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TECHNICAL REPORT

colour inside

Adjusted volume calculation for refrigerating appliances

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ADJUSTED VOLUME CALCULATION FOR REFRIGERATING APPLIANCES

FOREWORD

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IEC TR 63061, which is a Technical Report, has been prepared by subcommittee 59M: Performance of electrical household and similar cooling and freezing appliances, of IEC technical committee 59: Performance of household and similar electrical appliances.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
59M/71/DTR	59M/79/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

A recent international review of energy efficiency standards and energy labelling programs around the world found that refrigerators and freezers were covered by programs in some 75 countries, which included some 185 separate program measures. The report [1] found that household refrigerators and freezers were the most frequently covered products around the world in terms of programs to improve energy efficiency.

Despite being the most commonly covered products in energy efficiency programs, there are a range of different approaches used in different countries to define energy efficiency for refrigerators and freezers.

Besides specifying methods of energy measurement, IEC 62552-3 defines a clear and accurate method for the measurement and determination of compartment volume of household refrigerators and freezers. It is hoped that this international test method will be adopted by all countries in their local energy efficiency programs. However, a uniform approach to volume measurement is not always sufficient for energy efficiency policies, as this fails to take into account the impact of compartments that operate at different temperatures.

One of the most common approaches used to define the energy efficiency of refrigerators and freezers is the concept of adjusted volume. This approach was developed in the 1980s and essentially weights the volume of each compartment in proportion to the temperature difference between the compartment temperature and the ambient temperature outside of the appliance. This provides a method that takes into account, at least to some extent, the effect of variations in the relative size of different temperature compartments between different models. While there is a range of other possible approaches that can be used, adjusted volume is one method that is widely used around the world.

While the concept of adjusted volume is widely used and well accepted, it appears that there are some variations and differences in how this parameter is calculated and applied in different countries. This creates anomalies in how energy efficiency parameters are calculated between countries. While the exact approach used to define adjusted volume is ultimately a matter for individual countries, it is hoped that this document will provide a clear explanation of the approach and will provide a sound basis for how this can be applied in different conditions, as dictated by local policies. The purpose of this document is therefore to encourage alignment in national approaches to the definition and application of adjusted volume.

IEC 62552-3 defines two ambient temperatures for energy consumption measurement. Many countries, especially those with more temperate climates, will want to use this additional data to more accurately reflect the likely energy consumption of refrigeration appliances during normal use. This document assumes that the adjusted volume is calculated using the ambient air temperature expected during normal use of the refrigerating appliance. It is hoped that this will further encourage alignment of approaches across countries.

Ultimately, it is hoped that this document will foster dialogue and cooperation between countries and encourage the use of more uniform approaches to the calculation and application of adjusted volume, where this is used in energy efficiency policies and programs. This will further encourage trade, development of more uniform efficiency benchmarks and overall improvements in energy efficiency globally.

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1 Energy Standards and Labelling Programs Throughout The World In 2013, see http://www.iea-4e.org/publications or http://www.iea-4e.org/document/343/energy-standards-labelling-programs-throughout-the-world-in-2013

ADJUSTED VOLUME CALCULATION FOR REFRIGERATING APPLIANCES

1 Scope

This document, which is a technical report, sets out a uniform calculation method for the parameter of adjusted volume that is commonly employed in the calculation of energy efficiency household refrigerators, freezers and refrigerator-freezers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62552-3:2015, *Household refrigerating appliances – Characteristics and test methods – Part 3: Energy consumption and volume*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
compartment
enclosed space within a refrigerating appliance, which is directly accessible through one or more external doors, which may itself be divided into sub-compartments

3.2
sub-compartment
permanent enclosed space within a compartment which has a different operating temperature range from the compartment within which it is located

Note 1 to entry: Throughout this document, unless specified otherwise, the term ‘compartment‘ is taken to mean compartment and/or sub-compartment as appropriate for the context.

3.3
compartment type
refrigerating appliance compartment type as defined in accordance with IEC 62552-1

3.4
target temperature
reference compartment temperature for each specific compartment type which is used for determining energy and average power consumption attributes in IEC 62552-3

3.5
volume adjustment factor
K_c
coefficient applied to the rated volume of each compartment to take into account the differences in thermal load based on the target temperature for the specific compartment type

3.6
adjusted volume
V_{adj}
rated volume of each compartment as determined in accordance with IEC 62552-3 multiplied by the volume adjustment factor (K_c)

Note 1 to entry: The adjusted volume is expressed in adjusted litres.

3.7
average ambient temperature
T_{ka}
specified temperature within a labelling region used to represent the average temperature where the appliance operates

4 Determination of adjusted volume

4.1 General

Adjusted volume is a calculation that aims to provide an indication of the relative thermal load on each compartment at a given ambient temperature. The reference relative thermal load is always set at a volume adjustment factor (K_c) of 1.0 for a fresh food compartment type, which has a nominal operating temperature of 4 °C. Other compartment types will have a larger volume adjustment factor (> 1.0) when their typical operating temperature is colder than a fresh food compartment. Other compartment types will have a smaller volume adjustment factor (< 1.0) when their typical operating temperature is warmer than a fresh food compartment. For this document, the compartment temperature used to calculate the volume adjustment factor (K_c) for every compartment type is the target temperature as specified in IEC 62552-3 for energy consumption determination. While it is possible for most compartments to operate at slightly warmer or colder temperatures than the target temperature, the overall objective of IEC 62552-3 is to estimate the energy consumption at the target temperature for the relevant compartment type. The target temperature also represents an internationally agreed reference temperature for each compartment type. So use of the target temperature provides a standardized and consistent approach for the calculation of the volume adjustment factor.

IEC 62552-3 specifies two ambient temperatures for energy consumption determination. This provides options to more accurately estimate the energy consumption of the refrigerating appliance during use, especially in temperate climates. Possible approaches to more accurately estimate the energy consumption for different ambient temperatures are discussed in Annex A.

4.2 Determination of volume adjustment factor for each compartment type

The volume adjustment factor for each compartment type is specified in Table 1.

Table 1 – Volume adjustment factor by compartment type

Compartment type	Target temperature °C	Volume adjustment factor (K_c)
Pantry	17	(T_{ka} -17)/(T_{ka} -4)
Wine storage	12	(T_{ka} -12)/(T_{ka} -4)
Cellar	12	(T_{ka} -12)/(T_{ka} -4)
Fresh food	4	1,0
Chill	2	(T_{ka} -2)/(T_{ka} -4)
Zero-star	0	(T_{ka} -0)/(T_{ka} -4)
One-star	-6	(T_{ka} -(-6))/(T_{ka} -4)
Two-star	-12	(T_{ka} -(-12))/(T_{ka} -4)
Three-star and Four-star	-18	(T_{ka} (-18))/(T_{ka} -4)
Key T_{ka}: **Average ambient temperature** assumed during normal use		

For any compartment type, the volume adjustment factor can be calculated as follows:

$$K_{ci} = \frac{[T_{ka} - T_{ti}]}{[T_{ka} - T_{tff}]} \quad (1)$$

where

K_{ci} is the volume adjustment factor for compartment i;

T_{ti} is the target temperature of compartment i (°C);

T_{tff} is the target temperature of a fresh food compartment (4 °C).

Rules regarding the selection of target temperatures for compartments, in particular for compartments with operating ranges which span none of the target temperatures listed or for variable temperature compartments, as set out in IEC 62552-3, should be followed (refer to IEC 62552-3:2015, Table 1).

4.3 Adjusted volume calculation

The adjusted volume of a refrigerating appliance is calculated by summing the adjusted volumes for all compartments in accordance with the following equation.

$$V_{adj} = \sum_{i=1}^{n} K_{ci} \times V_i \quad (2)$$

where:

V_{adj} is the total adjusted volume of the refrigerating appliance (adjusted litres);

n is the number of compartments in the refrigerating appliance;

V_i is the volume of compartment i (litres);

NOTE See Annex B for guidance where several target temperatures can apply within a compartment.

K_{ci} is the volume adjustment factor for compartment i as determined in accordance with 4.2.

Annex A
(informative)

Average ambient temperature used to calculate the volume adjustment factor

Due to the differences in ambient temperature by region, the average ambient temperature used to calculate the energy efficiency and energy consumption of a refrigerating appliance using adjusted volume should be selected so that it is relevant to local normal use conditions in that region.

The average ambient temperature (T_{ka}) selected for the calculation of adjusted volume should be the same average ambient temperature that is assumed for energy consumption determination. The average ambient temperature is not defined in IEC 62552-3 and may vary by region. It should be based on the average temperature of rooms in which refrigerating appliances operate within each region.

IEC 62552-3 determines the energy consumption at only two ambient temperatures of 16 °C and 32 °C. To estimate the energy consumption at an ambient temperature between 16 °C and 32 °C, the measured energy consumption can be weighted appropriately in order to provide an estimate of the energy consumption at the locally relevant ambient temperature. As the energy consumption of a refrigerating appliance is not linear with changes in ambient temperature, the weighting should take this non-linear characteristic into account.

Figure A.1 shows the power consumed by a typical refrigerating appliance as a function of ambient temperature. The actual energy consumption expected at all temperatures between 16 °C and 32 °C would typically be a curve below the straight line connecting the energy at those two temperatures as shown in Figure A.1.

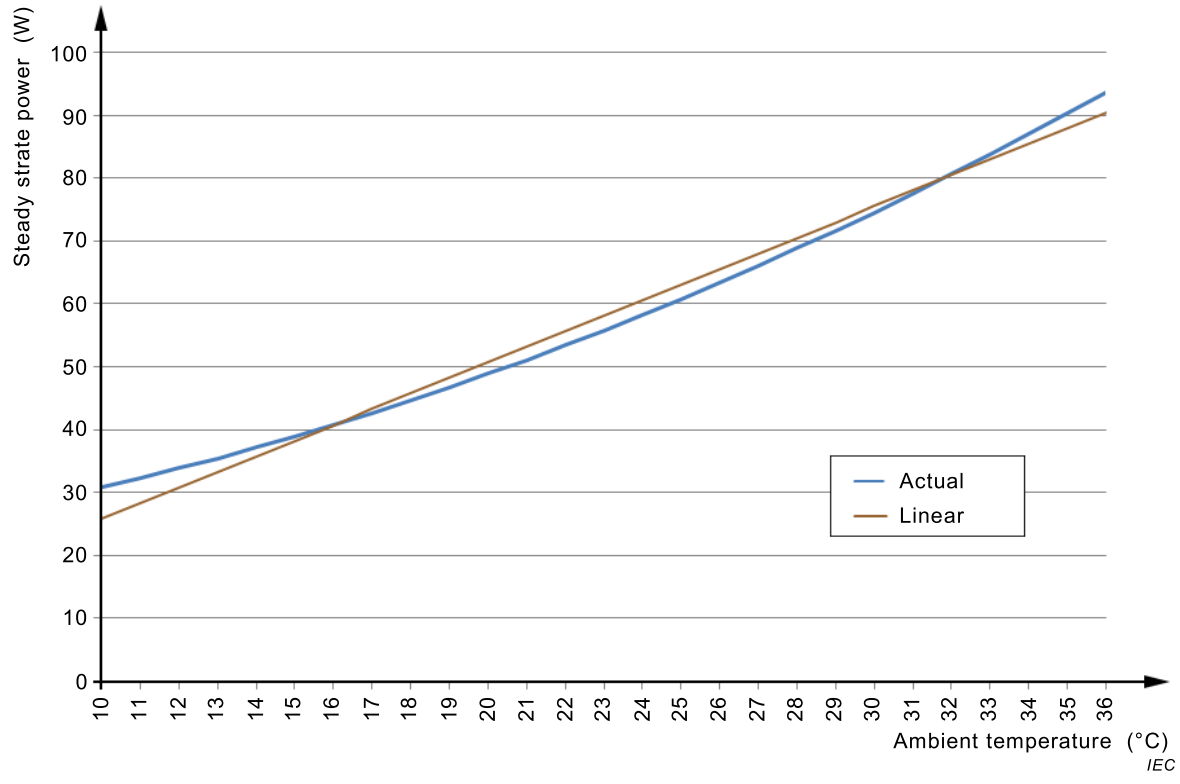

Figure A.1 – Power consumed by a typical refrigerating appliance as a function of ambient temperature

Thus, when estimating an energy value for an intermediate temperature, more emphasis needs to be put on the energy consumption measurement at 16 °C and less on the measurement at 32 °C than a simple linear interpolation between the two temperatures would imply. For example, if a refrigerating appliance is operating in an average ambient temperature of 24 °C, its consumption would be more accurately estimated by 0,56 of the energy consumption at 16 °C and 0,44 of the energy consumption at 32 °C, rather than weighting them both by 0,5.

Figure A.1 suggests that the actual energy consumption of a typical refrigerating appliance gets closer to the linear function as the ambient temperature gets closer to either 16 °C or 32 °C.

Table A.1 provides suggested weighting of energy values measured in accordance with IEC 62552-3 in order to estimate the annual energy consumption at different ambient temperatures between 16 °C and 32 °C.

Table A.1 – Suggested weighting of IEC energy values for different ambient temperatures

Actual average ambient temperature °C	Weighting of 16°C energy value	Weighting of 32°C energy value
16	360	5
17	343	22
18	326	39
19	308	57
20	289	76
21	269	96
22	248	117
23	227	138
24	204	161
25	181	184
26	157	208
27	132	233
28	106	259
29	80	285
30	52	313
31	24	341
32	-5	370

Weighting in columns 2 and 3 should add to a total of 365 days in a year. These weightings should be valid for most types of refrigerating appliances.

A more sophisticated approach could weigh the energy consumption for each month in accordance with Table A.1 based on the expected average monthly temperature around the refrigerating appliance. Such an approach may need to take account of the number of days in each month.

Extrapolation of weighting of energy values measured at 16 °C to 32 °C to estimate energy consumption for annual average ambient temperatures that lie outside of the range 16 °C to 32 °C is not recommended.

The calculations assume an ambient temperature normally distributed around the average ambient temperature of interest. Ambient temperatures above the average contribute more to the energy consumption than those below, this results in the fact that more days at 32 °C should be included (e.g. at 16 °C ambient temperature one should not take 365 days of 16 °C energy value, but 360).

Annex B
(informative)

Calculation of volume of sections or sub-compartments

B.1 Calculation volume

Calculation of compartment volume is based on the method specified in IEC 62552-3:2015 Annex H.

B.2 Calculation of the volume of the section or sub-compartment in the compartment whose target temperatures are different from each other

Figures B.1 to B.5 show typical examples of volume calculation for a two-star section or compartment inside the freezer compartment (three-star or four-star) and should be considered as generic examples. The examples shown in Figures B.1 to B.5 may be combined to adapt the calculation to be representative of the section or compartment in the refrigerating appliance under consideration.

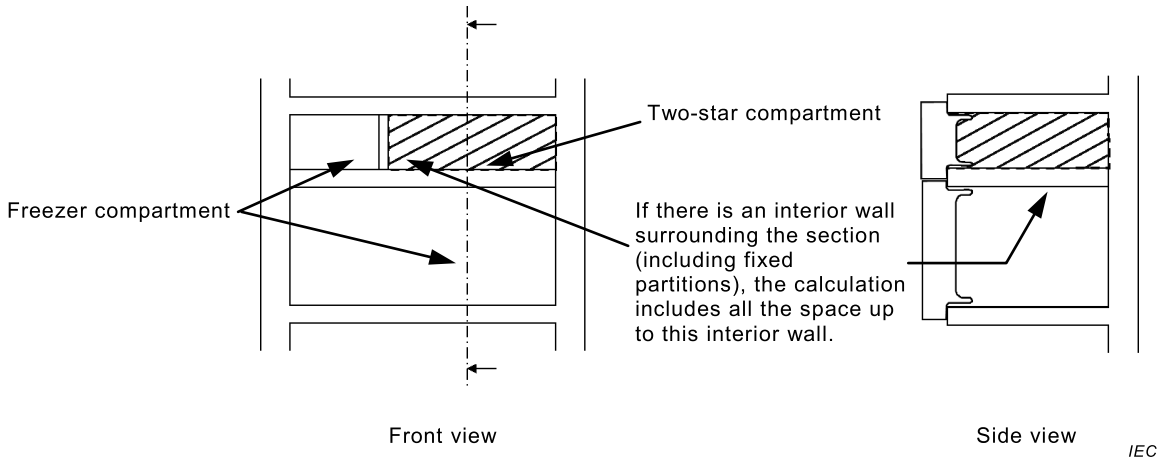

Figure B.1 – Part with partition in the freezer is a two-star compartment

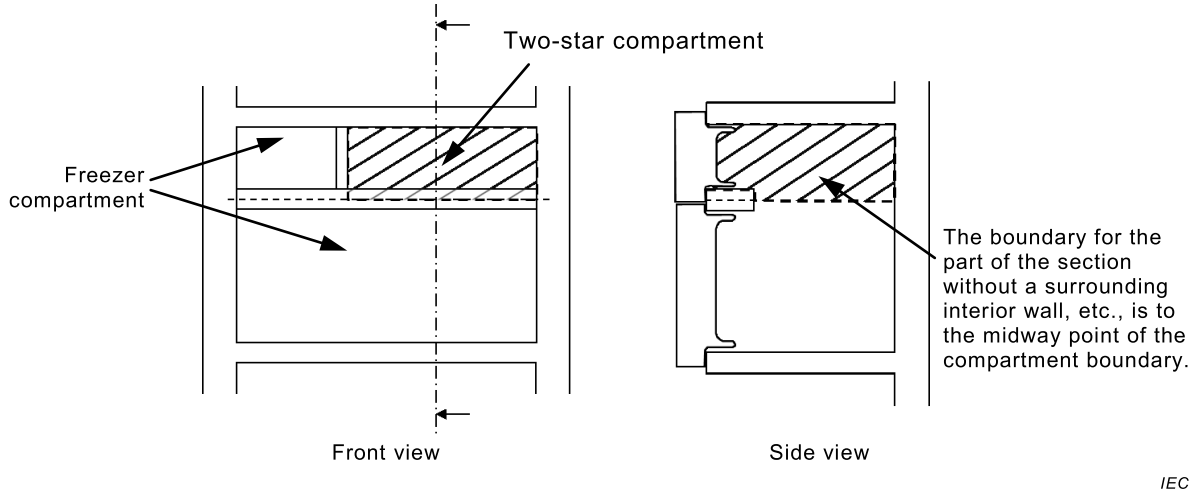

Figure B.2 – Part without partition in the freezer is a two-star compartment

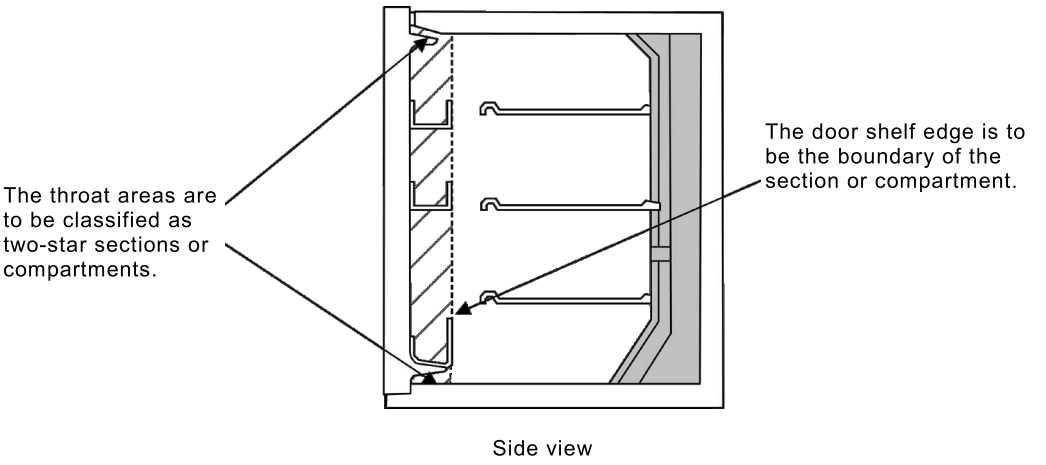

Figure B.3 – Freezer door shelves are a two-star section or compartment

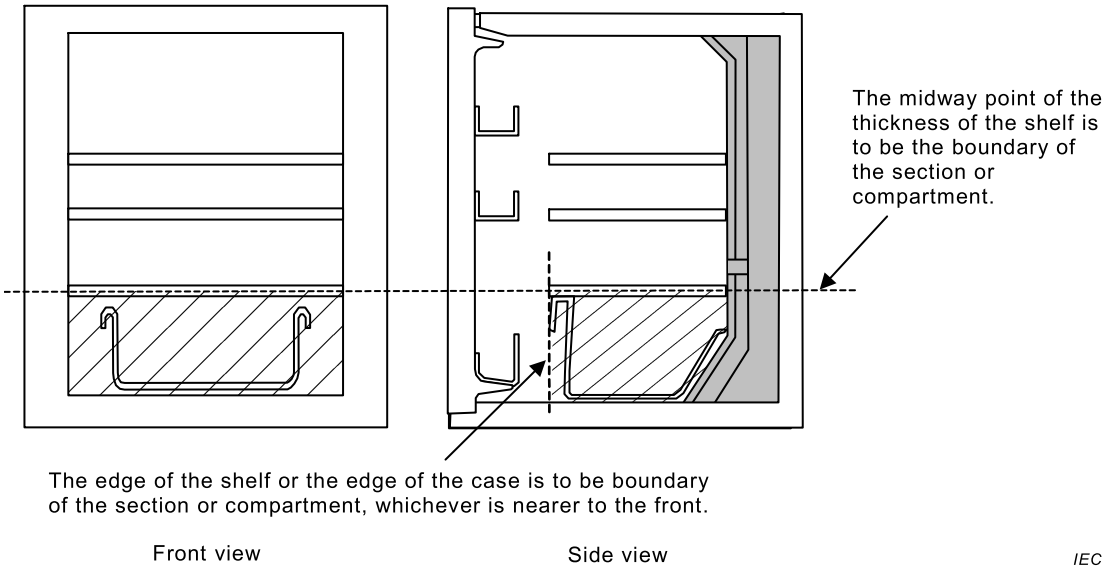

Figure B.4 – Drawer-type compartment in the freezer is a two-star section or compartment

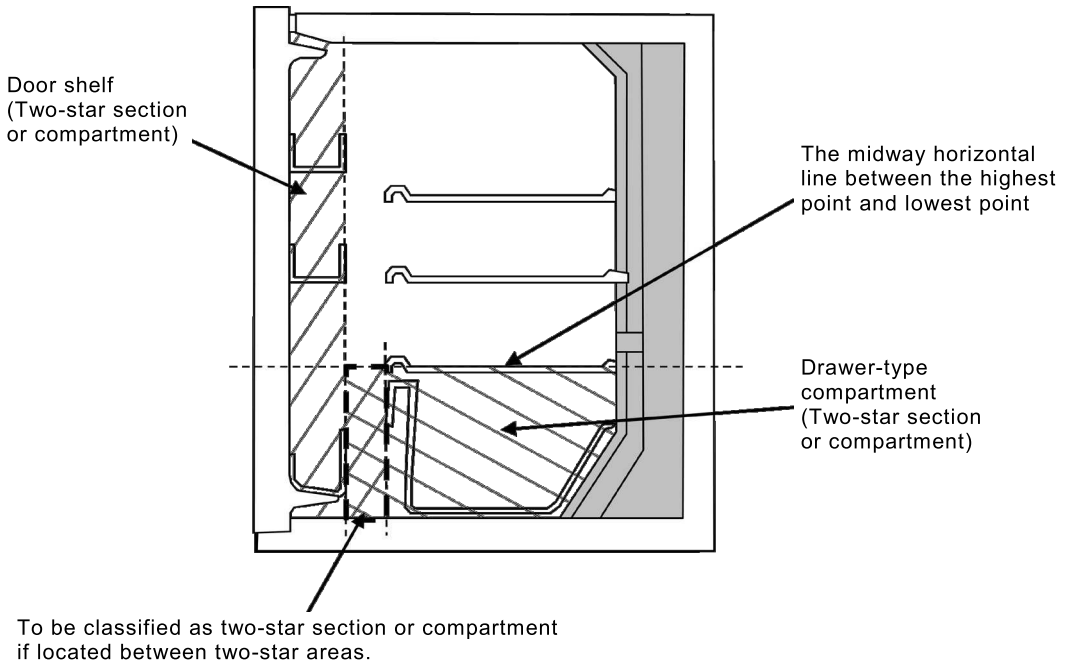

Figure B.5 – Space between a door shelf and drawer-type two-star section or compartment

Annex C
(informative)

Normalized volume

C.1 Background

Normalized volume is an alternative way of expressing the adjusted volume. The advantage of normalized volume is that, in most cases, the normalized volume is close to the measured volume of the refrigerating appliance. This allows the application of more sophisticated energy efficiency metrics that better reflect the energy drivers in refrigerating appliances, should this be of interest (see note). It also means that the volume used for energy efficiency calculations is similar to the model number or classification (where this is based on volume).

NOTE Some efficiency metrics use a function of volume to the power of 0,67 to represent surface area. This is valid for normalized volume, but not for adjusted volume.

C.2 Normalized volume

The normalized volume is the rated total volume of a refrigerating appliance times the ratio of the adjusted volume of the refrigerating appliance to the adjusted volume of a standard hypothetical appliance of the same general type.

$$V_{\text{norm}} = V_{\text{rated}} \times \frac{V_{\text{adj}}}{V_{\text{adj-std}}} \tag{C.1}$$

where:

V_{norm} is the normalized volume;

V_{rated} is the total volume for all compartments;

V_{adj} is the sum of adjusted volume of all compartments determined in accordance with 4.3;

$V_{\text{adj-std}}$ is the adjusted volume of a refrigerating appliance of a defined standard configuration of the same total volume.

The standard configuration is defined locally and should be set to be representative of products on the local market of the same basic type. Typically, separate standard configurations would be defined for refrigerators, refrigerator-freezers and separate freezers. For example, a standard configuration for a refrigerator-freezer might be defined as 70 % fresh food and 30 % freezer while the standard configuration for a separate freezer would typically be 100 % freezer.

A more useful way to calculate normalized volume is:

$$V_{norm} = \frac{V_{adj}}{K_{std}} \tag{C.2}$$

where

K_{std} is the compartment volume weighted value of K_{c} for all compartments.

C.3 Worked example

To illustrate the approach, the normalized volume of a refrigerator-freezer with a fresh food compartment of 297 l and a freezer compartment of 122 l is considered where the average ambient temperature during normal operation is 24 °C.

For the freezer compartment, the volume adjustment factor is given in 4.2 and is as follows:

$$K_{ci} = \frac{[T_{ka} - T_{ti}]}{[T_{ka} - T_{tff}]} = \frac{[24 - (-18)]}{[24 - 4]} = 2,1$$

The adjusted volume is given in 4.3 and is as follows:

V_{adj} = 297 x 1,0 + 122 × 2,1 = 553,2 adjusted litres

Note that in this case the total volume is 419 l (297 l + 122 l) and that the freezer makes up 29,1 % of the total compartment volume.

If it is assumed that a standard configuration for a refrigerator-freezer is 70 % fresh food and 30 % freezer, the K_{std} value at an **average ambient temperature** of 24 °C would be:

$$0,7 \times 1,0 + 0,3 \times \frac{[24 - (-18)]}{[24 - 4]} = 0,7 + 0,63 = 1,33$$

In this example the normalized volume is then given as:

$$V_{norm} = \frac{\left[\frac{553,2}{419}\right]}{1,33} \times 419 = 415,9 \text{ normalized litres}$$

Alternatively the adjusted volume of the standard configuration would be:

0,7 × 1,0 × 419 + 0,3 × 2,1 × 419 = 557.27 adjusted litres

$$V_{norm} = V_{rated} \times \frac{V_{adj}}{V_{adj-std}} = 419 \times \frac{553,2}{557,27} = 415,9 \text{ normalized litres}$$

Normalized volume corrects for differences in the relative size of compartments in exactly the same way as does adjusted volume (because it uses the adjusted volume as a basis for doing so) but the result is a volume that is much closer to the rated volume and therefore more suitable for use in a function that could estimate the surface area of the appliance (for example) based on volume to the power of 0,67.

Suggested configurations for standardized appliances are:

- refrigerators: 90 % fresh food, 10 % one-star;
- refrigerator-freezers: 70 % fresh food, 30 % freezer;
- separate freezers: 100 % three-star/four-star.

Bibliography

IEC 62552-1, *Household refrigerating appliances – Characteristics and test methods – Part 1: General requirements*

Energy Standards and Labelling Programs Throughout The World In 2013 (http://www.iea-4e.org/publications or http://www.iea-4e.org/document/343/energy-standards-labelling-programs-throughout-the-world-in-2013)

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