INTERNATIONAL STANDARD

IEC 60734

Third edition
2001-12

Household electrical appliances – Performance – Hard water for testing

Appareils électrodomestiques – Aptitude à la fonction – Eau dure pour les essais

Reference number
IEC 60734:2001(E)

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Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HOUSEHOLD ELECTRICAL APPLIANCES – PERFORMANCE – HARD WATER FOR TESTING

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International standard IEC 60734 has been prepared by subcommittee 59D: Home laundry appliances, of IEC Technical Committee 59: Performance of household electrical appliances.

This third edition of IEC 60734 replaces the second edition published in 1993.

The text of this standard is based on the following documents:

FDIS	Report on voting
59D/201/FDIS	59D/210/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annex B forms an integral part of this standard.

Annexes A and C are for information only.

Words in **bold** in the text are defined in clause 3.

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The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

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- withdrawn;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

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

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INTRODUCTION

This publication describes several methods to prepare water of standardised hardness to be used for testing household appliances in cases where the water quality is important for the reproducibility of the test results.

It is based on the second edition of IEC 60734, which describes two methods, A and B, of preparing water of three different water hardnesses. Experiences from application of the methods have shown that they are unnecessarily rigid for some purposes and thus expensive or not suited for the preparation of large quantities of water. Furthermore the hardness given is not in line with those stated in some performance standards. Complementary methods C1 and C2 have been developed to be used in such cases. These allow the use of natural instead of demineralised water.

Method A is used to prepare hard water of the correct total hardness. Preparation starts with demineralised water in which hardening salts are dissolved by bubbling carbon dioxide though the mixture.

Method B involves preparation in a similar way but with other salts, which are soluble without addition of carbon dioxide. This method will result in excessive amounts of some ions compared to method A. Both methods give water with specified temporary as well as permanent hardness.

Method C1 starts with natural water with higher hardness than required, while method C2 starts with soft natural water, which is hardened. Depending on the composition of the natural water, several other ions might be present. Restrictions regarding the amounts are given for some ions, which may influence the cleaning results when testing washing machines and dishwashers. No specification regarding temporary and permanent hardness is given.

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HOUSEHOLD ELECTRICAL APPLIANCES – PERFORMANCE – HARD WATER FOR TESTING

1 Scope

This International Standard describes the preparation of three types of water of different hardness intended to be used for testing the performance of household appliances such as washing machines, dishwashers, dryers, steam irons etc.

It defines the characteristics of these waters and establishes various methods to be used for obtaining them.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6059:1984, *Water quality – Determination of the sum of calcium and magnesium – EDTA titrimetric method*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1
water hardness
measurement, in degrees, indicating the quantity of alkaline earth salts (bicarbonates, sulphates, chlorides etc.) present in the water

3.2
total hardness
the sum of calcium and magnesium ions in the water

3.3
temporary hardness
the fraction of the total hardness equivalent to the bicarbonate content

3.4
permanent hardness
the difference between the total and the temporary hardness

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4 General

4.1 Principle

Hard water may be prepared according to different methods. Methods A and B may be used both for large and small amounts of water. Methods C1 and C2, which give less well defined hard waters, should only be used for large amounts.

Since natural waters are variable in character and hardness, the only procedure for the preparation of hard water with a completely specified composition starts with completely demineralised water according to 5.1, which is subsequently hardened to the right level. The rehardening may be performed in two ways, resulting in either a water with exactly the composition required in method A, according to 5.2, or a water with an excess of sodium, chlorine and sulphate ions, as required in method B, according to 5.3.

The second method takes less time to perform and the composition is satisfactory if the excess of ions is acceptable.

The third method, which does not allow exact control of the composition, gives water with the required hardness but may contain unknown ions as well. It starts with natural water, which is either diluted with demineralised water through method C1, according to 5.4.2, or rehardened through method C2, according to 5.4.3, depending on the source and object. The ratio between calcium and magnesium is kept within relatively wide limits. Some restrictions regarding the levels of metal ions are set.

NOTE Depending on the appliance to be tested, the prepared water may have to be cooled down to the required temperature.

4.2 Units

Hardness is expressed in mmol/l for the ions Ca^{2+} and Mg^{2+}.

NOTE A table for conversion into other hardness units is given in annex A.

4.3 Levels of water hardness

This standard defines three different levels of water hardness:

2,5 mmol/l
1,5 mmol/l } total hardness Ca + Mg
0,5 mmol/l

NOTE With these three values of water hardness it is possible to select one or more standardised hard waters, which would approximate the local natural waters available. If any other hardness is needed, it can be prepared in a similar way by interpolation of the given amounts of chemicals.

5 Composition and preparation of artificial hard waters

5.1 Demineralisation of natural water

Natural water is demineralised so that its specific resistance is 100 000 Ωcm or more (its conductivity not more than 10 µS/cm). Water of this quality can be obtained using an apparatus filled with a column of mixed cation and anion exchange resins or by equipment for reverse osmosis.

NOTE When an ion exchange resin is new, the first one or two preparations should be discarded. This is not necessary after each normal regeneration.

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5.2 Preparation of water method A

5.2.1 Composition of hard water prepared by method A

The temporary hardness component of the hard water consists of calcium hydrogen carbonate ($Ca(HCO_3)_2$). The permanent hardness component is equally divided between calcium chloride ($CaCl_2$) and magnesium sulphate ($MgSO_4$).

Table 1 – Composition of the hard water achieved with method A

Ions	Mol. weight	Total hardness mmol/l		
		0,5	1,5	2,5
		Ion concentrations mmol/l		
Ca^{2+}	40,0	0,42	1,25	2,08
Mg^{2+}	24,3	0,08	0,25	0,42
HCO_3^-	61,0	0,68	2,00	3,33
Cl^-	35,5	0,16	0,50	0,83
SO_4^{2-}	96,0	0,08	0,25	0,42
Temporary hardness mmol/l		0.34	1.00	1.67

5.2.2 Rehardening Method A

Amounts of salts to be added to achieve the desired hardness are given in annex B.

Dry calcium carbonate ($CaCO_3$) is weighed out in accordance with the desired temporary hardness and the quantity of water. This is mixed with a portion of demineralised water to form a slurry and then added to the remainder of water.

Carbon dioxide is bubbled in slowly by means of rods or circular spray heads pierced with small holes and distributed over the bottom of the storage tank. The pressure of the carbon dioxide cylinder is reduced by means of a reducing valve to approximately 35 kPa before passing into the tank. It may be necessary to heat the valve to prevent freezing.

This process, which lowers the pH value and converts the insoluble calcium carbonate into soluble calcium hydrogen carbonate, continues until the water becomes clear.

NOTE The process may take between 1 h and 3 h, depending on the quantity of water and the required hardness.

Solid calcium chloride ($CaCl_2 \cdot 2H_2O$) is then added in accordance with half of the desired permanent hardness. (1,47 mg $CaCl_2 \cdot 2H_2O$ per litre gives 0,01 mmol/l).

Solid magnesium sulphate ($MgSO_4 \cdot 7H_2O$) is then added in accordance with the other half of the desired permanent hardness. (2,46 mg $MgSO_4 \cdot 7H_2O$ per litre gives 0,01 mmol/l).

Air is added in to raise the pH to within the following pH ranges.

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Table 2 – Water hardness and respective pH value

Hardness	pH at 20 °C
0,5 mmol/l	8,0 – 8,3
1,5 mmol/l	7,5 – 8,0
2,5 mmol/l	7,3 – 7,7

This water shall be kept in closed tanks at normal room temperature without further agitation.

Readjust the pH if needed with HCl or NaOH before use of hard water.

5.3 Preparation of water method B

5.3.1 Composition of hard water prepared by Method B

The temporary hardness component of the hard water consists of calcium and magnesium hydrogen carbonates $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$. The permanent hardness component consists of the chlorides and sulphates of calcium and magnesium ($CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$).

Table 3 – Composition of the hard water achieved by method B.

Ions	Mol. weight	Total hardness mmol/l		
		0,5	1,5	2,5
		Ion concentrations mmol/l		
Ca^{2+}	40,0	0,37	1,11	1,85
Mg^{2+}	24,3	0,13	0,39	0,65
HCO_3	61,0	0,67	2,00	3,35
Cl^-	35,5	0,75	2,23	3,75
SO_4	96,0	0,13	0,39	0,65
Na^+	23,0	0,67	2,00	3,35
Temporary hardness mmol/l		0,33	1,00	1,67

5.3.2 Rehardening method B

Salts dissolved in water are added in amounts given in annex B.

Prepare the following solutions:

Solution 1	$NaHCO_3$	67,2 g/l	(800 mmol/l)
Solution 2	$MgSO_4\ 7H_2O$	38,0 g/l	(154,2 mmol/l)
Solution 3	$CaCl_2\ 2H_2O$	65,6 g/l	(446,1 mmol/l)

Add specified amounts of the three solutions to 0,7 litre of demineralised water and add up to 1,00 l for preparation of the three standardised different hardness. If large amounts of water are prepared, the addition is performed through automatic dosage. Bring the pH to within the following pH ranges with HCl or NaOH before use.

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Table 4 – Water hardness and respective pH value

Hardness	pH at 20 °C
0,5 mmol/l	8,0 – 8,5
1,5 mmol/l	7,5 – 7,9
2,5 mmol/l	7,3 – 7,7

5.4 Preparation of water method C

5.4.1 Composition of hard water prepared by method C

Water with a total hardness of 2,5 mmol/l is to be prepared. No differentiation is made between temporary and permanent hardness. The calcium hardness shall be (75 ± 15) % of the total hardness, which means a Ca^{2+}/Mg^{2+} ratio of 1,5 to 9.

The contents of the following metal ions which may influence the bleaching intensity if the water is used for cleaning purposes, shall be kept within the following limits:

iron	< 0,1 mg/l
copper	< 0,05 mg/l
manganese	< 0,05 mg/l

The chloride content shall be less than 4,5 mmol/l if the water is used for testing dishwashers. Use demineralised water for dilution if necessary.

The hardness of the natural water is analysed for its calcium and magnesium content. If the calcium/magnesium ratio is outside the limits, adjustments are made by dissolving some of the missing ions in the form of $Ca\ Cl_2 \cdot 2H_2O$ or $MgSO_4 \cdot 7\ H_2O$. Examples of adjustment are given in annex C.

5.4.2 Hardness adjustment method C1

Method C1 is used if the adjusted tap water is harder than the required hardness. Some of the tap water is softened by replacing calcium and magnesium against sodium by means of a cation exchange resin or by use of demineralised water for dilution. If the pH is too low, some CO_2 shall be removed by air bubbling.

The hardness of the natural water is analysed for its calcium and magnesium content. If the calcium/magnesium ratio is outside the limits of clause 5.4.1, adjustments are made by dissolving some of the missing ions in the form of $CaCl_2 \cdot 2\ H_2O$ or $MgSO_4 \cdot 7H_2O$.

Examples of mixing proportions are given in annex C.

5.4.3 Hardness adjustment method C2

This method is used if the tap water is too soft. The soft tap water is mixed with calcium and magnesium salts in such a way that the required hardness is obtained.

Examples of addition of salts are given in annex B.

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6 Storage of standardised hard water

Preferably standardised hard water shall be stored in closed tanks to exclude both air and light, to prevent loss of CO_2 and also to prevent contamination and growth of organic matter. If the tank is kept closed, the storage life is about one month but if the tank is left open the storage life is about one day.

6.1 Effects of heat on standardised hard water

When standardised hard water is heated from 20 °C to 90 °C scale forming will start at about 85 °C depending on the rate of heating. If it is heated to a lower temperature and kept heated, scale formation will also occur. Over 60 °C, crystalline aragonite will be formed. Under 40 °C, crystalline calcite will be formed.

NOTE Aragonite is voluminous with a needle structure and can rapidly obstruct small openings. Calcite is less voluminous but has a hard structure.

7 Checking

When checking the total hardness measure according to ISO 6059.

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Annex A
(informative)

Water hardness – Conversion table

A.1 Correspondence of water hardness units

1 mmol/l = 2,0 milliequivalents = 2 mval/l
= 100 ppm of $CaCO_3$
= 10 parts per 100 000
= 10 French degrees
= 7,0 English degrees
= 5,6 German degrees

A.2 Conversion into different degrees of hardness

The following table gives the conversion in French degrees, English degrees and German degrees for the values of hardness used in this standard.

Value in mmol/l	French degree	English degree	German degree
0,50	5	3,5	2,8
1,50	15	10,5	8,4
2,50	25	17,5	14,0

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Annex B
(normative)

Amounts of salts to be used for rehardening demineralised water

B.1 Method A

Amounts of salts to be added in mg/l demineralised water. The minimum quality for the salts is >98 % purity.

	Total hardness mmol/l		
	0,5	**1,5**	**2,5**
$CaCO_3$	33	100	167
$CaCl_2 \cdot 2H_2O$	12	37	61
$MgSO_4 \cdot 7H_2O$	21	61	103

B.2 Method B

Amounts of salt-solutions to be added in ml/l of demineralised water

	Total hardness mmol/l		
	0,5	**1,5**	**2,5**
$NaHCO_3$ – solution 1	0,83	2,50	4,17
$CaCl_2 \cdot 2H_2O$ – solution 2	0,83	2,50	4,17
$MgSO_4 \cdot 7H_2O$ – solution 3	0,83	2,50	4,17

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Annex C
(informative)

Amounts of waters to be mixed at various degrees of hardness of the natural water according to methods C1 and C2

C.1 Method C1: Use of softened hard natural water

Some of the natural water has to be softened first by use of a cation exchanger to a maximum hardness of 0,05 mmol/l, or use demineralised water for dilution.

The examples are valid for water with a hardness of 2,5 mmol/l. If softer water is needed, increase the addition of softened water proportionally.

Table C.1– Natural water which is too hard – Examples for dilution to 2,5 mmol/l

Natural water			Soft water	Total amount	Remarks
Hardness mmol/l	Ca^{2+}/Mg^{2+}	Amount l	Amount l		
2,8	4	890	110	1 000	
3,0	4	830	170	1 000	
3,5	2,3	710	290	1 000	
4,0	9	630	370	1 000	
3,0	1				see table C.2
3,0	∞				see table C.2

$$\text{Natural water volume} = \frac{2{,}5\,(\text{Valid for } 2{,}5\,\text{mmol/l})\,\text{total water volume}}{\text{total hardness}}$$

Table C.2 – Adjustment of the ratio between Ca^{2+} and Mg^{2+}

Natural water		$CaCl_2 \cdot 2\,H_2O$	$MgSO_4 \cdot 7\,H_2O$	New hardness	New ratio	Chloride added
Hardness mmol/l	Ca^{2+}/Mg^{2+}	mg/l	mg/l	mmol/l	Ca^{2+}/Mg^{2+}	mg/l
4,0	1	588		8,0	3	284
4,0	∞		330	5,3	3	
3,0	1	441		6,0	3	213
3,0	∞		246	4,0	3	
2,5	1	365		5,0	3	176
2,5	∞		204	3,3	3	
2,0	1	294		4,0	3	142
2,0	∞		165	2,7	3	

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After the adjustment, the water is mixed with softened water according to table I.

For dishwasher tests, check chloride in final preparation. Maximum 4,5 mmol/l (= 160 mg/l) allowed.

C.2 Method C2: Use of soft natural water

Table C.3 – Natural water which is too soft – Examples for rehardening to 2,5 mmol/l

Natural water		$CaCl_2 \cdot 2\ H_2O$	$MgSO_4 \cdot 7\ H_2O$	New hardness	New ratio
Hardness mmol/l	**Ratio** Ca^{2+}/Mg^{2+}	mg/l	mg/l	mmol/l	Ca^{2+}/Mg^{2+}
1,0	1,5	188	54	2,50	3
1,0	9	144	128	2,50	3
1,0	1	203	30	2,50	3
1,0	∞	128	155	2,50	3
2,0	1,5	176		3,20[a]	3
2,0	9	12	103	2,50	3
2,0	1	292		4,00[a]	3
2,0	∞		165	2,67	3

[a] Too hard water as a result of Ca^{2+}/Mg^{2+} ratio adjustment, which shall be diluted with softened water according to table I.

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ISBN 2-8318-6091-1



ICS 97.030

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