: | Type: N/A<br>WxD: N/A<br>No. Plates: N/A |

| **Test item particulars…………………………………..:** | |
|---|---|
| | No. Tubes: N/A |
| Evaporator (Freezer) ....................................................: | Type: N/A |
| | WxD: N/A |
| | No. Plates: N/A |
| | No. Tubes: N/A |
| Thermostat setting .........................................................: | Electronic control |

**Possible test case verdicts:**

- Test object does meet the requirement ..................... : P (Passed)
- Test object does not meet the requirement ............... : F (Failed)
- Test case does not apply to the test object ............... : N/A (Not applicable)
- Test is not checked..................................................... : N/C (Not checked)

**General remarks:**

The test results presented in this test report relate only to the object tested, not selected by UL Verification Services Inc.

This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.
The test report includes only the clauses required in the reference standard.

The laboratory adopted Accuracy Method decision rule that sources of uncertainty are minimized. Therefore, measurement uncertainty does not take into account to determine the conformance with the limit or specific requirements.

The Uncertainty of Measurement (UoM) for each unit measured in this Test Report is estimated in accordance with the procedure No. 23-CL-G0851. Details of the estimation of UoM may be made available upon request.

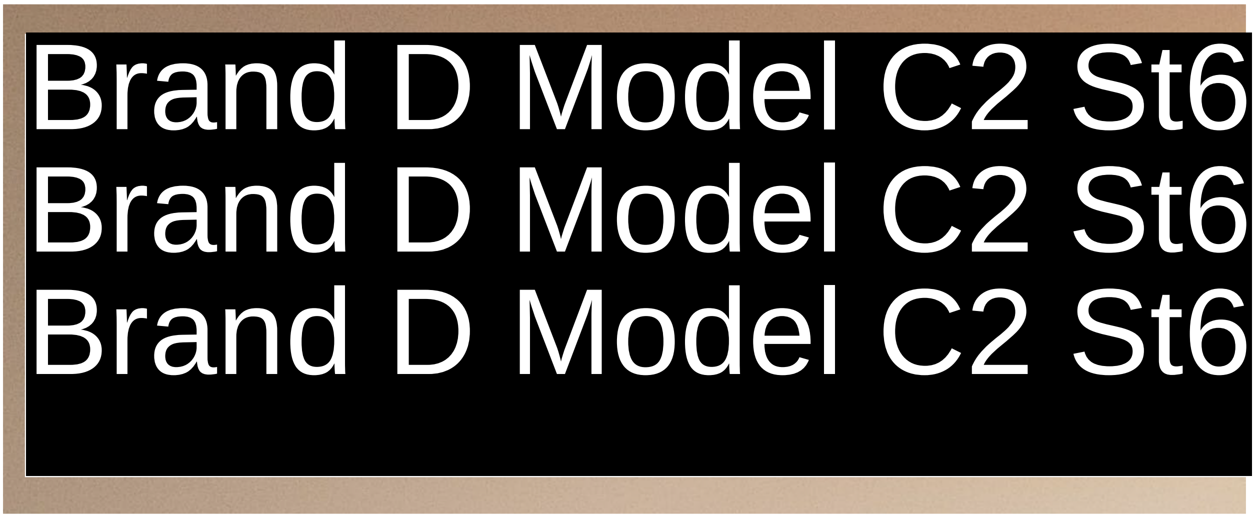
”(See appended table)” refers to a table appended to the report.

"(See appended sketch)" refers to a sketch appended to the report.

**Other product information:**

Status of sample upon receipt: ☒ New and operational ☐ Reconditioned ☐ Damaged

**Copy of marking plate:**



**Product photos:**

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | | |
|---|---|---|---|
| **Part 1 Cl.4** | **CLASSIFICATION** | | |
| | Refrigerating appliance classified into four climate classes or into a range of classes | | - |
| | SN - Extended temperate (+10 to +32)°C...............: | | N/C |
| | N - Temperate (+16 to +32)°C................................: | | N/C |
| | ST - Subtropical (+16 to +38)°C..............................: | | N/C |
| | T - Tropical (+16 to +43)°C.....................................: | | N/C |

| | | | |
|---|---|---|---|
| **Part 3 Cl.6** | **DETERMINATION OF ENERGY CONSUMPTION** | | |
| 6.2 | Objective | | - |
| | Measurement of the temperature and energy consumption for a representative period of steady state operation. | | - |
| | In the case of products with automatic defrost functions, the incremental energy during defrost and recovery is determined for a specified number of representative and valid defrost and recovery periods. | | - |
| 6.3 | Number of test runs | | P |
| | The energy consumption is determined at ambient temperatures of 16 °C and 32 °C either: | | P |
| | a) directly from the results of a single test run; | | P |
| | b) by interpolation between the results of two or more test runs. | | N/A |
| 6.4 | Steady state power consumption | See appended table | P |
| 6.5 | Defrost and recovery energy and temperature change | | P |
| | Ambient temperatures of both 16 °C and 32 °C. | | P |
| | The additional energy associated with defrost and recovery is reported in Watt-hour (Wh). | | P |
| | The temperature change associated with defrost and recovery is reported in degree Kelvin-hour (Kh). | | P |
| 6.8.2 | Daily energy consumption | | - |
| | The ambient temperature (°C)……………………..: | 16 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh)……………………………..: | $E_{daily16C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh)………….……………………..: | $E_{daily16C}$ = 799 | P |

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|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 31.8 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 70.89 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 48 | P |
| | The average temperature for each compartment (°C)……………………………..…………………: | $T_{average}$ = -0.41 (Unfrozen)<br>$T_{average}$ = -18.2 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)………………….……..: | $T_{ss}$ = -0.41 (Unfrozen)<br>$T_{ss}$ = -18.2 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = 1.70 (Unfrozen)<br>$\Delta Th_{df}$ = 7.83 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 32 °C | - |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily32C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..…..: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..………………………...: | $E_{daily32C}$ = 1541 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 60.48 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………….…..: | $\Delta E_{df}$ = 89.33 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 24.0 | P |
| | The average temperature for each compartment (°C)…………………………………………………...: | $T_{average}$ = 3.91 (Unfrozen)<br>$T_{average}$ = -18.7 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)………………….……..: | $T_{ss}$ = 3.91 (Unfrozen)<br>$T_{ss}$ = -18.57(Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)…………………………….…: | $\Delta Th_{df}$ = -0.49 (Unfrozen)<br>$\Delta Th_{df}$ = 3.98 (Frozen) | P |
| | The ambient temperature (°C)……………………..: | 22 °C | - |

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|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |
| | The energy of refrigerating appliances without a defrost control cycle (Wh/24)……..…………………..: | $E_{daily22C}$ = | N/A |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = | N/A |
| | The measured steady state temperature for each compartment is recorded with this value (°C)…..….: | T = | N/A |
| | The energy of refrigerating appliances with one defrost system (Wh/24)…..………………………….: | $E_{daily22C}$ = 1038 | P |
| | The steady state power for the selected temperature control setting (W)……………………………………..: | P = 40.65 | P |
| | The representative incremental energy for defrost and recovery in accordance with Annex C (see C.5) (Wh)……………………………………………………..…: | $\Delta E_{df}$ = 100.6 | P |
| | The estimated defrost interval in accordance with Annex D (h)……………………………………………..: | $\Delta t_{df}$ = 39.0 | P |
| | The average temperature for each compartment (°C)……………………………………………………...: | $T_{average}$ = 0.78 (Unfrozen)<br>$T_{average}$ = -19.07 (Frozen) | P |
| | The average steady state temperature in the compartment for the temperature control setting in accordance with Annex B (°C)………………….……..: | $T_{ss}$ = 0.78 (Unfrozen)<br>$T_{ss}$ = -19.07 (Frozen) | P |
| | The representative accumulated temperature difference over time for defrost and recovery for the relevant compartment in accordance with Annex C (see Clause C.5) (Kh)……………………………..…: | $\Delta Th_{df}$ = 0.88 (Unfrozen)<br>$\Delta Th_{df}$ = 6.36 (Frozen) | P |
| 6.8.3 | Interpolation | | N/A |
| 6.8.4 | Specified auxiliaries | See appended table | P |
| 6.8.5 | Total energy consumption | See appended table | P |

| Part 3 An. G | **DETERMINATION OF LOAD PROCESING EFFICIENCY** | | |
|---|---|---|---|
| G.5 | Determination of load processing efficiency | | P |
| G.5.2 | Quantification of input energy | See appended table | P |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | P |
|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 16°C | | | | | | | | |
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | |
| | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | |
| | U 1 Unfrozen comp. | °C | -0.44 | | -0.41 | | | |
| | F 1 Frozen comp. | °C | -17.90 | | -18.23 | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 413.4 | |
| Frozen volume | L | 192.6 | |
| Unfrozen comp. load | kg | 4.961 | |
| Frozen comp. load | kg | 0.770 | |
| $E_{input - test}$ | Wh | 188 | |
| $\Delta E_{additional\ test}$ | Wh | 147 | |
| $Efficiency_{load}$ | Wh/Wh | 1.277 | |
| $E_{input\ nominal}$ | Wh | 163 | |
| $\Delta E_{processing}$ | Wh/d | 127.5 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Part 3 An. G** | **TABLE: Determination of load processing efficiency** | **P** |
|---|---|---|

| Ambient temp.: 32°C | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Thermostat setting** | | | **[Ref_Frz] N/C_N/C** | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | U 1 Unfrozen comp. | °C | 3.91 | - | 3.70 | | | | |
| | F 1 Frozen comp. | °C | -18.39 | - | -18.82 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 413.4 | |
| Frozen volume | L | 192.6 | |
| Unfrozen comp. load | kg | 4.961 | |
| Frozen comp. load | kg | 0.770 | |
| $E_{input - test}$ | Wh | 272 | |
| $\Delta E_{additional test}$ | Wh | 230.5 | |
| $Efficiency_{load}$ | Wh/Wh | 1.179 | |
| $E_{input nominal}$ | Wh | 269 | |
| $\Delta E_{processing}$ | Wh/d | 228.2 | |
| Voltage | Volt/Hz | 115/60 | |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Part 3 An. G | TABLE: Determination of load processing efficiency | | | | | | | | P |
|---|---|---|---|---|---|---|---|---|---|
| Ambient temp.: 22°C | | | | | | | | | |
| Thermostat setting | | | [Ref_Frz] N/C_N/C | | | | | | |
| No. | Description | Unit | Ave. SS start | Max value | Ave. SS end | | | | |
| | T 1 Unfrozen comp. | °C | 0.82 | - | 0.62 | | | | |
| | T 1 Frozen comp. | °C | -18.78 | - | -19.53 | | | | |

| | | | |
|---|---|---|---|
| Unfrozen volume | L | 413.4 | |
| Frozen volume | L | 192.6 | |
| Unfrozen comp. load | kg | 4.961 | |
| Frozen comp. load | kg | 0.770 | |
| $E_{input - test}$ | Wh | 222 | |
| $\Delta E_{additional\ test}$ | Wh | 185 | |
| $Efficiency_{load}$ | Wh/Wh | 1.198 | |
| $E_{input\ nominal}$ | Wh | 203 | |
| $\Delta E_{processing}$ | Wh/d | 169.4 | |
| Voltage | Volt/Hz | 115/60 | |

| | TABLE: Calculation of energy consumption | - |
|---|---|---|

| | | |
|---|---|---|
| $E_{daily\ 16C}$ | 799 | Wh/d |
| $E_{daily\ 32C}$ | 1541 | Wh/d |
| $\Delta E_{processing\ 16C}$ | 127.5 | Wh/d |
| $\Delta E_{processing\ 32C}$ | 228.2 | Wh/d |

| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

**The following factors are as defined for the European Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| **$E_{total}$ =** | **427** | **kWh/year** |
|---|---|---|

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 182,5 |
| | 182,5 |

| **$E_{total}$ =** | **492** | **kWh/year** |
|---|---|---|

**The following factors are as defined in Australian / New Zealand Region**

| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| **$E_{total}$ =** | **378** | **kWh/year** |
|---|---|---|

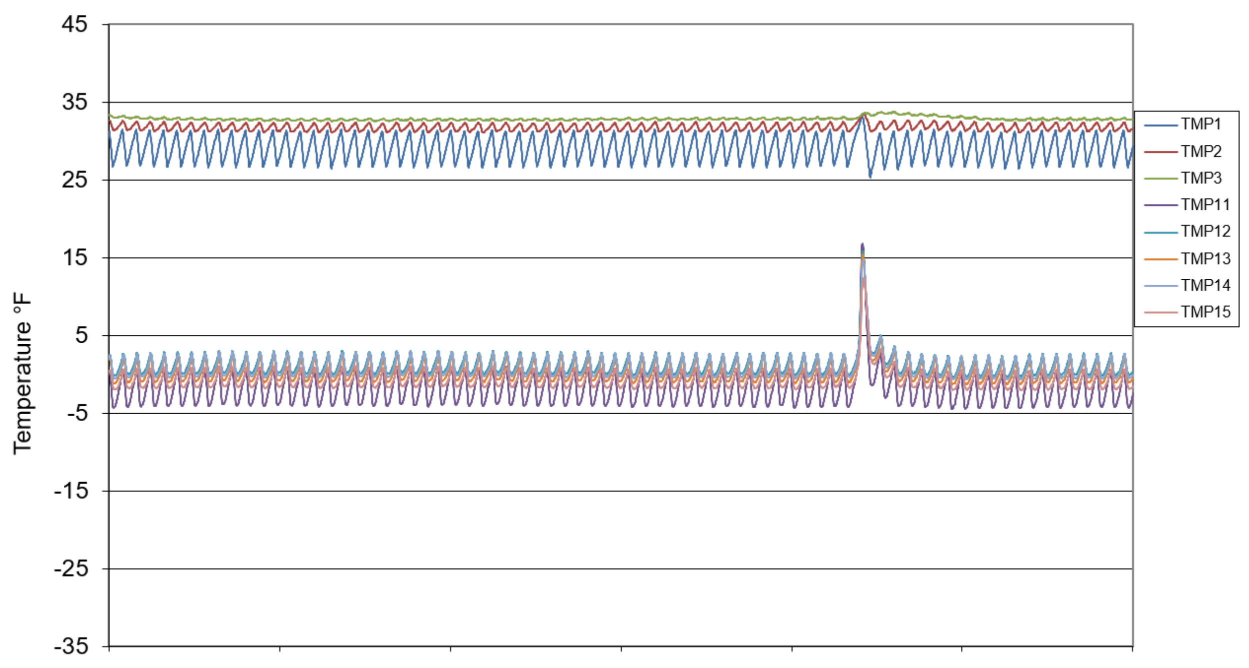
| $E_{total} = f\{ E_{daily\ 16C} , E_{daily\ 32C} \} + \Delta E_{processing\ -\ annual}$ | |
|---|---|
| Regional equivalent operating factors: | 248 |
| | 117 |

| **$E_{total}$ =** | **486** | **kWh/year** |
|---|---|---|

| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

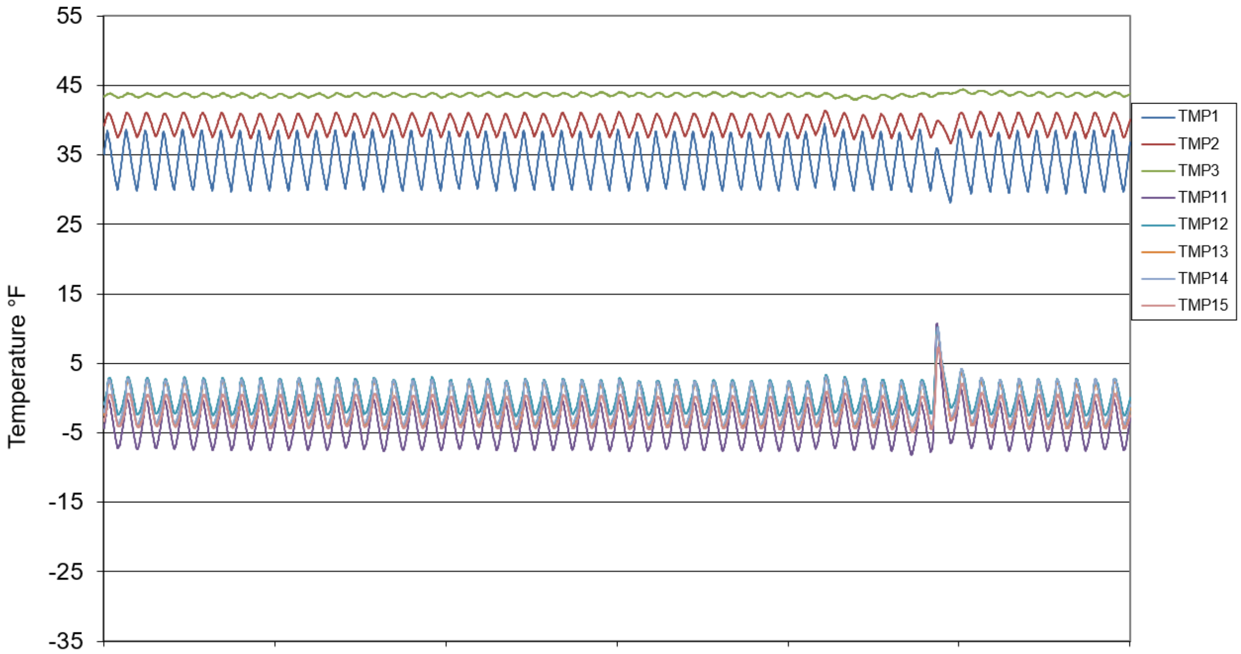
| **Annex 1** | **-** | | | | |
|---|---|---|---|---|---|
| **Clause** | **Measurement / testing** | **Testing / measuring equipment / material used** | **Instrument ID** | **Calibration** | |
| | | | | **Last** | **Expiry** |
| Part 1 An. A | Temperature | Thermocouples type T | 0429 | 10/2019 | 10/2020 |
| Part 1 An. A | Humidity | Hygrometer probe | 1182 | 9/2019 | 9/2020 |
| Part 1 An. A | Air velocity | Anemometer probe | 0550 | 11/2019 | 11/2020 |
| Part 1 An. A | Power / Energy consumption | Power analyzer / Energy meter | 0430 | 10/2019 | 10/2019 |

| **Annex 2** | **Graph of energy consumption test: 16°C** | **-** |
|---|---|---|



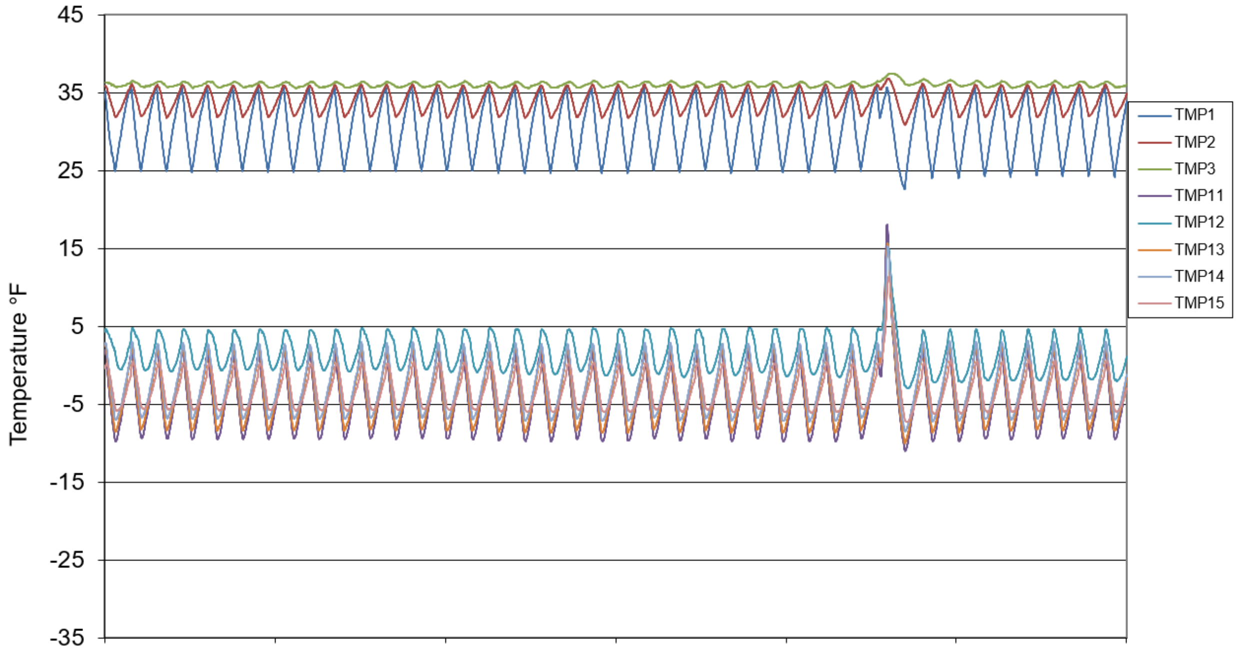
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 2 | Graph of energy consumption test: 32°C | - |
|---|---|---|



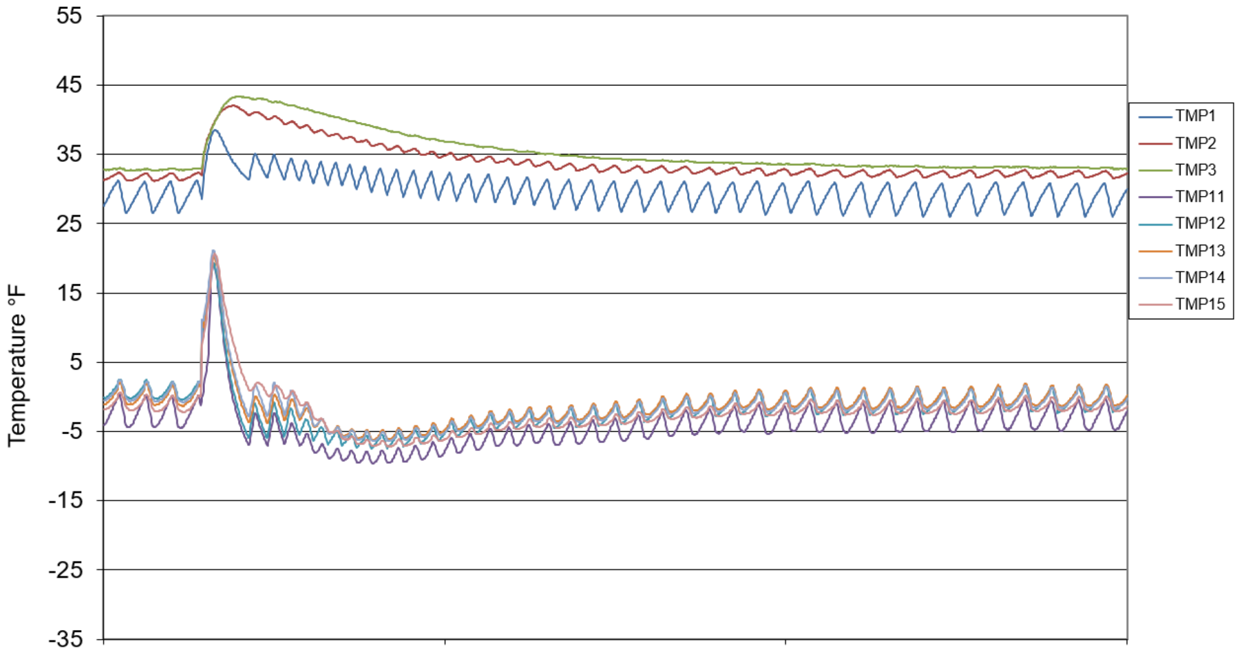
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 2 | Graph of energy consumption test: 22°C | - |
|---|---|---|



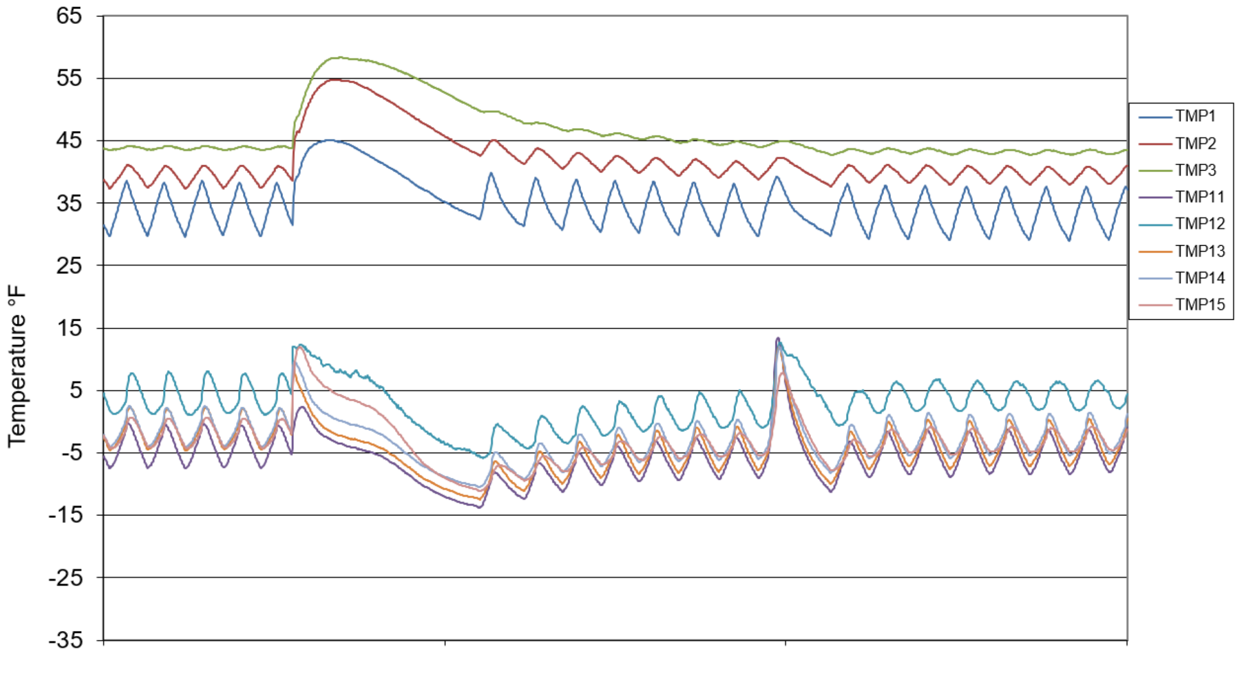
| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| | | |
|---|---|---|
| **Annex 3** | **Graph of load processing efficiency test: 16°C** | **-** |



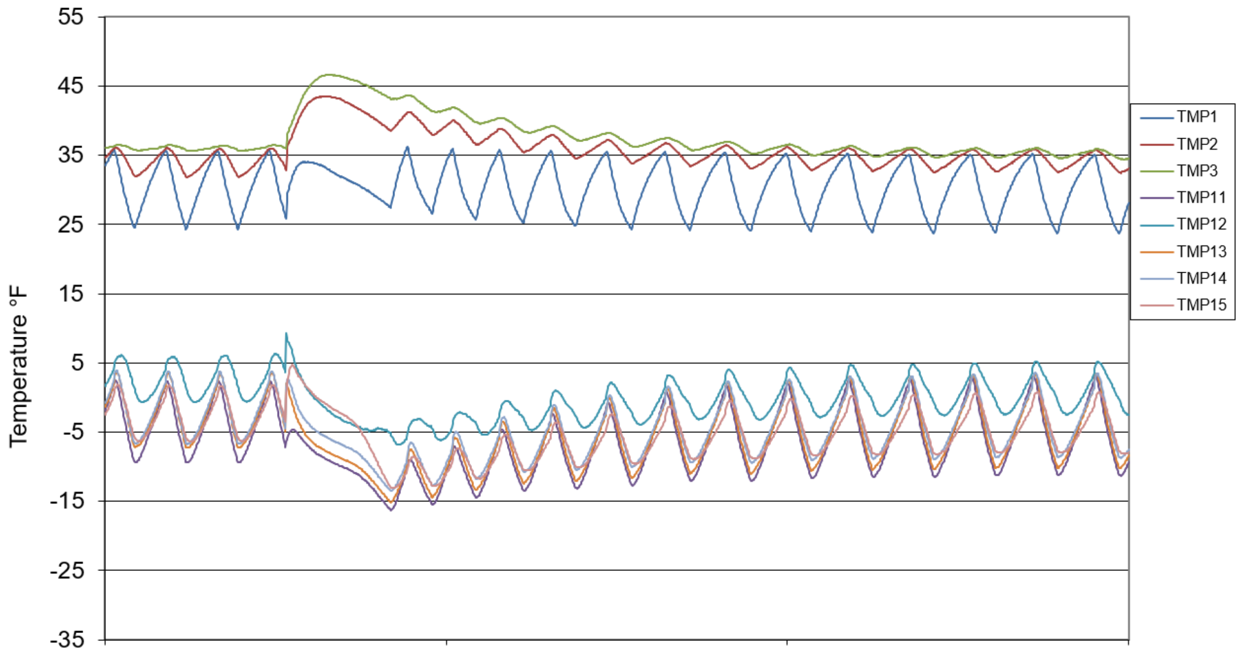
| IEC 62552 | | | |
|---|---|---|---|
| Clause | Requirement - Test | Result - Remark | Verdict |

| Annex 3 | Graph of load processing efficiency test: 32°C | - |
|---|---|---|



| IEC 62552 | | | |
|---|---|---|---|
| **Clause** | **Requirement - Test** | **Result - Remark** | **Verdict** |

| **Annex 3** | **Graph of load processing efficiency test: 22°C** | **-** |
|---|---|---|




**END OF TEST REPORT**

Back to Instructions tab

| Title | |
|---|---|
| Test Report Template Name: | Consumer R-RF-MRef |
| Version Number: | v2.1 |
| Latest Template Revision: | 11/18/2019 |
| Tab Name: | General Info & Test Results |
| File Name: | Refrigerator Brand D Model C2 S DOE Test Datasheet.xlsx |
| Test Start Date: | 8/22/2020 |
| Test Completion Date: | 8/29/2020 |

| 1. Lab Information | |
|---|---|
| Lab Name: | UL Verification Services Inc. |
| Lab Location: | Newton, Iowa |

| 2. Test Information | |
|---|---|
| Date Test Started: | 8/22/2020 |
| Date Test Finished: | 8/29/2020 |

| 3. Product Information | |
|---|---|
| Brand: | Brand D |
| Manufacturer: | [redacted] |
| Manufacturer Model Number: | Model C2 |
| Serial Number: | [redacted]976 |
| Date of Manufacture (if available): | |
| Product Class: | 7 |
| Product Type: | Refrigerator-Freezer |
| Size: | Standard-sized |
| Received Date: | 3/5/2020 |
| Received Condition: | Good |
| Anti-Sweat Heather (ASH) Switch: | No |
| Default ASH Switch Position: | |
| Number of Separate Auxiliary Compartments: | 0 |
| Variable ASH: | No |
| Demand-Response Capable: | No |
| Automatic Icemaker: | Yes |
| Number of Compressors: | 1 |
| Defrost Control Type: | Variable |
| Number of Unique Defrost Frequencies: *(e.g. as described in Appendix A Sections 4.2.3 - 4.2.4)* | |
| Outer Dimensions (in.) | |
| Height: | |
| Width: | |
| Depth: | |

| 4. Explain how defrost control type was determined. |
|---|
| *Include necessary data on the raw data tabs if it is used to determine control type.* |
| |

| 5. Test Results | | |
|---|---|---|
| **Variable** | **Result** | **Units** |
| **Measured Volumes** | | |
| Fresh Food | 14.65 | $ft^3$ |
| Freezer | 6.77 | $ft^3$ |
| Cooler | | $ft^3$ |
| Total Volume | 21.4 | $ft^3$ |
| Adjusted Volume | 26.6 | $ft^3$ |
| **Energy Use** | | |
| ASH Switch OFF | 677 | kWh/yr |
| ASH Switch ON* | | kWh/yr |
| Overall* | 677 | kWh/yr |
| * If necessary | | |

*NOTE: Copy only; sign off is done in the Report Sign-Off Block tab*

| 6. Test Report Sign-Off Block | | |
|---|---|---|
| **We certify that the information and data in this report: (1) were obtained from the specific test unit under test; (2) were obtained during the specific test being reported; (3) were not copied from any other source, except where instructed to do so; and (4) were not altered or modified in any way.** | | |
| **Role** | **Date** | **Entity** |
| Test Completion | 8/29/2020 | UL |
| Template Completion | 12/3/2020 | UL |
| Report Review by Test Lab | | |
| Report Review by Test Lab | | |