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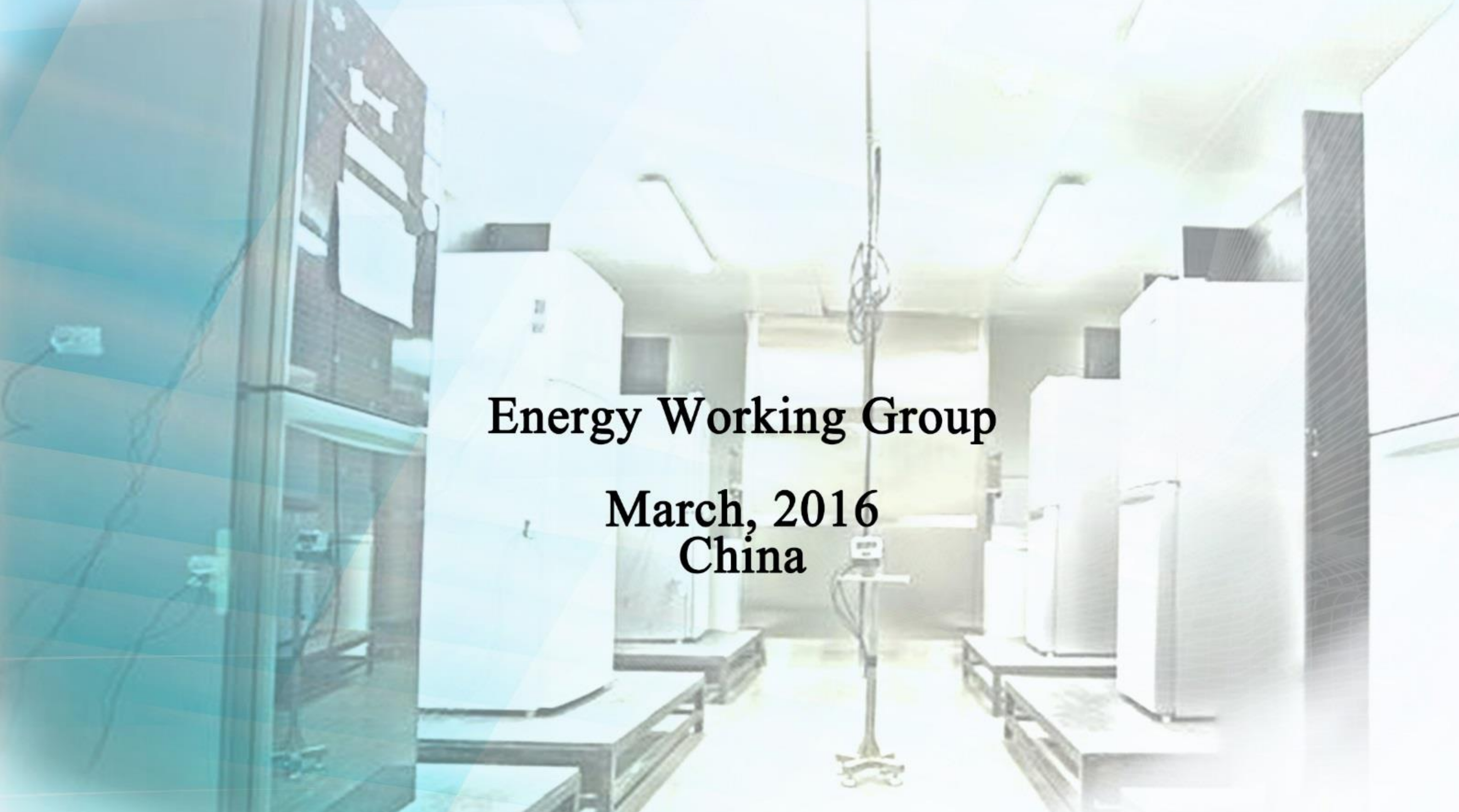
Differences / synergies between energy efficiency test methods for refrigerators in APEC region and with the new IEC 62552

Laboratory Test Report



Energy Working Group

March, 2016
China

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Content

1. Introduction 3
2. Sample and Test Protocol 4
   2.1 Samples 4
   2.2 Test protocol 4
3. Test results 6
   3.1 Energy consumption test results 6
      3.1.1 Energy consumption test results with load processing 6
      3.1.2 Energy consumption test data without load processing test 7
   3.2 Volume 9
   3.3 EEI calculation results 11
4. Results Analysis and Suggestion 13
   4.1 Rationality analysis of IEC 62552:2015 13
   4.2 Results Analysis 13
      4.2.1 Upright refrigerator 14
      4.2.2 Chest freezer 17
      4.2.3 Upright refrigerator-freezer 21
      4.2.4 Upright frost-free refrigerator-freezer 24
      4.2.5 Summary of the main impact factors on energy consumption 28
5. China's Experience on Adopting the IEC 62552:2015 29
6. Conclusion 30

Annex I-1 Test Procedures of Upright Refrigerator 33
Annex I-2 Test Procedures of Upright Two-door Refrigerator-freezer 36
Annex I-3 Test Procedures of Chest freezer 40
Annex I-4 Test Procedures of Upright two-door frost-free refrigerator-freezer 43

1. Introduction

Energy Efficiency (EE) policies, evaluation methods and test methods for refrigerators in APEC region have been summarized in the ‘desktop research report of Differences/synergies between energy efficiency test methods for refrigerators in APEC region and with IEC 62552’.

EE labelling scheme is commonly applied by APEC economies based on their EE standards or laws, and 17 economies have mandatory EE labelling scheme. Those economies do not include Indonesia whose EE labelling is under development, and Brunei, Papua New Guinea and Peru without EE policies. Three ways of MEPS (Minimum Efficiency Performance Standard)-only and EE Grade/Star Ratings system and EE Grades (Star Ratings System) + MEPS have been applied effectively to regulate the EE labelling of each economy.

Important parameters – EEI (Energy Efficiency Index) or SRI (Star Rating Index) and MEPS, are determined by: testing energy consumption, total volume and compartment/appliances category. 4 samples of refrigerators (upright refrigerator, upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer) with constant energy consumption and volume declared by manufactures, have been selected to verify the different EE levels because of different situation in APEC economies and different regulations of above parameters in their economy.

Test methods being applied widely have been taken to deep understand the key elements on testing energy consumption and total volume, and they are IEC 62552:2015, IEC 62552:2007, AS/NZS 4474.1:2007+A1:2008+A2:2011, and USA Standard.

Taking the same samples of upright refrigerator, upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer as above, the Project Overseer assigned China Vkan Certification Co., Ltd to carry out laboratory test to deep analyse the differences of EE test methods in each economy and identify key factors having significant impacts on differences of testing energy consumption and total volume. The testing results and analysis have been described in this report.

APEC economies can refer to this report and the previous desktop report to further evaluate the impacts of the new IEC 62552 on their current EE testing, if economies intend to adopt the standard in future, and the reports can also be useful references for testing laboratories capacity building.

China has made the progress of national EE standard of GB12021.2 been revised referred to the IEC 62552:2015, and this new revised standard has been issued by Sep, 2015 and will implement since Oct 1st, 2016. Currently, the new GB12021.2 covers products scope of refrigerator, chest freezer, refrigerator-freezer and wine cellars. Round Robin Test (RRT) has been organized since 2014 among qualified labs in China to verify the impacts of the new standards on current EE labelling system. The EE labelling system will also be changed to new version according to new standard implementation by Oct 1st, 2016. Training workshops and sessions on the basis of project outputs have been organized in the project for testing experts in testing labs and manufactures labs. Related experience in testing laboratories can also be shared within APEC region in future.

2. Sample and Test Protocol

2.1 Samples

The research team selected samples with adequate performance to the four test standards of IEC 62552:2015, IEC 62552:2007, AS/NZS 4474.1:2007+A1:2008+A2:2011, and USA Standard. Samples of upright refrigerator, upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer are all purchased from the market with information specified as below:

Figure 2-1 Test sample of upright refrigerator, Upright refrigerator-freezer, Chest freezer, Upright frost-free refrigerator-freezer (from left to right)

Table 2-1 Samples specification of the 4 samples

Items	upright refrigerator	upright refrigerator-freezer	chest freezer	upright frost-free refrigerator-freezer
Model	BC-92	BCD-200	BD-295	BCD-322W
Climatic class	ST	ST	ST	ST
Temperature control device	Mechanical	Mechanical	Mechanical Single temperature control	Electronically Double temperature controls
Rated volume (fresh food /frozen food)	92L/--	137L/63L	--/295L	234L/88L
Rated energy consumptions	0.40kWh/24h	0.50kWh/24h	0.90kWh/24h	0.76 kWh/24h
Manufacturer	HISENSE	SIEMENS	LG	SIEMENS

2.2 Test protocol

Test items include energy consumption (daily energy consumption and annual energy consumption), volume, energy efficiency index (EEI, EE Grade, MEPS).

The samples were tested based on four standards separately, shown as below:

- IEC 62552:2015 Household refrigerating appliances – Characteristics and test methods（test method）;
  GB 12021.2-2015 The maximum allowable values of the energy consumption and energy efficiency grade for household refrigerators（EE）
- IEC 62552:2007 Household refrigerating appliances – Characteristics and test methods;
  GB 12021.2-2008 The maximum allowable values of the energy consumption and energy efficiency grade for household refrigerators（EE）
- USA test method standard
  Appendix A1To Subpart B Of 10 CFR Part 430 / Appendix A To Subpart B Of 10 CFR Part 430 Uniform Test Method For Measuring The Energy Consumption Of Electric Refrigerators And Electric Refrigerator-Freezers
  AppendixA1 To Subpart B Of 10 CFR Part 430 / Appendix B To Subpart B Of 10 CFR Part 430 Uniform Test Method For Measuring The Energy Consumption Of Electric Freezers
  USA EE Directive-ENERGY STAR® Program Requirements for Residential Refrigerators And / Or Freezers Partner Commitments
- AU test method standard-AS/NZS 4474.1:2007+A1:2008+A2:2011
  AU EE standard-AS/NZS 4474.2:2009+A1:2011+A2:2014

The Chinese test method standard GB/T 8059 in version 2007 and 2015 is almost the same as IEC 62552 2007 and 2015 respectively, so Chinese EE standard GB/T1202.2 is used to calculate EEI, EE Grade, MEPS with reflection of IEC 62552 in 2007 and 2015 versions.

The test items and testing standard are summarized in table 2-2.

Table 2-2 Test items and testing standards

Standard / *Item*	*IEC 62552:2015*	*IEC 62552:2007*	*AU **S**tandard*	*US **S**tandard*
Daily energy consumption	√	√	√	√
Annual energy consumption	√	√	√	√
Volume	√	√	√	√
EEI	√1)	√2)	√	_
EE Grade	√1)	√2)	√	_
MEPS	√1)	√2)	√	√

Note: 1) EEI, EE Grade, MEPS are calculated according to GB 12021.2-2015;

2) EEI, EE Grade, MEPS are calculated according to GB 12021.2-2008;

Detailed test procedures for the 4 samples can be found in Annex I-1 (upright refrigerator), Annex I-2 (upright refrigerator-freezer), Annex I-3 (chest freezer) and Annex I-4 (upright frost-free refrigerator-freezer).

3. Test results

3.1 Energy consumption test results

3.1.1 Energy consumption test results with load processing

All energy consumption testing results have been summarized in table 3-1 and fig. 3-1. For the same product, different energy consumption testing values have been found by the 4 testing methods. And for different product category, the quantity of differences of achieved energy consumption tested value is shown differently. For example, upright frost-free refrigerator-freezer has the most significant differences on energy consumption testing results among the four standards. And chest freezer's results are the least significant different. This again reflects the category of appliances is one influencing factors in energy consumption differences analysis.

Table 3-1 Annual energy consumption test results with load processing (Unit: KWh/y)

Test Standards / *Appliance*	*IEC 62552:2015*	*IEC 62552:2007*	*Australia Standard*	*USA Standard*
Upright refrigerator	221.002	169.360	315.360	303.680
Upright refrigerator-freezer	245.811	200.385	281.780	273.750
Chest freezer	430.099	383.250	383.980	347.480
Upright frost-free refrigerator-freezer	337.300	269.370	382.155	405.515

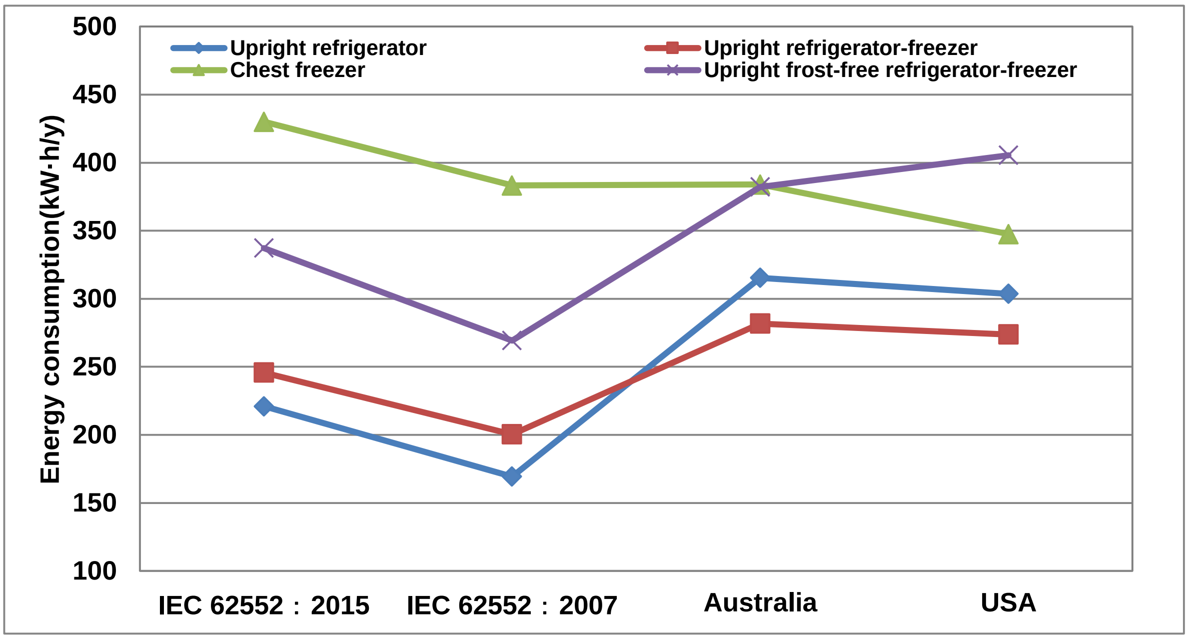


Fig. 3-1 Annual energy consumption test results with load processing

Deviations of testing energy consumption data among IEC 62552:2007, USA Standard, AU standard from IEC 62552:2015 is shown in Table 3-2. Significant differences can be found on the deviation among IEC 62552:2007, AU standard, USA standard from IEC 62552:2015.

The deviations of three standards from IEC 62552:2015 are different from the four appliances that:

- For upright refrigerator, the test results according to AU standard has the most deviation from IEC 62552:2015;
- For upright refrigerator-freezer, the test results according to IEC 62552:2007 has the most deviation from IEC 62552:2015;
- For chest freezer, the test results according to USA standard has the most deviation from IEC 62552:2015 and the deviations are close to each other in the IEC 62552:2007, AU standard and US standard compared to IEC 62552:2015;
- For upright frost-free refrigerator-freezer, the test result according to AU standards has the least deviation from IEC 62552:2015.

Table 3-2 Deviation of annual energy consumption in other test standards from IEC 62552:2015

Test standards / Appliance	IEC 62552:2007	Australia	US
Upright refrigerator	-23.4%	42.6%	37.4%
Upright refrigerator-freezer	-18.5%	14.6%	11.4%
Chest freezer	-10.9%	-10.7%	-19.2%
Upright frost-free refrigerator-freezer	-20.1%	13.3%	20.2%

3.1.2 Energy consumption test data without load processing test

Load processing efficiency test is an additional test required in IEC 62552:2015 compared to the IEC 62552:2007, which is used as the basis for a manufacture claim. In order to analyze the energy consumption differences among the four standards for the 4 samples without load processing, that can provide equal basis energy consumption results comparison with the rest standard, the test data in table 3-1 is treated without load processing energy consumption and summarized in table 3-3 and fig. 3-2. Slightly decrease of energy consumption for the 4 sample using the IEC 62552:2015 without load processing has been tested comparing the IEC 62552:2007.

The table 3-3 is the basis for further analysis of main impacting factor on energy consumption. For the same sample, different energy consumption values have been tested with the 4 different testing standards. Moreover, it has shown the most significant difference for upright refrigerator on energy consumption with the 4 selected testing standards, and the least significant difference for chest freezer.

Table 3-3 Annual energy consumption test data without load processing (Unit: KWh/y)

Appliance \ Test standards	IEC 62552:2015 (without loading efficiency test)	IEC 62552:2007	Australia	USA
Upright refrigerator	207.400	169.360	315.360	303.680
Upright refrigerator-freezer	216.150	200.385	281.780	273.750
Chest freezer	369.325	383.250	383.980	347.480
Upright frost-free refrigerator-freezer	302.025	269.370	382.155	405.515

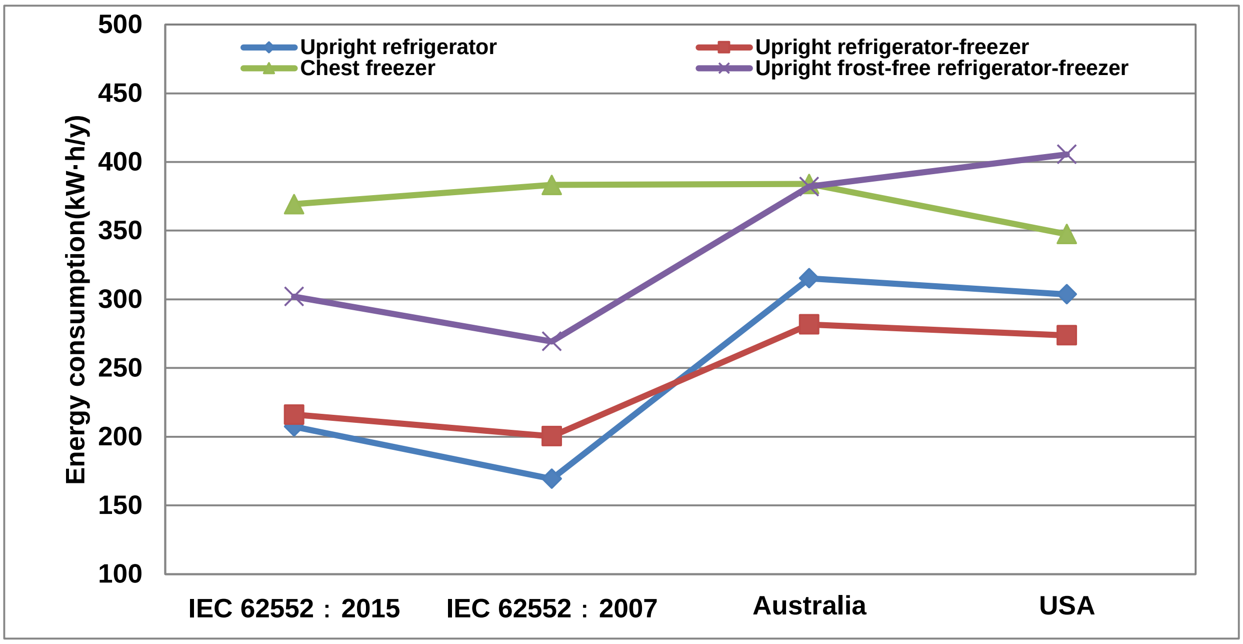


Fig. 3-2 Annual energy consumption test data without load processing test

Deviations of testing energy consumption data without load processing among IEC 62552:2007, USA Standard, AU standard from IEC 62552:2015 is shown in Table 3-4. For upright refrigerator and upright refrigerator-freezer, AU standard has the most significant difference from the IEC 62552:2015 compared to IEC 62552:2007 and US standard (52.1%, 30.3% respectively). For chest freezer and upright frost-free refrigerator freezer, the US standard has the most significant difference from the IEC 62552:2015 (-6.0% and 34.3% respectively).

Table 3-4 Deviation of energy consumption without load processing by other test standards from IEC 62552:2015 (Unit: KWh/y)

Test standards	*IEC 62552:2007*	*Australia*	*US*
Upright refrigerator	-18.3%	52.1%	46.4%
Upright refrigerator-freezer	-7.3%	30.3%	26.5%
Chest freezer	3.8%	4.0%	-6.0%
Upright frost-free refrigerator-freezer	-10.8%	26.5%	34.3%

In table 3-5, it has been concluded the detailed differences of energy consumption with and without load processing using the IEC 62552 standard of 2007 and 2015 to understand the impacts of load processing on energy consumption. The increase ratio of energy consumption with load processing in the IEC 62552:2015 has been analyzed in the table as well. It has illustrated that load processing efficiency test has significant influence on the test results for upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer, especially for chest freezer, which is 14.1% of increasing ratio.

Table 3-5 The additional energy consumption for the 4 samples with load processing in IEC 62552:2015

Test standards	*IEC 62552:2015 with load processing*	*Additional energy for load processing*	*increasing ratio*
Upright refrigerator	221.002	13.602	6.2%
Upright refrigerator-freezer	245.811	29.661	12.1%
Chest freezer	430.099	60.774	14.1%
Upright frost-free refrigerator-freezer	337.300	35.275	10.5%

3.2 Volume

Volume test results of upright refrigerator, upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer have been specified in table 3-6 and figure 3-3. Differences are not that significant among the 4 samples with the applied 4 standard.

Table 3-6 Volume testing results (unit: /L)

Test standards	*IEC 62552:2015*	*IEC 62552:2007*	*Australia*	*US*
Upright refrigerator	106.048	103.199	120.819	106.048
Upright refrigerator-freezer	211.413	204.189	214.912	211.413
Chest freezer	294.309	293.184	294.309	294.309
Upright frost-free refrigerator-freezer	332.687	311.026	352.795	332.687

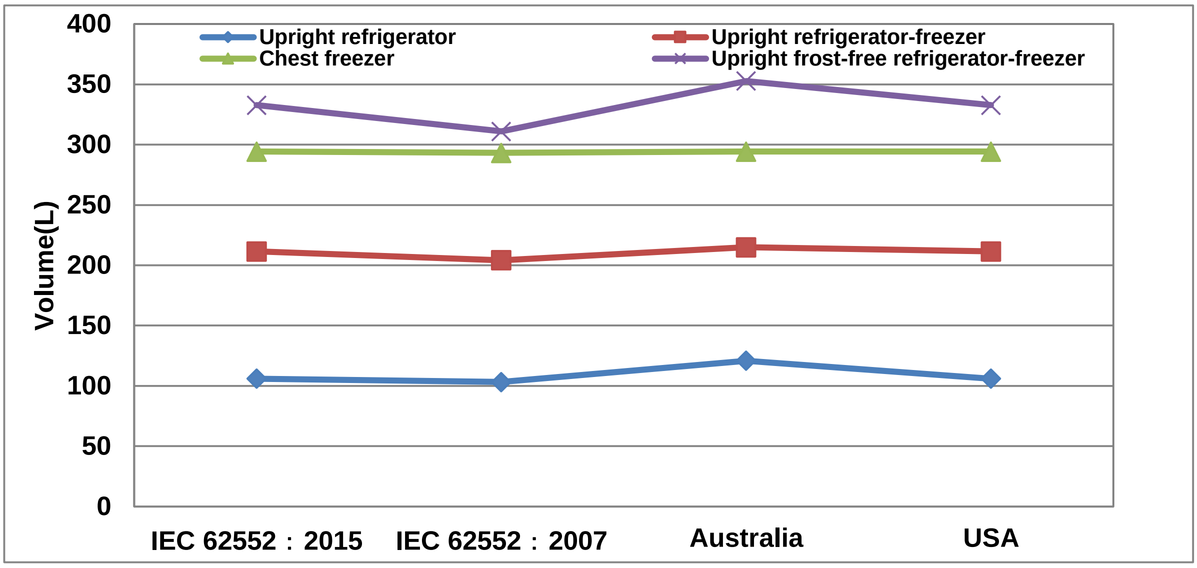


Fig 3-3 Volume test data (unit: /L)

Deviations of volume test data among IEC 62552:2007, USA Standard, AU standard from IEC 62552:2015 can be referred to table 3-7. It can be seen that for chest freezer, volume are almost the same based on the applied 4 standards, and for upright refrigerator, AU standards has the most deviation, and for upright refrigerator-freezer and upright frost-free refrigerator-freezer, the IEC 62552:2007 has the most significant deviation. US standard is kept the same value, no deviation with the new IEC 62552:2015 standard on volume testing results.

Table 3-7 Deviation of volume in the 4 testing standards from IEC 62552:2015

Test standards	*IEC 62552:2007*	*AU*	*USA*
Upright refrigerator	-2.6%	13.9%	0%
Upright refrigerator-freezer	-3.4%	1.7%	0%
Chest freezer	-0.4%	0%	0%
Upright frost-free refrigerator-freezer	-6.5%	6.0%	0%

3.3 EEI calculation results

Calculated EEI, EE grade and MEPS, which is derived from the energy consumption test results without load processing test, have been concluded into table 3-8, 3-9 and 3-10. When the EEI and energy efficiency grades are calculated based on the IEC 62552: 2007 and IEC 62552: 2015, and the algorithm in Chinese standard GB 12012.2-2008 and GB 12021.2-2015 is applied.

Because in US, only MEPS are applied in EE regulations, EE grade is not discussed here with US standard. In China, the worst energy efficiency is Grade 5 and the best is Grade 1, and in Australia, the worst energy efficiency is Grade 1, and the best is Grade 10. From the table 3-9, it can be seen that the 4 samples behave as the poor energy efficiency product both in China with the new IEC 62552:2015 and in Australia, although the test methods are differently regulated. And except chest freezer, the other 3 samples show different energy efficiency level in the IEC 62552:2015 and IEC 62552:2007.

Table 3-8 Energy efficiency index (EEI) calculated results

Test standards	*IEC 62552:2015 with China standard GB 12021.2-2015*	*IEC 62552:2007 with China standard GB 12012.2-2008*	*AU*
Upright refrigerator	0.752	0.656	0.800
Upright refrigerator-freezer	0.421	0.411	3.300
Chest freezer	0.592	0.617	2.800
Upright frost-free refrigerator-freezer	0.372	0.377	3.100

Table 3-9 Energy efficiency grade calculated results

Test standards	*IEC 62552:2015 with China standard GB 12021.2-2015*	*IEC 62552:2007 with China standard GB 12012.2-2008*	*AU*
Upright refrigerator	5	2	1
Upright refrigerator-freezer	3	2	3
Chest freezer	3	3	2.5
Upright frost-free refrigerator-freezer	3	1	3

From table 3-10 and fig.3-4 it can be found that USA has the highest MEPS requirement for the 4 samples compared with other 3 standards.

Table 3-10 MEPS calculated result (Unit: KWh/y)

Test standards	*IEC 62552:2015 with China standard GB 12021.2-2015*	*IEC 62552:2007 with China standard GB 12012.2-2008*	*Australia*	*USA*
Upright refrigerator	219.963	232.279	345.333	219.029
Upright refrigerator-freezer	348.968	390.334	386.403	300.33
Chest freezer	509.707	538.332	444.040	241.149
Upright frost-free refrigerator-freezer	547.624	571.565	600.616	443.918

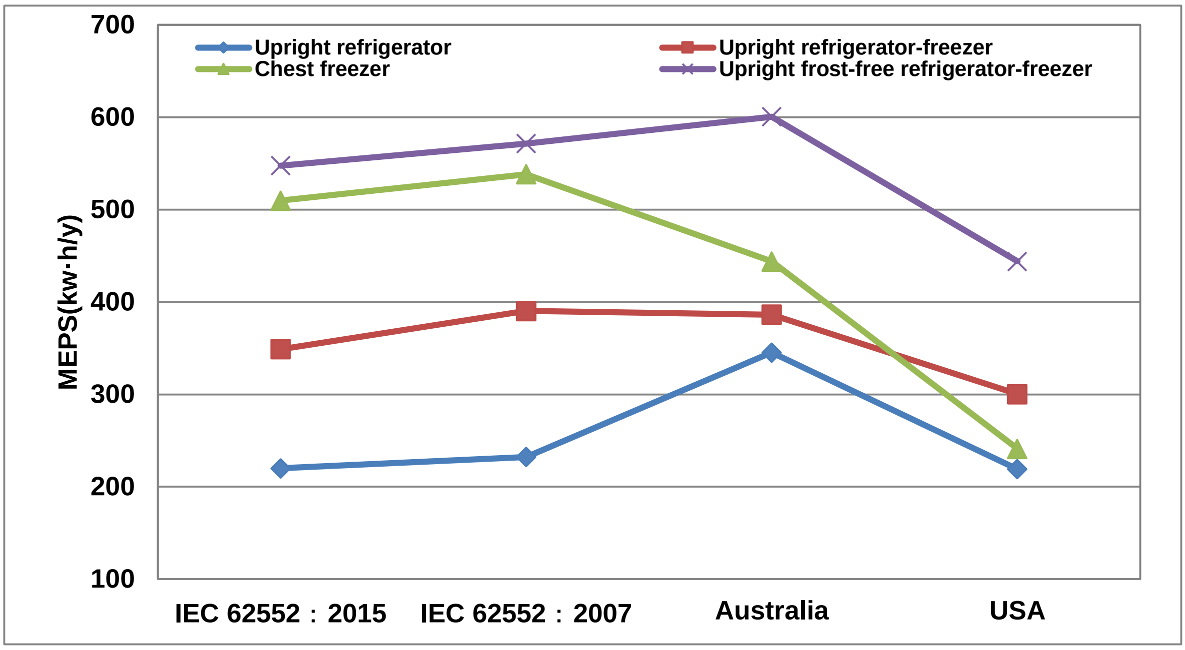


Fig 3-4 The MEPS values

What needs to be mentioned here is when economies making EE standards or directions reflected as EE Grade and MEPS, energy consumption and volume are not the only contributions to the energy efficiency evaluation, parameters of reflecting economy EE policy are also important. In other words, because of different EE policy regulation for the same product in different economies, the EE Grade and MEPS will be yielded differently as theoretically energy consumption and volume of one product is constant.

4. Results Analysis and Suggestion

4.1 Rationality analysis of IEC 62552:2015

The background of the new IEC 62552 was to develop one performance standard for household cooling appliances which will be used worldwide for energy efficiency grades (label) and minimum efficiency performance limits. The new IEC 62552 has modified energy consumption testing with corrections for the IEC 62552:2007, with points described as in below:

- Appliances are tested in empty condition (currently loaded with packages);
- Tests are to be performed at two ambient temperatures (16℃ and 32℃ instead of 25℃ only);
- The fresh food compartment temperature is reduced to 4℃;
- Using cylinder is easy and fast to get measurement results instead of M package in frozen compartment;
- A new adaptive test algorithm is introduced in energy consumption testing;
- Volumes measurement will be based on the ‘cooled volume’.

The new standard is structured as Part 1 – General requirements, Part 2 – Performance requirements, Part 3 – Energy consumption and volume. The testing method of energy consumption is more related to the specifications or configurations of the latest refrigerator, which also reflects the actual installation and usage environment in home. It is simple and easily reproducible condition for quick adaptation. However, a complex data processing will be arisen after application the new IEC 62552 standard.

4.2 Results Analysis

Hereby, the philosophy of analyzing key impacting factors of energy consumption test methods is to choose two standards with similar certain testing conditions but one or two main different testing conditions, and then to understand the different testing condition’s impacts on energy consumption. Sample’s characteristics impacts on energy consumption have been analyzed by deviation or two points interpolation methods.

During the analysis below for each product sample, the effect of load processing test on energy consumption is summarized. Other differences of test conditions required in IEC 62552:2015, such as requirements for test room, the distance of rear of appliance, position of cylinder for ambient temperature, etc. which have minor effect on the energy consumption results are not analyzed here. Besides, requirements for calculation of energy consumption in IEC 62552:2015 to improve the accuracy have not been considered in the report either.

4.2.1 Upright refrigerator

When conducting all tests on the upright refrigerator using the IEC 62252:2015, IEC 62552:2007, Australia test standards and USA test standards. The main differences of testing condition have been demonstrated in the table 4-1, and the test data were shown in the table 4-2.

Table 4-1 Differences of test conditions on upright refrigerator among the 4 standard

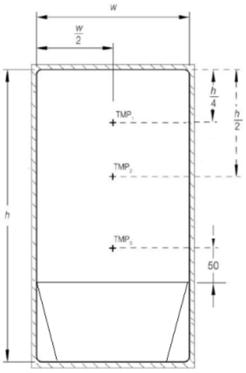
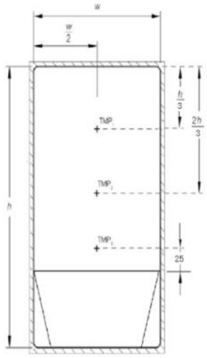
Test standards / Elements	IEC 62552:2015	IEC 62552:2007	Australia	USA
Room test ambient temperature	16.0℃and 32.0℃	25.0℃	32.0℃	32.2℃
Target temperature of fresh-food comp.	Average: 4.0℃	Average: 5.0℃ Min.: 0℃, Max.: 10℃	Average: 3.0℃	Average: 3.9℃
Fresh-food comp. storage temperature sensor	Cylinder1 with 25g±5%, and a maximum dimension of 18mm	Cylinder2 with 15.2mm diameter and 15.2mm height	Cylinder3 with 25mm diameter and 25mm height	Cylinder4 with 29mm diameter and 29mm height
Storage plan of fresh-food comp. storage temperature sensor				

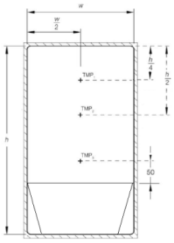
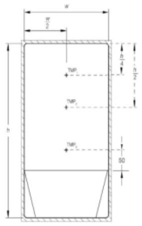
Table 4-2 Test conditions and testing results on upright refrigerator

Item	Unit	IEC 62552：2015				IEC 62552：2007		Australia		USA	
Ambient temperature	℃	16		32		25		32		32.2	
Temperature control settings:		5.5	5	5.9	5.7	4	5	4.8	6	4.5	8
Temperature in fresh food storage compartment	℃	3.3	5.1	3.7	4.9	6.1	3.8	4.3	2.4	5.8	-1.5
Steady state power	**W**	10.8	9.3	36.4	32.7	-	-	-	-	-	-
Energy consumption per 24h	**kWh/24h**	0.259	0.223	0.874	0.785	0.44	0.49	0.733	0.906	0.7	1.205
Energy consumption by interpolation	**kWh/24h**	0.245		0.852		0.463		0.864		0.831	
△Eprocessing (kwh/day)	Wh/24h	16.000		56.100		-	-	-	-	-	-
Standard energy consumption	**kWh/24h**	0.533				0.463		0.864		0.831	
Total Energy consumption	**kWh/24h**	0.568				0.463		0.864		0.831	

Based on the test condition difference and test result data for the upright refrigerator, the key impact factors have been analyzed, which are specified in below respectively.

a. Ambient temperature

Table 4-3 Ambient temperature impacts on energy consumption for upright refrigerator

Elements \ standards	IEC 62552:2015	IEC 62552:2015
Room test ambient temperature	Different (16.0℃)	Different(32.0℃)
Target temperature of fresh-food comp.	Same(4.0℃)	Same(4.0℃)
Storage plan of fresh-food comp. storage temperature sensor	Same 	Same 
Tested daily energy consumptions, kWh/24h	0.245	0.852
Deviation:	(0.852-0.245)/0.852*100%=71.2%	

According to IEC 62552:2015 the sample was tested under condition of two ambient temperatures –16.0℃ and 32.0℃ , so comparing the test data under the two ambient temperature condition is helpful to understand the impacts of ambient temperature on energy consumption for upright refrigerator. From the table 4-3, it can be understood that the energy consumption at 32℃ambient temperature is 71.2% higher than at 16℃ ambient temperature, and when the ambient temperature increases 1 K, the energy consumption will increase 4.5% for upright refrigerator.

a. Target temperature of fresh-food compartment

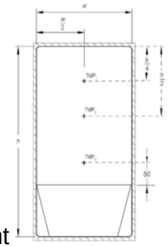
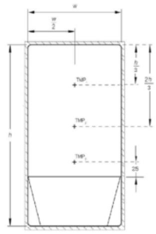
Table 4-4 target temperature of fresh-food compartment effect on energy consumption for upright refrigerator

Item	**Unit**	**IEC 62552：2015**			
Ambient temperature	℃	16		32	
Temperature control settings:		5.5	5	5.9	5.7
Temperature in fresh food storage compartment	℃	3.3	5.1	3.7	4.9
Temperature in “four-star” frozen food storage compartment	℃	-	-	-	-
Energy consumption per 24h	kWh/24h	0.259	0.223	0.874	0.785
Energy consumption by interpolation（T_{target}=5r）	kWh/24h	0.225		0.778	
Energy consumption by interpolation（T_{target}=4r）	kWh/24h	0.245		0.852	
Additional energy consumption ratio for target temperature change	%	8.9%		9.5%	

Two point interpolation has been used for analyzing energy consumption at 4℃ and 5℃ (target temperature of fresh-food compartment) under condition of 16℃and 32℃ ambient temperature. The additional energy consumption is 8.9% at 16℃ ambient temperature to achieve 4℃ target temperature compared with to achieve 5℃ for upright refrigerator. And at 32℃ ambient temperature, the additional energy consumption is 9.5%. Therefore, when targeted temperature changes 1K in fresh food compartment, additional energy consumption will increase 9% approximately.

b. Storage plan and temperature sensor of fresh-food compartment.

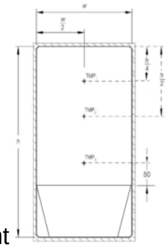
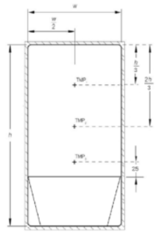
Table 4-5 impacts of storage plan and temperature sensor of fresh-food compartment on energy consumption

Elements / standards	IEC 62552:2015	USA
Room test ambient temperature	Similar (32.0℃)	Similar (32.2℃)
Target temperature of fresh-food comp.	Similar (4.0℃)	Similar (3.9℃)
Storage plan of fresh-food comp. storage temperature sensor	Different 	Different 
Tested daily energy consumptions, kWh/24h	0.852	0.832
Deviation:	(0.852-0.832)/0.852*100%=2.3%	

Differences of test conditions are storage plan of fresh-food comp., storage temperature sensor and the setting of thermostat between IEC 62552:2015 (at 32℃) and the USA standards. So with the above table 4-5, the deviation of test results of energy consumption of 2.3% is due to differences of the testing condition differences illustrated.

c. Products adaptability under condition of two different ambient temperatures

Table 4-6 Impacts of products adaptability under two different ambient temperature on energy consumption

Elements / standards	IEC 62552:2015	IEC 62552:2007
Room test ambient temperature	Similar (16℃ and 32℃）	Similar (25℃
Target temperature of fresh-food comp.	Different (4.0℃)	Different (5.0℃)
Storage plan of fresh-food comp. storage temperature sensor	Different 	Different 
Standard energy consumption, kWh/24h	0.533	0.463
Total deviation (target temperature, storage plan and temperature sensor, two tests at different ambient temperatures)	(0.533-0.463)/0.533*100%=13.1%	
Deviation of target temperature of fresh-food comp.	9%	
Deviation of storage plan and temperature sensor of fresh-food comp.	2.3%	
Deviation of products adaptability under two different ambient temperatures	Almost same(13.1-2.3-9)=1.7%	

When calculate the interpolation energy consumption between at 16℃ and 32℃, the ambient factor is 0.53 (at 16℃, there are 192 days per year, and at 32℃, there are 173 days per year) and the average temperature is 23.58℃. The interpolation result for energy consumption can be accepted at average temperature of 24℃ in the IEC 62552:2015, that is almost the same as 25℃ in IEC 62552:2007. So, if no consideration of the effects of target temperature, and storage plan and temperature sensor on energy consumption, the results of products adaptability under two different ambient temperatures are almost the same as the result at 25℃ ambient temperature (deviation value of 1.7% for upright refrigerator in table 4-6 has verified the analysis, and this is correspond to the theory analysis).

4.2.2 Chest freezer

With the same procedure for chest freezer as upright refrigerator, the main differences of testing conditions have been identified in the table 4-7, and the test data were shown in the table 4-8.

Table 4-7 Differences of test conditions on chest freezer among the 4 standards

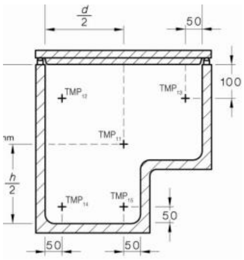
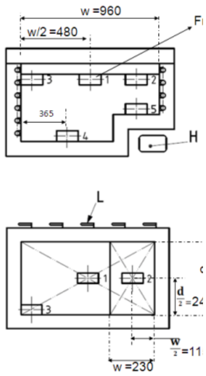
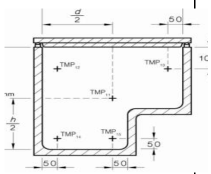
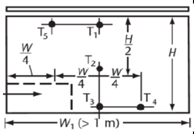
Test standards / Elements	IEC 62552:2015	IEC 62552:2007	Australia	USA
Room test ambient temperature	16.0℃ and 32.0℃	25.0℃	32.0℃	32.2℃
Target temperature of frozen-food comp.	Average: -18.0℃	Max.: -18.0℃	Average: -15.0℃	Average: -17.8℃
Frozen-food comp. storage temperature sensor	Cylinder1 with 25g±5%, and a maximum dimension of 18mm	M-packages	Cylinder with 25mm diameter and height	M-packages
Storage plan of frozen-food comp. storage temperature sensor				

Table 4-8 Test conditions and testing results on chest freezer among the 4 standards

Item	Unit	IEC 62552：2015				IEC 62552：2007		Australia		USA	
Ambient temperature	℃	16		32		25		32		32.2	
Temperature control settings:		3.7	3.4	3.5	3	5	4	2	1.5	4	1
Temperature in "four-star" frozen food storage compartment	℃	-18.7	-17.8	-18.4	-17.7	-19.2	-17.0	-15.5	-14.5	-18.1	-12.0
Steady state power	**W**	28.8	27.7	55.4	53.9	-	-	-	-	-	-
Energy consumption per 24h	**kWh /24h**	0.691	0.665	1.330	1.294	1.106	1.004	1.067	1.037	0.963	0.754
Energy consumption by interpolation	**kWh /24h**	0.671		1.309		1.051		1.052		0.952 (1.36*)	
△Eprocessing (Wh/day)	Wh /24h	144.800		183.700		-	-	-	-	-	-
Standard energy consumption	**kWh /24h**	0.973				1.051		1.052		0.952	
Total Energy consumption	**kWh /24h**	1.137				1.051		1.052		0.952	

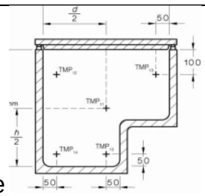
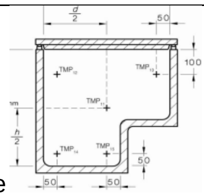
Note: According to DOE standard, the energy consumption of chest freezer will be multiplied by 0.7, so the value of 1.36 is the test data without the factor of 0.7.

On the basis of the testing conditions and testing data analysis, the following key impact factors on energy consumption test result testing of chest freezer are:

- room test ambient temperature,
- target temperature of frozen-food comp.
- storage plan of frozen-food comp.
- storage temperature sensor,
- frozen-food comp. storage temperature sensor,
- calculated annual energy consumption
- calculated daily energy consumption.
- Those factors have been analysed to understand the importance of contribution to energy consumption one-by-one below.

a. Ambient temperature

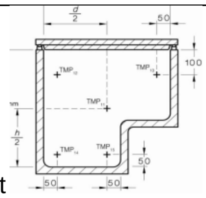
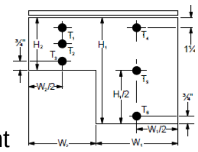
Table 4-9 Impacts of ambient temperature on energy consumption for chest freezer

Elements \ standards	IEC 62552:2015	IEC 62552:2015
Room test ambient temperature	Different (16.0℃)	Different(32.0℃)
Target temperature of frozen-food comp.	Same(-18.0℃)	Same(-18.0℃)
Storage plan of frozen-food comp. storage temperature sensor	Same 	Same 
Frozen-food comp. storage temperature sensor	Same(Cylinder)	Same(Cylinder)
Tested daily energy consumptions, kWh/24h	0.671	1.309
Deviation:	(1.309-0.671)/1.309*100%=48.7%	

According to IEC 62552:2015 the sample was tested at two ambient temperatures, so the impacts of ambient temperature on energy consumption for chest freezer can be achieved by analysis the differences of tested data of energy consumption under two ambient temperatures. It can be understood from the table 4-9 that the energy consumption at 32℃ambient temperature is 48.7% higher than that at 16℃ ambient temperature, and when the ambient temperature increases 1 K, the energy consumption will increase 3.0% for chest freezer.

b. Empty load and storage temperature sensor of frozen-load comp.

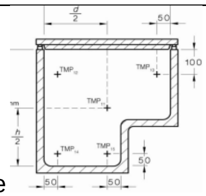
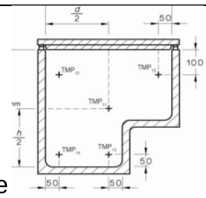
Table 4-10 Impacts of empty load and storage temperature sensor of frozen-load comp. on energy consumption on chest freezer

Elements \ standards	**IEC 62552:2015**	**USA**
Room test ambient temperature	Similar(32.0℃)	Similar(32.2℃)
Target temperature of frozen-food comp.	Similar(-18.0℃)	Similar(-17.8℃)
Empty load of frozen-food comp. storage temperature sensor	Different 	Different 
Frozen-food comp. storage temperature sensor	Different(Cylinder)	Different(M-packages)
Tested daily energy consumptions, kWh/24h	1.309	1.36
Deviation:	(1.309-1.36)/1.309*100%=-3.9%	

It is required in IEC 62552:2015 that the frozen compartment shall be empty and the comp. temperature should be tested by cylinder for energy consumption, but in the US standard, it should be tested with package in the frozen compartment and the temperature should be tested by M package. The rest test conditions are similar between IEC 62552:2015 (at 32℃) and DOE, therefore, the energy consumption according to IEC 62552:2015 (at 32℃) is 3.9% less than DOE can be reflected as the causes of empty load of frozen-food comp. and storage temperature sensor different from the 2 standards.

c. Target temperature of frozen-food compartment

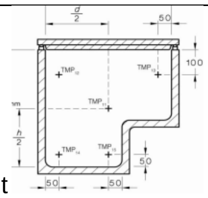
Table 4-11 Impacts of target temperature of frozen-food comp. on energy consumption for chest freezer

Elements / standards	IEC 62552:2015	AU
Room test ambient temperature	Same (32.0℃)	Same (32.0℃)
Target temperature of frozen-food comp.	Same(-18.0℃)	Different (-15.0℃)
Storage plan of frozen-food comp. storage temperature sensor	Same 	Same 
Frozen-food comp. storage temperature sensor	Same(Cylinder)	Same(Cylinder)
Tested daily energy consumptions, kWh/24h	1.309	1.052
Deviation:	(1.309-1.052)/1.309*100%=19.6%	

Comparing the test conditions of IEC 62552:2015 (at 32℃) and Australia standard for chest freezer, it can be found that factor of target temperature of frozen-food comp. is different. Hence, the additional energy consumption of 19.6% is because of -18℃ target temperature increasing to -15℃ target temperature for frozen-compartment. The additional energy consumption ratio for target temperature change is 6.5% for frozen-compartment if there is 1K target temperature increase.

d. Determination of frozen-food compartment temperature

Table 4-12 Impacts of Determination of frozen-food compartment temperature on energy consumption for chest freezer

Elements / Standards	IEC 62552:2015	IEC 62552:2007
Room test ambient temperature	Similar(16℃ and 32.0℃)	Similar(25℃)
Target temperature of frozen-food comp.	same(-18.0℃)	same (-18.0℃)
Empty load of frozen-food comp. storage temperature sensor	Different 	Different
Frozen-food comp. storage temperature sensor	Different(Cylinder)	Different(M-packages)
Determination of target temperature	Average of temperature sensors	The maximum of temperature sensors
Standard energy consumption , kWh/24h	0.973	1.051
Total deviation (empty load and storage temperature sensor, determination of frozen-food compartment temperature)	(0.973-1.051)/0.973 *100%=-8.0%	
Deviation of empty of frozen-food comp. storage temperature sensor	-3.9%	
Deviation of determination of frozen-food compartment temperature	-8%-(-3.9%)=-4.1%	

In IEC 62552:2015 for chest freezer, it is required that the frozen compartment is empty, the temperature sensor is cylinder, and the compartment temperature is determined by the average of temperature sensors with packages. While in IEC 62552:2007, different requirements are regulated as of the temperature sensor is M package, and compartment temperature is determined by the maximum of M packages. Therefore, impacts of empty loads in compartment and storage position of temperature sensor on energy consumption for frozen-food compartment (-3.9%) can be understood because of the M package in frozen food compartment. Then impact of maximum of M package in frozen-food compartment on energy consumption for frozen-food compartment is -4.1%.

4.2.3 Upright refrigerator-freezer

Differences of testing conditions for upright refrigerator-freezer and testing results are concluded in table 4-13 and table 4-14.

Table 4-13 Difference of test conditions on upright refrigerator-freezer among the 4 standards

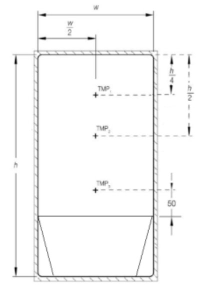
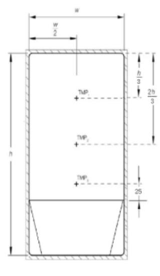
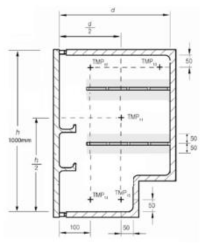
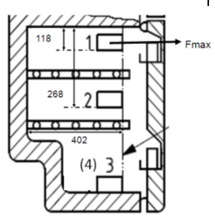
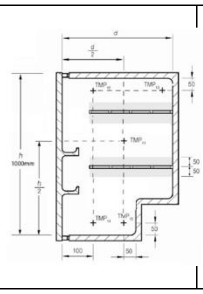
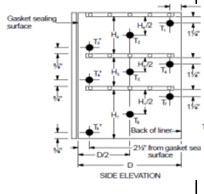
Test standards / Elements	IEC 62552:2015	IEC 62552:2007	Australia	USA
Room test ambient temperature	16.0℃ and 32.0℃	25.0℃	32.0℃	32.2℃
Target temperature of fresh-food comp.	Average: 4.0℃	Average: 5.0℃ Min.: 0℃, Max.: 10℃	Average: 3.0℃	Average: 3.9℃
Target temperature of frozen-food comp.	Average: -18.0℃	Max.: -18.0℃	Average: -15.0℃	Average: -17.8℃
Frozen-food comp. storage temperature sensor	Cylinder1 with 25gind, and a maximum dimension of 18mm	M-packages	Cylinder with 25mm diameter and long	M-packages
Fresh-food comp. storage temperature sensor	Cylinder1 with 25gind, and a maximum dimension of 18mm	Cylinder2 with 15.2mm diameter and 15.2mm height	Cylinder3 with 25mm diameter and 25mm height	Cylinder4 with 29mm diameter and 29mm height
Storage plan of fresh-food comp. storage temperature sensor				
Storage plan of frozen-food comp. storage temperature sensor				

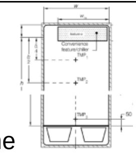
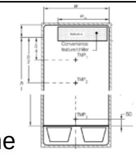
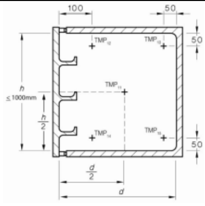
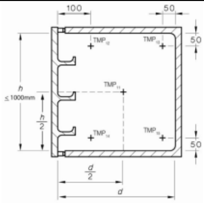
Table 4-14 Test conditions and testing results on upright refrigerator-freezer among the 4 standards

Item	Unit	IEC 62552：2015				IEC 62552：2007		Australia		USA	
Ambient temperature	℃	16		32		25		32		32.2	
Temperature control settings:	℃	5	4.1	4.9	4.6	4.3	4.8	4.5	4.9	3	5
Temperature in fresh food storage compartment	℃	3.6	4.1	3.7	4.9	3.9	2.1	4.6	2.4	8.9	1.3
Temperature in “four-star” frozen food storage compartment	℃	-20.9	-19.3	-21.6	-20.4	-17.1	-18.7	-20	-22.2	-14.6	-25.7
Steady state power	W	30.8	28.3	30.8	28.3	-	-	-	-	-	-
Energy consumption per 24h	kWh/24h	0.475	0.432	0.739	0.679	0.5	0.587	0.689	0.803	0.497	0.88
Energy consumption by interpolation	kWh/24h	0.441		0.724		0.550		0.772		0.743	
△Eprocessing (Wh/day)	kWh/24h	50.700		111.100		-	-	-	-	-	-
Standard energy consumption	kWh/24h	0.574				0.550		0.772		0.743	
Total Energy consumption	kWh/24h	0.654				0.550		0.772		0.743	

Key effecting factors on energy consumption for upright refrigerator-freezer have been analyzed in specifically as below. These elements are room test ambient temperature, target temperature of fresh-food comp., target temperature of frozen-food comp., storage plan of fresh-food comp. storage temperature sensor, storage plan of frozen-food comp. storage temperature sensor, frozen-food comp. storage temperature sensor, calculated annual energy consumption and calculated daily energy consumption, and products adaptability under twice tests of different ambient temperatures. In this part, only ambient temperature and products adaptability under twice tests of different ambient temperatures have been prioritized analyzed here because other factors have been analyzed in the products of upright refrigerator and chest freezer.

a. Ambient temperature

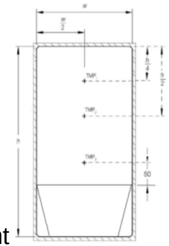
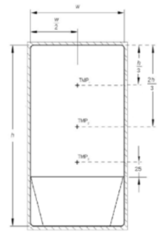
Table 4-15 ambient temperature effect on energy consumption

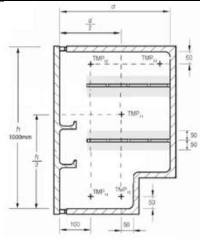
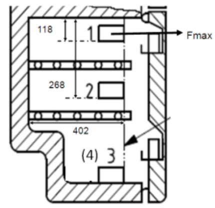
Elements / Standards	IEC 62552:2015	IEC 62552:2015
Room test ambient temperature	Different (16.0℃)	Different(32.0℃)
Target temperature of fresh-food comp.	Same(4.0℃)	Same(4.0℃)
Target temperature of frozen-food comp.	Same(-18.0℃)	Same(-18.0℃)
Storage plan of fresh-food comp. storage temperature sensor	Same 	Same 
Storage plan of frozen-food comp. storage temperature sensor	Same 	Same 
Frozen-food comp. storage temperature sensor	Same(Cylinder)	Same(Cylinder)
Tested daily energy consumptions, kWh/24h	0.441	0.724
Deviation:	(0.724-0.441)/0.724*100%=39.1%	

By analyzing the testing results of energy consumption at the two ambient temperatures in IEC 62552:2015, it can be reflected from table 4-15 that the energy consumption at 32℃ambient temperature is 39.1% higher than that at 16℃ ambient temperature for upright refrigerator. This also means when the ambient temperature increases 1 K, the energy consumption will increase 2.4% for upright refrigerator-freezer.

b. Products adaptability under twice tests of different ambient temperatures

Table 4-16 Impacts of products adaptability under twice tests of different ambient temperature effect on energy consumption for upright refrigerator-freezer

Elements / standards	IEC 62552:2015	IEC 62552:2007
Room test ambient temperature	Similar (16℃ and 32℃)	Similar (25℃)
Target temperature of fresh-food comp.	Different (4.0℃) Interpolation comp.	Different (5.0℃)
Target temperature of frozen comp.	Same (-18.0℃)	Same (-18.0℃) Interpolation comp.
Storage plan of fresh-food comp. storage temperature sensor	Different 	Different 

Elements standards	IEC 62552:2015	IEC 62552:2007
Storage plan of frozen-food comp. storage temperature sensor	 Different	
Determination of target temperature of fresh-food comp.	Same (averge of temperature sensors)	Same (averge of temperature sensors)
Determination of target temperature of frozen-food comp.	Different (Average of temperature sensors)	Different (The maximum of temperature sensors)
Standard energy consumption, kWh/24h	0.574	0.550
Total deviation (determination of target temperature of frozen-food comp.,empty in the frozen-food comp., two tests at different ambient temperatures)	(0.574-0.550)/0.574*100%=4.2%	
Deviation of target temperature of frozen-food comp determination	-4.1%	
Deviation of empty load in the frozen-food comp.	-4.9%	
Deviation of products adaptability under twice tests of different ambient temperatures	(4.2-(-4.1)-(-4.9))=13.2%	

Two points interpolation of energy consumption is realized for upright refrigerator-freezer by fresh-food comp. according to IEC 62552:2015 and frozen-food comp. according to IEC 62552:2007. In this way, three factors affecting the energy consumption testing results within the two standards, that are target temperature of frozen-food comp. empty load in the frozen-food comp, and product adaptability under twice tests at different ambient temperatures. The deviation of target temperature of frozen-food comp. determination is -4.1% according to the analysis for chest freezer and the deviation of empty load in the frozen-food comp is -4.9% according to the analysis for refrigerator-freezer, so the deviation of product adaptability under twice tests of different ambient temperatures is 13.2%, because this sample is single control refrigerator-freezer appliance.

4.2.4 Upright frost-free refrigerator-freezer

Differences of testing conditions of upright frost-free refrigerator-freezer in the IEC 62252:2015, IEC 62552:2007, Australia test standards and USA test standards have been summarized in the table 4-17. Actual testing conditions and testing results data have been shown in the table 4-18.

Table 4-17 Differences of test conditions on upright frost-free refrigerator-freezer among 4 standards

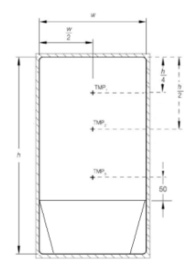
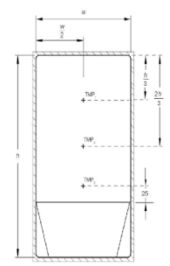
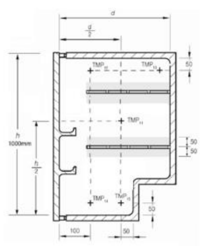
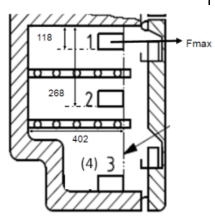
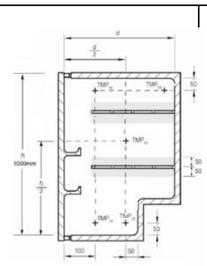
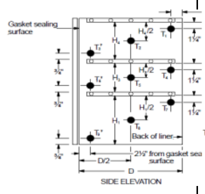
Test standards / Elements	IEC 62552:2015	IEC 62552:2007	Australia	USA
Room test ambient temperature	16.0℃and 32.0℃	25.0℃	32.0℃	32.2℃
Target temperature of fresh-food comp.	Average: 4.0℃	Average: 5.0℃ Min.: 0℃, Max.: 10℃	Average: 3.0℃	Average: 3.9℃
Target temperature of frozen-food comp.	Average: -18.0℃	Max.: -18.0℃	Average: -15.0℃	Average: -17.8℃
Frozen-food comp. storage temperature sensor	Cylinder1 with 25g±5%，and a maximum dimension of 18mm	M-packages	Cylinder with 25mm diameter and height	Cylinder with 25.4mm diameter and height
Fresh-food comp. storage temperature sensor	Cylinder1 with 25g±5%，and a maximum dimension of 18mm	Cylinder2 with 15.2mm diameter and 15.2mm height	Cylinder3 with 25mm diameter and 25mm height	Cylinder4 with 29mm diameter and 29mm height
Storage plan of fresh-food comp. storage temperature sensor				
Storage plan of frozen-food comp. storage temperature sensor				

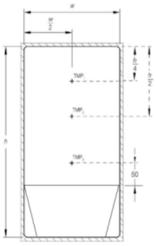
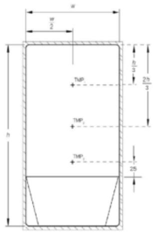
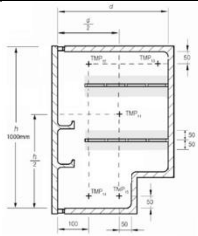
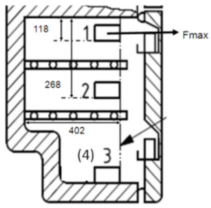
Table 4-18 Test conditions and testing results for frost-free refrigerator-freezer using the 4 standards

Item	Unit	IEC 62552：2015				IEC 62552：2007		Australia		USA	
Ambient temperature	℃	16		32		25		32		32.2	
Temperature control settings:		R:4 F:-18	R:5 F:-16	R:4 F:-17	R:5 F:-16	R:5 F:-18	R:4 F:-20	R:3 F:-16	R:5 F:-16	R: 5 F:-20	R: 2 F:-24
Temperature in fresh food storage compartment	℃	2.9	5.6	3.6	4.7	5.2	4.1	4.7	1.9	4.3	0.2
Temperature in “four-star” frozen food storage compartment	℃	-19.3	-17.2	-19.1	-18	-16.2	-18.1	-17.9	-18.4	-22.3	-25.1
Steady state power	W	22.5	19.7	41.3	39.7	-	-	-	-	-	-
Energy consumption per 24h	kWh/24h	0.582	0.515	1.079	1.041	0.701	0.764	1.009	1.071	1.101	1.431
Energy consumption by interpolation	kWh/24h	0.555		1.065		0.737		1.047		1.133	
△Eprocessing (Wh/day)	Wh/24h	62.100		126.600		-	-	-	-	-	-
Standard energy consumption	kWh/24h	0.797				0.737		1.047		1.133	
Total Energy consumption	kWh/24h	0.889				0.737		1.047		1.133	

Product adaptability under testing condition of two different ambient temperatures

Table 4-19 Impacts of product adaptability under testing condition of two different ambient temperatures on energy consumption

Elements / Standards	IEC 62552:2015	IEC 62552:2007
Room test ambient temperature	Similar (16℃ and 32℃)	Similar (25℃)
Target temperature of fresh-food comp.	Different (4.0℃) Interpolation comp.	Different (5.0℃) Interpolation comp.
Target temperature of frozen comp.	Same (-18.0℃) Interpolation comp.	Same (-18.0℃) Interpolation comp.

Elements \ Standards	IEC 62552:2015	IEC 62552:2007
Storage plan of fresh-food comp. storage temperature sensor	 Different	 Different
Storage plan of frozen-food comp. storage temperature sensor	 Different	
Determination of target temperature of fresh-food comp.	Same (averge of temperature sensors)	Same (averge of temperature sensors)
Determination of target temperature of frozen-food comp.	Different (Average of temperature sensors)	Different (The maximum of temperature sensors)
Standard energy consumption, kWh/24h	0.797	0.737
Total deviation (determination of target temperature of frozen-food comp., empty in the frozen-food comp., two tests at different ambient temperatures)	(0.797-0.737)/0.797*100%=7.5%	
Deviation of target temperature of fresh-food comp.	9%	
Deviation of Storage plan of fresh-food comp.	2.3%	
Deviation of target temperature of frozen-food comp determination	-4.1%	
Deviation of empty load in the frozen-food comp.	-4.9%	
Deviation of two tests at different ambient temperatures	Almost same(7.5-9-2.3-(-4.1)-(-4.9))=5.2%	

Two pints interpolation has been used to calculate the energy consumption for frost free refrigerator freezer at fresh-food comp. and frozen-food comp. for the two standards, since two thermostats are installed in the two compartments to control the temperatures. There are five factors affecting the energy consumption testing results for IEC 62552 (2007) and IEC 62552 (2015): target temperature of fresh-food comp., storage plan of fresh-food comp., target temperature of frozen-food comp., empty load in the frozen-food comp, products adaptability of twice tests at different ambient temperatures.

The deviation of target temperature at fresh-food comp. is 9% and the deviation of storage plan of fresh-food comp. is 2.3% according to analysis for upright refrigerator, and the deviation of target temperature of frozen-food comp. determination is -4.1% according to the analysis for chest freezer and the deviation of empty load in the frozen-food comp is -4.9 according to the analysis for refrigerator-freezer, so the deviation of products adaptability for twice tests at different ambient temperatures is 5.2% for frost-free refrigerator-freezer.

4.2.5 Summary of the main impact factors on energy consumption

On the basis of differences of testing conditions demonstration among the 4 selected standards for the 4 selected samples, that has been summarized in tables 4-1, 4-7, 4-13, 4-17, and analysis of testing results data as illustrated in table 4-2, 4-8, 4-14, 4-18 respectively for the 4 samples, key impacting factors - ambient temperature, target temperature, storage plan and temperature sensor and product adaptability for one sample, have been identified in table 4-3/4/5/6 for upright refrigerator, table 4-9/10/11/12 for chest freezer, table 4-15/16 for refrigerator-freezer and table 4-19 for frost free refrigerator-freezer. Overall summary for all above impacting factors and their contribution quantities have been concluded in table 4-20.

Then it can be concluded that key impacting factors of ambient temperature, target temperature in fresh food compartment and in frozen food compartment, storage plan of temperature sensor in fresh-food compartment and frozen-food compartment, determination of frozen-food compartment temperature and product adaptability for twice tests under two different temperatures, have been identified, and each of their contribution value to energy consumption has been calculated and analyzed. For example, when ambient temperature of refrigerator increases 1K, the energy consumption will be increased by 4.5%.

Table 4-20 Quantities conclusion of main impacting factors on energy consumption

Impact factor	Compartment or appliance	Result	Compared standards
Ambient temperature	refrigerator	+4.5% by 1K increase	IEC 62552:2015 (16℃-32℃)
	freezer	+3.0% by 1K increase	
	refrigerator-freezer	+2.4% by 1K increase	
Target temperature	fresh-food comp.	+9% by 1K decrease	IEC 62552:2015 (interpolation)
	frozen-food comp.	-6.5% by 1K increase	IEC 62552:2015-Australia
Storage temperature sensor and storage plan	fresh-food comp.	+2.3%	IEC 62552:2015(at 32℃) -USA
Storage temperature sensor (cylinder instead of M package) and empty load	frozen-food comp.	-3.9%	IEC 62552:2015(at 32℃) -USA
Determination of frozen-food compartment temperature (average temperature instead of maximum M package)	frozen-food comp.	-4.1%	IEC 62552:2015-IEC 62552:2007
Twice tests adaptability for one sample at different ambient temperatures	refrigerator	+1.7%	IEC 62552:2015-IEC 62552:2007
	refrigerator-freezer(single temperature control)	+13.2%	IEC 62552:2015-IEC 62552:2007
	frost-free refrigerator-freezer	+5.2%	IEC 62552:2015-IEC 62552:2007

5. China's Experience on Adopting the IEC 62552:2015

The first time for releasing the refrigerator EE standard in China was traced back to 1989, and the standard no. was GB 12021.2 – 89 (minimum energy consumption and test methods for household electrical refrigerator). In 1999, the standard of GB 12021.2-89 has been revised to promote energy efficiency improvement on refrigerators production. And in 2007, this standard has been revised twice. Up to 2012, combining with stimulation policy issued in country level that to issue subsidies for purchasing energy saving household appliances, the EE grade 1 products had been increased to 90%, and products in grade 2 or in between grade 1 and 2 had been covered 100% in China market.

This makes refrigerators in the market difficult to be differentiated from EE perspective, and sent barriers on new EE technology development. Furthermore, consumers are difficult in selecting EE products when they have such purchase intention. Since 2015, China has attached great importance in energy saving technology, products and services promotion, which has been reflected a series of soon-issued government orders, i.e. Comments on Strengthening Energy Saving Standardization from General Administration of State Council in 2015, in which, indexes of 80% and above EE index shall achieve to international level, and 20% of out-of-date products and technologies shall be suspended and withdrawn.

Demanding from multiple stakeholders of EE standard in refrigerators, in 2013, SAC (Administration of Standardization Commission of China) made a plan of revising the GB 12021.2 -2008 which set milestone of officially launching of the standard revision. From 2013 to 2015, preparation work for the standard revision has been made:

- On Jan 17, 2013, the 1st workshop on refrigerator standard revision discussion has been organized. Outcomes of deep analysis of the new IEC 62552, principle and core barriers of current national standard of EE in refrigerator have been realized. It was concluded that the new IEC 62552 would be the reference standard for China standard revision, and energy consumption test methods in the new IEC 62552 standard have been agreed to implement round robin test among well qualified labs in China Household Electrical Appliances Research Institute, China Vkan Certification Co., Ltd, End-user energy consumption lab of China National Institute of Standardization, Haier Group, Midea Group, BSH Electrical Appliances Co., Ltd., Sumsung and so on.
- On Mar 22, 2014, the 2nd workshop on refrigerator standard revision has been organized in Hangzhou. Outputs have been achieved: EE evaluation system and EE testing methods, EEI on the basis of laboratory testing results in the 1st workshop, and more expansion laboratory testing has been organized to collect bigger volume of testing data.
- In Feb, 2015, Version of Draft Standard for Examination has been validated by Standard Review Committee.
- In Sep, 2015, the newly revised "Mimum Energy Performance and EE Grade on household refrigerators" has been issued, and it is regulated that the new standard will come to effect on Oct 1st in 2016. And meanwhile, the new EE labelling will be implemented. The product scope of refrigerator, chest freezer, refrigerator freezer and wine cellars are covered in the new China standard.

Compared to the old 2008 version of GB 12021.1, according to the report of Market Development Status and Future Trend in Refrigerator of China (2014 to 2018), the new standard will realize 5% of refrigerators in EE new grade 1 among the market, and 10% ~ 20% products in EE new grade 2. This will encourage the new energy saving technology development in the market and accelerating out-of-dated technologies out of market. Furthermore, policies of EE such as top runner program, energy star in China, government procurement and so on will be more benefited to the market and society. However, because of the changes of standard, manufactures and testing labs shall prepare more to meet the requirement:

- Training of thorough understanding of each part, item of testing and algorithm in the new IEC62552 shall be organized. Especially for load testing, uncertainty will be arising following the regulated testing procedures. Hence, harmonized testing procedure shall be drawn out. Much better option is to refer to Australia experience that RRT being organized to improve labs' capacity.
- One big change in the new IEC 62552 is the temperature condition of 16℃ and 32℃, this has been more improved the standards adaptability in different geology region. But for the manufactures, they have so many samples to be tested, maybe in one test room some samples should be tested at 16℃ and the others should be tested at 32℃, the test period for one test room will be prolonged. So they have to build more test rooms or rebuild the test room which can be divided into two parts and can be controlled at 16℃ and 32℃ simultaneously and separately for the two parts.
- Future products design shall be improved to meet the new standard requirement, such as frequency conversion compressor application, heat-insulation property and foaming process for foam materials, single-temperature-controller being replaced to double-temperature-controller, structure and raw materials of door materials in refrigerator, intelligent controlling system application, and heat exchanger's improvement. Undoubtedly, those mentioned new technology and new materials application will cause higher cost for manufacture and return to product price. How to balance manufacturing cost, market price and policy leverage role shall be further researched.

6. Conclusion

In the laboratory testing report - Differences / synergies between energy efficiency test methods for refrigerators in APEC region and with the new IEC 62552, 4 test standards of IEC 62552:2015, IEC 62552:2007, AS/NZS 4474.1:2007+A1:2008+A2:2011, and USA Standard have been selected because they are widely applied in the APEC region. Samples of upright refrigerator, upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer are all purchased from the market, with constant values of energy consumption and volume and performance. China Vkan Certification Co., Ltd is the subcontractor of the project to carry out laboratory test, and China Standard Certification Co., Ltd has organized the technical working group to deep analyse the differences of EE test methods and identified key impacting factors on energy consumption in the standards.

For the same product, different energy consumption testing values have been found by the 4 testing standards. And for different product category, the quantity of differences of energy consumption tested value among the 4 testing standards has shown differently. For example, upright frost-free refrigerator-freezer has the most significant differences on energy consumption testing results among the four standards. And chest freezer's results are the least significant different. This again reflects the category of appliances is one influencing factors in energy consumption differences analysis.

The deviations of energy consumption with load processing testing value in standards of IEC 62552:2007, AU and US standard from IEC 62552:2015 are different from the four appliances.

- For upright refrigerator, the test results according to AU standard has the most deviation from IEC 62552:2015;
- For upright refrigerator-freezer, the test results according to IEC 62552:2007 has the most deviation from IEC 62552:2015;
- For chest freezer, the test results according to USA standard has the most deviation from IEC 62552:2015 while the deviations are close to each other in the IEC 62552:2007, AU standard and US standard compared to IEC 62552:2015;
- For upright frost-free refrigerator-freezer, the test result according to USA standards has the most deviation from IEC 62552:2015.

Load processing efficiency test is an additional test required in IEC 62552:2015 compared to the IEC 62552:2007, which is used as the basis for manufactures claim. Energy consumption without load processing is slightly lower than that with load processing. Increasing ratio of energy consumption load processing efficiency test has significant influence on the test results for upright refrigerator-freezer, chest freezer and upright frost-free refrigerator-freezer, especially for chest freezer, which is 14.1% of increasing ratio. For the same sample, different energy consumption values have been tested with the 4 different testing standards.

Differences of volume testing results are not that significant among the 4 samples with the applied 4 standards.

EE evaluation methods of EE grades and MEPS are also compared with the basis of testing results of energy consumption and volume for the 4 samples. In US, highest MEPS value has been achieved for the same sample compared to the other 3 standards. And for EE Grade, the 4 samples behave as the poor energy efficiency product both in China with the new IEC 62552:2015 and in Australia, although the test methods are differently regulated. And except chest freezer, the other 3 samples show different energy efficiency level in the IEC 62552:2015 and IEC 62552:2008.

Moreover, key impacting factors - ambient temperature, target temperature, storage plan and temperature sensor and product adaptability for one sample, have been identified for the 4 samples seperately. And the philosophy is to choose two standards with similar certain testing conditions but one or two main different testing conditions, and then to understand the different testing condition's impacts on energy consumption. Sample's characteristics impacts on energy consumption have been analyzed by deviation or two point interpolation methods. Overall summary for all above impacting factors and their contribution quantities have been concluded in table 4-20.

It can be concluded that key impacting factors of ambient temperature, target temperature in fresh food compartment and in frozen food compartment, storage plan of temperature sensor in fresh-food compartment and frozen-food compartment, determination of frozen-food compartment temperature and product adaptability for twice tests under two different temperatures, have been identified, and each of their contribution value to energy consumption has been calculated and analyzed.

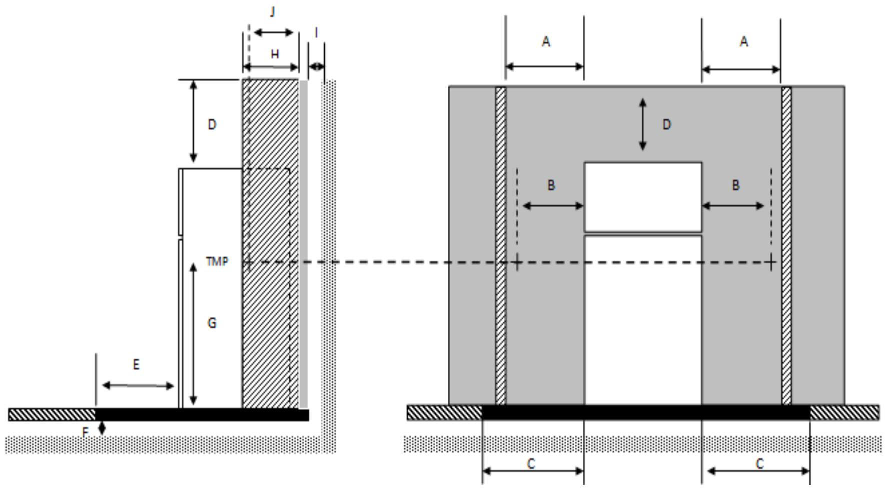
When ambient temperature of refrigerator increases 1K, the energy consumption will be increased by 4.5%., 3.0%, and 2.4% respectively for refrigerator, chest freezer andrefrigerator-freezer. For fresh food compartment, if the target temperature increases 1K, energy consumption will increase 9%, and for frozen food compartment, the energy consumption will decrease 6.5%. Storage plan of temperature sensor in fresh food compartment has 2.3% impacts on energy consumption, while for frozen food compartment, its impacts is (-3.9%). Again in frozen food compartment, impact of determination of storage temperature on energy consumption is (-4.2%). Impacts of product adaptability to the twice different ambient temperature conditions on energy consumption are 1.7%, 13.2% and 5.2% respectively for refrigerator, refrigerator-freezer, and frost refrigerator freezer respectively.

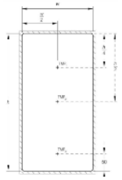
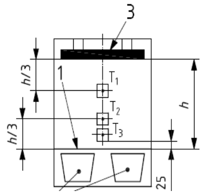
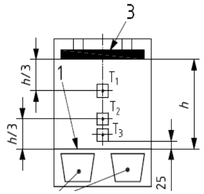
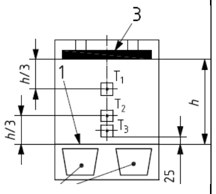
Other differences of test conditions required in IEC 62552:2015, such as requirements for test room, the distance of rear of appliance, position of cylinder for ambient temperature, etc. which have little effect on the energy consumption results have not been analysed. And other requirements for calculation of energy consumption in IEC 62552:2015 help to improve the accuracy is not considered in the results analysis.

China's experience of adopting the new standard on refrigerators as well as corresponding adaptations of policy, such as EE labelling, and manufactures have been shared as a case for economies in APEC to referred when they intend to modify their EE standards according to the new IEC 62552. If possible, widely scope of Round Robin Test organizing among APEC is helpful to build capacity of laboratory in understanding the IEC 62552:2015 in the region.

Annex I-1 Test Procedures of Upright Refrigerator

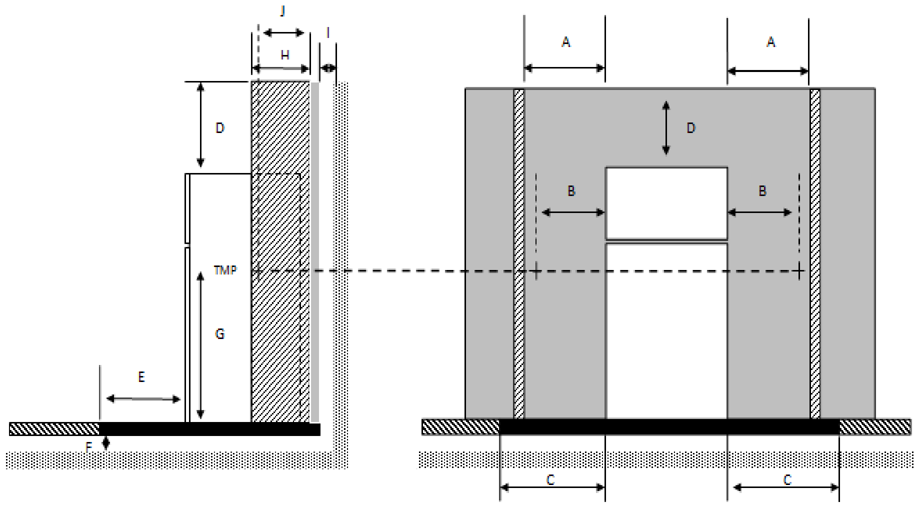
Test condition and factors	*IEC 62552:2015*		*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Test voltage/frequency:	220V/50Hz		220V/50Hz	220V/50Hz	220V/50Hz
Room test ambient temperature uncertainty	16.0℃	32.0℃	25.0℃	32.0℃	32.2℃
Room test ambient humidity uncertainty	60%				
Room air circulation	0.20m/s				
Room vertical ambient temperature gradient	1K/m				
Room temperature control device uncertainty	±0.3℃				
Room humidity control device uncertainty	±0.3℃				
Storage temperature uncertainty	±0.3℃				
Watt-hour meters	Readable:0.001W				
Time interval accurate	60s				

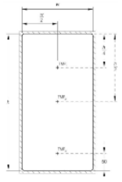
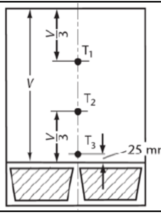
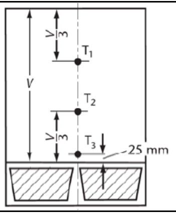
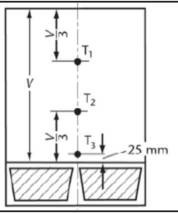
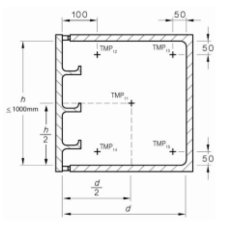
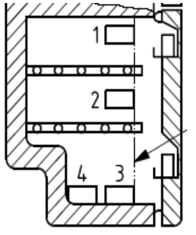
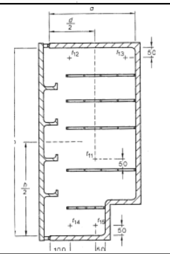
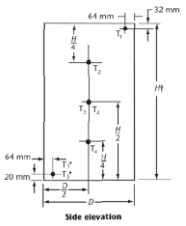
Test condition and factors	*IEC 62552:2015*	*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Installation of refrigerators	 Unit: m			
	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.05 G:0.85 H:0.3 I:0.03 J:0.3	A:0.3 B:0.35 C:0.5 D:0.3 E:0.3 F:0.05 G:/ H:0.3 I:0.03 J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.7 H:0.3 I:/ J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.62 H:0.3 I:Min. J:center
anti-condensation heaters setting	Not applicable			
All shelves setting	Vegetable box in position			
Accessories setting	All accessories in position			
Measurement of storage temperature (fresh-food)	Cylinder with 18mm diameter and 18mm long	Cylinder with 15.2mm diameter and 15.2mm long	Cylinder with 25mm diameter and 25mm long	Cylinder with 29mm diameter and 29mm long

Test condition and factors		*IEC 62552:2015*				*IEC 62552:2007*		*AS/NZS 4474.1:2007+ A1:2008+A2:2011*		*USA test standard*	
Target temperature (fresh-food)		Average: 4.0℃				Average: 5.0℃ Min.: 0℃ Max.: 10℃		Average: 3.0℃		Average: 3.9℃	
Storage plan of storage temperature (fresh-food)											
Load energy consumption test		Applicable				Not applicable		Not applicable		Not applicable	
Test result											
Storage temperature measure (fresh-food)	t_{1m}(℃)										
	t_{2m}(℃)										
	t_{3m}(℃)										
	t_{ma}(℃)										
Determination method of the energy											
Test period(minute)											
Measured energy consumption(kWh)											
Energy consumption by interpolation (kWh/year)											

Annex I-2 Test Procedures of Upright Two-door Refrigerator-freezer

Test condition and factors	*IEC 62552:2015*		*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Test voltage/frequency:	220V/50Hz		220V/50Hz	220V/50Hz	220V/50Hz
Room test ambient temperature uncertainty	16.0℃	32.0℃	25.0℃	32.0℃	32.2℃
Room test ambient humidity uncertainty	60%				
Room air circulation	0.20m/s				
Room vertical ambient temperature gradient	1K/m				
Room temperature control device uncertainty	±0.3℃				
Room humidity control device uncertainty	±0.3℃				
Storage temperature uncertainty	±0.3℃				
Watt-hour meters	Readable:0.001W				
Time interval accurate	60s				

Test condition and factors	*IEC 62552:2015*	*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Installation of refrigerators	 Unit: m			
	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.05 G:0.85 H:0.3 I:0.03 J:0.3	A:0.3 B:0.35 C:0.5 D:0.3 E:0.3 F:0.05 G:/ H:0.3 I:0.03 J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.7 H:0.3 I:/ J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.62 H:0.3 I:Min. J:center
anti-condensation heaters setting	Not applicable			
All shelves setting	Vegetable box in position			
Accessories setting	All accessories in position			
Measurement of storage temperature (fresh-food)	Cylinder with 18mm diameter and 18mm long	Cylinder with 15.2mm	Cylinder with 25mm diameter	Cylinder with 29mm diameter

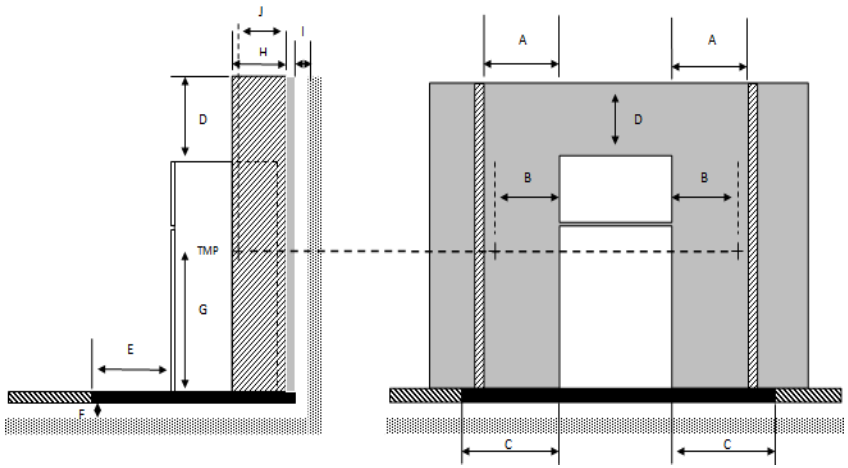
Test condition and factors	*IEC 62552:2015*	*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
		diameter and 15.2mm long	and 25mm long	and 29mm long
Measurement of storage temperature (frozen-food)	Cylinder with 18mm diameter and 18mm long	M-packages	Cylinder with 25mm diameter and 25mm long	M-packages
Target temperature (fresh-food)	Ave.: 4.0℃	Ave.: 5.0℃ Min.: 0℃ Max.: 10℃	Ave.: 3.0℃	Ave.: 3.9℃
Target temperature (frozen-food)	Ave.: -18.0℃	Max.: -18.0℃	Ave.: -15.0℃	Ave.: -17.8℃
Storage plan of storage temperature (fresh-food)				
Storage plan of storage temperature (frozen-food)				
Load energy consumption test	Applicable	Not applicable	Not applicable	Not applicable
Test result				

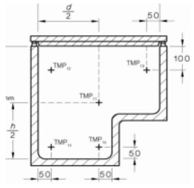
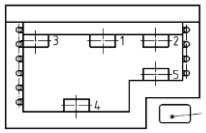
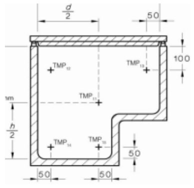
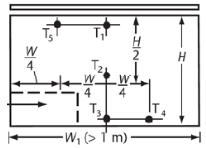
Storage temperature measure (fresh-food)	t_{1m}(℃)										
	t_{2m}(℃)										
	t_{3m}(℃)										
	t_{ma}(℃)										

Test condition and factors		*IEC 62552:2015*				*IEC 62552:2007*		*AS/NZS 4474.1:2007+ A1:2008+A2:2011*		*USA test standard*	
Storage temperature measure(frozen-food)	F_{1m}(°C)										
	F_{2m}(°C)										
	F_{3m}(°C)										
	F_{4m}(°C)										
	F_{5m}(°C)										
	F_{ma}(°C)										
Determination method of the energy											
Test period(minute)											
Measured energy consumption(kWh)											
Energy consumption by interpolation (kWh/year)											

Annex I-3 Test Procedures of Chest freezer

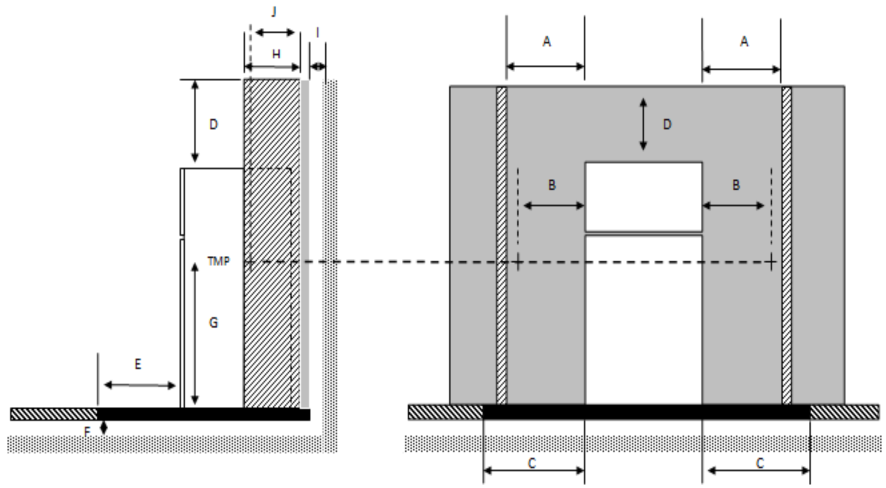
Test condition and factors	*IEC 62552:2015*		*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Test voltage/frequency:	220V/50Hz		220V/50Hz	220V/50Hz	220V/50Hz
Room test ambient temperature uncertainty	16.0℃	32.0℃	25.0℃	32.0℃	32.2℃
Room test ambient humidity uncertainty	60%				
Room air circulation	0.20m/s				
Room vertical ambient temperature gradient	1K/m				
Room temperature control device uncertainty	±0.3℃				
Room humidity control device uncertainty	±0.3℃				
Storage temperature uncertainty	±0.3℃				
Watt-hour meters	Readable:0.001W				
Time interval accurate	60s				

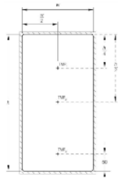
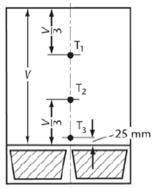
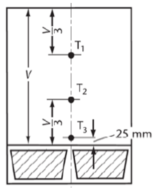
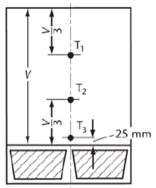
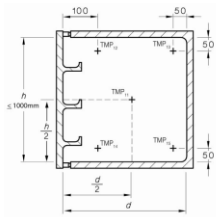
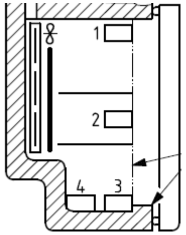
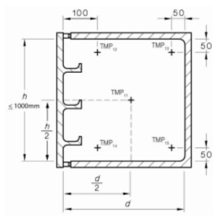
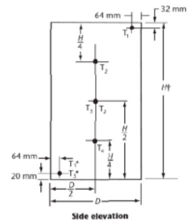
Test condition and factors	*IEC 62552:2015*	*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Installation of refrigerators	 Unit: m			
	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.05 G:0.85 H:0.3 I:0.03 J:0.3	A:0.3 B:0.35 C:0.5 D:0.3 E:0.3 F:0.05 G:/ H:0.3 I:0.03 J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.7 H:0.3 I:/ J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.62 H:0.3 I:Min. J:center
anti-condensation heaters setting	Not applicable			
All shelves setting	Not applicable			
Accessories setting	Not applicable			
Measurement of storage temperature (frozen-food)	Cylinder with 18mm diameter and 18mm long	M-packages	Cylinder with 25mm diameter and 25mm long	M-packages
Target temperature (frozen-food)	Ave.: -18.0℃	Max.: -18.0℃	Ave.: -15.0℃	Ave.: -17.8℃

Test condition and factors		*IEC 62552:2015*				*IEC 62552:2007*		*AS/NZS 4474.1:2007+ A1:2008+A2:2011*		*USA test standard*	
Storage plan of storage temperature (frozen-food)											
Load energy consumption test		Applicable				Not applicable		Not applicable		Not applicable	
Test result											
Storage temperature measure(frozen-food)	F_{1m}(°C)										
	F_{2m}(°C)										
	F_{3m}(°C)										
	F_{4m}(°C)										
	F_{5m}(°C)										
	F_{ma}(°C)										
Determination method of the energy											
Test period(minute)											
Measured energy consumption(kWh)											
Energy consumption by interpolation (kWh/year)											

Annex I-4 Test Procedures of Upright two-door frost-free refrigerator-freezer

Test condition and factors	*IEC 62552:2015*		*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Test voltage/frequency:	220V/50Hz		220V/50Hz	220V/50Hz	220V/50Hz
Room test ambient temperature uncertainty	16.0℃	32.0℃	25.0℃	32.0℃	32.2℃
Room test ambient humidity uncertainty	60%				
Room air circulation	0.20m/s				
Room vertical ambient temperature gradient	1K/m				
Room temperature control device uncertainty	±0.3℃				
Room humidity control device uncertainty	±0.3℃				
Storage temperature uncertainty	±0.3℃				
Watt-hour meters	Readable:0.001W				
Time interval accurate	60s				

Test condition and factors	*IEC 62552:2015*	*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Installation of refrigerators	 Unit: m			
	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.05 G:0.85 H:0.3 I:0.03 J:0.3	A:0.3 B:0.35 C:0.5 D:0.3 E:0.3 F:0.05 G:/ H:0.3 I:0.03 J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.7 H:0.3 I:/ J:/	A:0.3 B:0.25 C:0.5 D:0.3 E:0.3 F:0.3 G:0.62 H:0.3 I:Min. J:center
anti-condensation heaters setting	Not applicable			
All shelves setting	Vegetable box in position			
Accessories setting	All accessories in position			
Measurement of storage temperature (fresh-food)	Cylinder with 18mm diameter and 18mm long	Cylinder with 15.2mm diameter and 15.2mm long	Cylinder with 25mm diameter and 25mm long	Cylinder with 29mm diameter and 29mm long

Test condition and factors	*IEC 62552:2015*	*IEC 62552:2007*	*AS/NZS 4474.1:2007+ A1:2008+A2:2011*	*USA test standard*
Measurement of storage temperature (frozen-food)	Cylinder with 18mm diameter and 18mm long	M-packages	Cylinder with 25mm diameter and 25mm long	Cylinder with 29mm diameter and 29mm long
Target temperature (fresh-food)	Ave.: 4.0℃	Ave.: 5.0℃ Min.: 0℃ Max.: 10℃	Ave.: 3.0℃	Ave.: 3.9℃
Target temperature (frozen-food)	Ave.: -18.0℃	Max.: -18.0℃	Ave.: -15.0℃	Ave.: -17.8℃
Storage plan of storage temperature (fresh-food)				
Storage plan of storage temperature (frozen-food)				
Load energy consumption test	Applicable	Not applicable	Not applicable	Not applicable

Test result											
Storage temperature measure (fresh-food)	t_{1m}(℃)										
	t_{2m}(℃)										
	t_{3m}(℃)										
	t_{ma}(℃)										
Storage temperature measure(frozen-food)	F_{1m}(℃)										

Test condition and factors		*IEC 62552:2015*				*IEC 62552:2007*		*AS/NZS 4474.1:2007+ A1:2008+A2:2011*		*USA test standard*	
	F_{2m}(°C)										
	F_{3m}(°C)										
	F_{4m}(°C)										
	F_{5m}(°C)										
	F_{ma}(°C)										
Determination method of the energy											
Test period(minute)											
Measured energy consumption(kWh)											
Energy consumption by interpolation (kWh/year)											

APEC Project: [EWG 04 2014A - Technical Reference on Harmonization of Energy Efficiency Test Methods of Refrigerators Toward the New IEC 62552 among APEC Region]

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