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Magnesium and magnesium alloys — Magnesium alloy ingots and castings

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National foreword

This British Standard is the UK implementation of ISO 16220:2017. It supersedes BS ISO 16220:2005, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NFE/35, Light metals and their alloys.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Magnesium and magnesium alloys — Magnesium alloy ingots and castings

Magnésium et alliages de magnésium — Lingots et pièces moulées en alliage de magnésium

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 79, *Light metals and their alloys*, Subcommittee SC 5, *Magnesium and alloys of cast or wrought magnesium*.

This third edition cancels and replaces the second edition (ISO 16220:2005), which has been technically revised by the addition of new alloys. It also incorporates the amendment ISO 16220:2005/Amd.1:2007.

Introduction

This document classifies the magnesium alloys into a number of grades suitable for the applications to which they might be used.

Some of the alloys referenced in this document can be the subject of a patent or of patent applications and their listing herein is not to be construed in any way as the granting of a licence under such patent rights.

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INTERNATIONAL STANDARD ISO 16220:2017(E)

Magnesium and magnesium alloys — Magnesium alloy ingots and castings

1 Scope

This document specifies the chemical composition of magnesium alloy ingots and castings. It also specifies the mechanical properties of separately cast samples of these alloys (see Clause 7). By agreement, it also specifies the mechanical properties of magnesium alloy castings determined from samples cut from a casting.

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.

NOTE For information on equivalent International Standards see Annex A.

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 80000-1:2009, *Quantities and units — Part 1: General*

EN 1559-5, *Founding — Technical condition of delivery — Part 5: Additional requirements for magnesium alloy castings*

3 Terms and definitions

No terms and definitions are listed in this document.

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

4 Material designation

4.1 General

The material shall be designated as given in Tables 1 to 5.

4.2 Temper designation

The following symbols for temper designation shall be used.

— F: as-cast; applies to products that require no heat treatment following the casting processes.

— T4: solution heat-treated and naturally aged; applies to products that have no further treatment after solution heat treatment.

— T5: as-cast and artificially aged; applies to products that are cooled from the casting process, and then artificially aged to improve mechanical properties or dimensions.

— T6: solution heat-treated and artificially aged; applies to products that are solution heat treated followed by artificially aging.

4.3 Casting process designation

The following symbols shall be used for the designation of the different casting processes.

— S: sand casting.

— K: permanent mould casting.

— D: pressure die casting.

— L: investment casting.

4.4 Designation for ordering

The designation used for ordering shall include, in the following order, the number of castings, a mention of this document, the ISO alloy designation, the designation for the heat treatment process (temper), and the designation for the casting process.

EXAMPLE An order for 20 castings, conforming to this document, of magnesium alloy ISO-MC21120, delivered in as-cast (F temper) and made by sand casting (S) is as follows:

20 castings – ISO 16220 - ISO-MgAl9Zn1(A) (or ISO-MC21120 or ISO-AZ91D)-F-S

5 Requirements

5.1 Chemical composition

The chemical composition of magnesium alloy ingots shall conform to the requirements for the appropriate material given in Table 1.

The chemical composition of magnesium alloy castings shall conform to the requirements for the appropriate material given in Table 2.

Conformance shall be determined by the manufacturer by analysing samples taken at the time the ingots or castings are produced.

NOTE For additional information regarding the manganese and iron contents see Annex B.

5.2 Mechanical properties of castings

The mechanical properties obtained from test pieces prepared from separately cast samples for sand castings and permanent mould castings shall meet the requirements given in Tables 3 and 4. As appropriate, the tests shall be carried out in accordance with Clause 8.

NOTE 1 Mechanical properties obtained from test pieces prepared from separately cast samples for investment castings are not specified, as experience is limited. As a general rule they are similar to those for permanent mould castings.

NOTE 2 The values obtained from test pieces cut from castings can differ from the minimum values specified in the tables because of imperfections (gas pores, shrinkage cavities, inclusions) and the machining process applied. Variation in the casting structure can also affect the property values.

NOTE 3 For pressure-die castings, the mechanical properties strongly depend on the process parameters; therefore, the properties given in Table 5 are for guidance only.

The Brinell hardness test shall be carried out on sound areas of castings or on a test piece that has not been stressed. Hardness tests are only to be carried out where appropriate and when there is a real difference between the different states of heat treatment.

5.3 Frequency of testing

The frequency of testing shall be in accordance with EN 1559-5.

5.4 General condition of the product

Ingots shall be free of dust, burrs, salty inclusions and be homogeneous in thickness and weight to a standard agreed with the purchaser.

Castings shall have a clean surface and shall be free from visible and internal imperfections to a standard also agreed between the manufacturer and the purchaser.

6 Sampling

Conditions for sampling, formation of batches and frequency of verification shall be as specified in EN 1559-5.

7 Test pieces for mechanical properties

7.1 Design

The design of test pieces shall be subject to an agreement between the manufacturer and the purchaser.

7.2 Test pieces obtained from separately cast samples

7.2.1 Sand-cast samples

Test pieces may be in the machined or unmachined condition.

The following conditions shall apply:

— samples shall be cast in sand moulds and without artificial chilling;

— the minimum diameter of the test piece shall be 12 mm;

— the gauge length and the parallel length shall conform to ISO 6892-1.

7.2.2 Permanent-mould cast samples

Test pieces may be in the machined or unmachined condition.

The following conditions shall apply:

— the minimum diameter of the test piece shall be 12 mm;

— the gauge length and parallel length shall conform to ISO 6892-1.

7.2.3 Pressure-die cast samples

For pressure die castings, it is not recommended to test mechanical properties on separately cast bars or coupons. It is more appropriate to test the whole casting under conditions comparable to the ones expected in service.

The values given in Table 5 are for guidance only. These are not typical, but they are the minimum values that can be expected on separately pressure cast bars (with none or very limited machining) and with a cross section of 20 mm^2 and a typical thickness of 2 mm.

7.2.4 Investment cast samples

Test pieces may be in the machined or unmachined condition.

The following conditions shall apply:

— the minimum diameter of the test piece shall be 5 mm;

— the gauge length and parallel length shall conform to ISO 6892-1.

7.3 Test pieces cut from castings

The geometry and location of test pieces cut from castings shall be specified by agreement between the manufacturer and the purchaser.

If it is agreed between the manufacturer and the purchaser to use circular cross-section test pieces, the minimum diameter shall be 4 mm.

8 Test methods

8.1 Tensile test

Tensile tests shall be carried out in accordance with ISO 6892-1.

8.2 Brinell hardness test

Brinell hardness tests shall be carried out in accordance with ISO 6506-1.

A test ball of 5 mm diameter is recommended. By agreement between the manufacturer and the purchaser, a smaller ball diameter may be used for thin-wall castings.

9 Retests

Retests shall be carried out in accordance with EN 1559-5.

10 Rounding of numbers

The number representing the result for any value specified in this document shall be expressed with the same number of decimal places as the corresponding number in this document. The rounding of numbers shall meet the requirements of ISO 80000-1:2009, B.3, rule A or B. The choice shall be left to the discretion of the manufacturer, unless the use of one of the rules is agreed by the time of acceptance of the order.

Table 1 — Chemical composition of magnesium alloy ingots

Alloy group	Material designation			Composition % mass fraction																	
	Designation by symbols	Designation by numbers	ASTM designation	Min. or max.	Mg	Al	Zn	Mn[a]	RE[b]	Zr	Ag	Y	Gd	Li	Sr	Ca	Si	Fe	Cu	Ni	Other each
MgAlZn	ISO-MgAl8Zn1	ISO-MB21110	AZ81	min. max.	Rem.	7,2 8,5	0,45 0,9	0,17 0,4									– 0,05	– 0,004	– 0,025	– 0,001	– 0,05
	ISO-MgAl9Zn1(A)	ISO-MB21120	AZ91	min. max.	Rem.	8,5 9,5	0,45 0,9	0,17 0,40									– 0,08	– 0,004	– 0,025	– 0,001	– 0,01
	ISO-MgAl9Zn1(B)	ISO-MB21121	AZ91	min. max.	Rem.	8,0 10,0	0,3 1,0	0,1 0,50									– 0,3	– 0,03	– 0,020	– 0,01	– 0,05
	ISO-MgAl9Zn-1Ca	ISO-MB21122	AZ91	min max	Rem.	8,5 9,5	0,45 0,9	0,17 0,40								0,5 2,5	– 0,08	– 0,004	– 0,025	– 0,001	– 0,01
	ISO-MgAl6Zn3	ISO-MB21130	AZ63	min. max.	Rem.	5,5 6,5	2,7 3,3	0,15 0,35									– 0,05	– 0,005	– 0,015	– 0,001	– 0,05
MgAlMn	ISO-MgAl2Mn	ISO-MB21210	AM20	min. max.	Rem.	1,7 2,5	– 0,20	0,35 0,60									– 0,08	– 0,004	– 0,008	– 0,001	– 0,01
	ISO-MgAl5Mn	ISO-MB21220	AM50	min. max.	Rem.	4,5 5,3	– 0,30	0,28 0,50									– 0,08	– 0,004	– 0,008	– 0,001	– 0,01
	ISO-MgAl6Mn	ISO-MB21230	AM60	min. max.	Rem.	5,6 6,4	– 0,30	0,26 0,50									– 0,2	– 0,004	– 0,008	– 0,001	– 0,01
	ISO-MgAl10Mn	ISO-MB21240	AM100	min. max.	Rem.	9,4 10,6	– 0,20	0,13 0,35									0,7 1,2	– 0,004	– 0,008	– 0,001	– 0,01
MgAlSi	ISO-MgAl2Si	ISO-MB21310	AS21	min. max.	Rem.	1,9 2,5	– 0,20	0,2 0,6									0,7 1,2	– 0,004	– 0,008	– 0,001	– 0,01
	ISO-MgAl4Si	ISO-MB21320	AS41	min. max.	Rem.	3,7 4,8	– 0,20	0,2 0,6									– 0,08	– 0,004	– 0,008	– 0,001	– 0,01
MgAIRE	ISO-MgAI4RE4	ISO-MB21410	AE44	min. max.	Rem.	3,6 4,4	– 0,20	0,15 0,50	3,6 4,6								– 0,08	– 0,004	– 0,008	– 0,001	– 0,01
MgAlSr	ISO-MgAl5Sr2	ISO-MB21510	AJ52	min. max.	Rem.	4,6 5,5	– 0,20	0,24 0,6							1,8 2,3		– 0,08	– 0,004	– 0,008	– 0,001	– 0,01
	ISO-MgAl6Sr2	ISO-MB21520	AJ62	min. max.	Rem.	5,5 6,6	– 0,20	0,24 0,6							2,1 2,8		– 0,08	– 0,004	– 0,008	– 0,001	– 0,01

Table 1 *(continued)*

Alloy group	Material designation			Composition % mass fraction																	
	Designation by symbols	Designation by numbers	ASTM designation	Min. or max.	Mg	Al	Zn	Mn[a]	RE[b]	Zr	Ag	Y	Gd	Li	Sr	Ca	Si	Fe	Cu	Ni	Other each
MgAlCa	ISO-MgAl-6Ca2RE2	ISO-MB25120	AE62	min. max.	Rem.	6,1 6,7	– 0,4	0,13 0,35	2,2 2,8							2,0 2,4	– 0,08	– 0,004	– 0,05	– 0,001	– 0,01
	ISO-MgAl-6Ca2Sr	ISO-MB25130	AX62	min. max.	Rem.	5,7 6,4	– 0,10	0,30 0,40							0,22 0,30	1,8 2,3	– 0,10	– 0,004	– 0,001	– 0,001	– 0,01
MgZnCu	ISO-MgZn-6Cu3Mn	ISO-MB32110	ZC63	min. max.	Rem.	– 0,2	5,5 6,5	0,25 0,75									– 0,20	– 0,05	2,4 3,0	– 0,01	– 0,01
MgZn-REZr	ISO-MgZn-4RE1Zr[d]	ISO-MB35110	ZE41	min. max.	Rem.	– –	3,5 5,0	– 0,15	1,0 1,75	0,1 1,0							– 0,01	– 0,01	– 0,03	– 0,005	– 0,01
	ISO-MgRE3Zn-2Zr[d]	ISO-MB65120	EZ33	min. max.	Rem.	– –	2,0 3,0	– 0,15	2,4 4,0	0,1 1,0							– 0,01	– 0,01	– 0,03	– 0,005	– 0,01
	ISO-MgRE3Zn-Zr[d]	ISO-MB65130	EZ30	min. max.	Rem.	– –	0,14 0,7	– 0,05	2,0 3,5	0,3 1,0						– 0,05	– 0,01	– 0,01	– 0,03	– 0,005	– 0,01
MgREAg-Zr	ISO-MgAg2RE2Zr[e]	ISO-MB65210	QE22	min. max.	Rem.	– –	– 0,2	– 0,15	2,0 3,0	0,1 1,0	2,0 3,0						– 0,01	– 0,01	– 0,03	– 0,005	– 0,01
	ISO-MgRE2Ag-1Zr[e]	ISO-MB65220	EQ21	min. max.	Rem.	– –	– 0,2	– 0,15	1,5 3,0	0,1 1,0	1,3 1,7						– 0,01	– 0,01	0,05 0,10	– 0,005	– 0,01
MgYREZr	ISO-MgY5RE4Zr[fg]	ISO-MB95310	WE54	min. max.	Rem.	– –	– 0,2	– 0,15	1,5 4,0	0,1 1,0		4,75 5,5		– 0,2			– 0,01	– 0,01	– 0,03	– 0,005	– 0,01
	ISO-MgY4RE3Zr[fg]	ISO-MB95320	WE43	min. max.	Rem.	– –	– 0,2	– 0,15	2,4 4,4	0,1 1,0		3,7 4,3		– 0,2			– 0,01	– 0,01	– 0,03	– 0,005	– 0,01
MgGdYZr	ISO-MgGd7Y6Zr	ISO-MB69110	VW76	min. max.	Rem.	– –	– –	– 0,03		0,2 1,0		5,5 6,5	6,5 7,5	– 0,2			– 0,01	– 0,010	– 0,02	– 0,005	– 0,01
	ISO-MgGd10Y3Zr	ISO-MB69120	VW103	min. max.	Rem.	– –	– 0,2	– 0,05		0,3 1,0		2,5 3,5	8,5 10,5				– 0,01	– 0,01	– 0,03	– 0,005	– 0,01

Table 1 *(continued)*

Alloy group	Material designation			Composition % mass fraction																	
	Designation by symbols	Designation by numbers	ASTM designation	Min. or max.	Mg	Al	Zn	Mn[a]	RE[b]	Zr	Ag	Y	Gd	Li	Sr	Ca	Si	Fe	Cu	Ni	Other each
MgREG-dZr[h]	ISO-MgRE3G-d1Zr	ISO-MB65410	EV31	min. max.	Rem.	– –	0,20 0,50	– 0,03	2,6 3,1	0,1 1,0	– 0,05		1,0 1,7					– 0,01	– 0,01	– 0,002	– 0,01

Table 2 — Chemical composition of magnesium alloy castings

Alloy group	Material designation			Composition % mass fraction																		
	Designation by symbols	Designation by numbers	ASTM designation	Casting process	Min. or max.	Mg	Al	Zn	Mn[a]	RE[b]	Zr	Ag	Y	Gd	Li	Sr	Ca	Si	Fe	Cu	Ni	Other each	Fe/Mn
MgAlZn	ISO-MgAl8Zn1	ISO-MB21110	AZ81	S,K,L	min. max.	Rem.	7,0 8,5	0,40 1,0	0,13 0,50									– 0,05	– 0,004	– 0,025	– 0,001	– 0,05	– 0,032
	ISO-MgAl9Zn1(A)	ISO-MB21120	AZ91	D	min. max.	Rem.	8,5 9,5	0,35 0,9	0,15 0,50									– 0,08	– 0,004	– 0,025	– 0,001	– 0,01	– 0,032
	ISO-MgAl9Zn1(A)	ISO-MB21120	AZ91	S,K,L	min. max.	Rem.	8,3 9,7	0,40 1,0	0,17 0,35									– 0,08	– 0,004	– 0,025	– 0,001	– 0,01	– 0,032
	ISO-MgAl9Zn1(B)	ISO-MB21121	AZ91	D,S,K,L	min. max.	Rem.	8,0 10,0	0,3 1,0	0,1 0,60									– 0,3	– 0,03	– 0,020	– 0,01	– 0,05	– 0,032
	ISO-MgAl9Zn-1Ca	ISO-MB21122	AZ91	D	min. max.	Rem.	8,3 9,7	0,35 1,0	0,15 0,50								0,5 2,5	– 0,1	– 0,005	– 0,003	– 0,002	– 0,01	– 0,032
	ISO-MgAl6Zn3	ISO-MB21130	AZ63	S,K,L	min. max.	Rem.	5,3 6,7	2,5 3,5	0,10 0,50									– 0,05	– 0,005	– 0,015	– 0,001	– 0,05	– 0,032
MgAlMn	ISO-MgAl2Mn	ISO-MB21210	AM20	D	min. max.	Rem.	1,6 2,5	– 0,20	0,33 0,70									– 0,08	– 0,004	– 0,008	– 0,001	– 0,01	– 0,012
	ISO-MgAl5Mn	ISO-MB21220	AM50	D	min. max.	Rem.	4,4 5,3	– 0,30	0,26 0,60									– 0,08	– 0,004	– 0,008	– 0,001	– 0,01	– 0,015
	ISO-MgAl6Mn	ISO-MB21230	AM60	D	min. max.	Rem.	5,5 6,4	– 0,30	0,24 0,50									– 0,2	– 0,004	– 0,008	– 0,001	– 0,01	– 0,021
	ISO-MgAl10Mn	ISO-MB21240	AM100	S,K,L	min. max.	Rem.	9,4 10,6	– 0,20	0,10 0,50									0,7 1,2	– 0,004	– 0,008	– 0,001	– 0,01	– 0,022
MgAlSi	ISO-MgAl2Si	ISO-MB21310	AS21	D	min. max.	Rem.	1,8 2,5	– 0,20	0,18 0,70									0,7 1,2	– 0,004	– 0,008	– 0,001	– 0,01	– 0,022
	ISO-MgAl4Si	ISO-MB21320	AS41	D	min. max.	Rem.	3,5 4,8	– 0,20	0,18 0,70									– 0,08	– 0,004	– 0,008	– 0,001	– 0,01	– 0,022
MgAlRE[c]	ISO-MgAl4RE4	ISO-MB21410	AE44	D	min. max.	Rem.	3,5 4,5	– 0,20	0,15 0,50	3,5 4,5								– 0,08	– 0,004	– 0,008	– 0,001	– 0,01	

Table 2 *(continued)*

Alloy group	Material designation			Composition % mass fraction																		
	Designation by symbols	Designation by numbers	ASTM designation	Casting process	Min. or max.	Mg	Al	Zn	Mn[a]	RE[b]	Zr	Ag	Y	Gd	Li	Sr	Ca	Si	Fe	Cu	Ni	Other each	Fe/Mn
MgAlSr	ISO-MgAl5Sr2	ISO-MB21510	AJ52	D	min. max.	Rem.	4,5 5,5	– 0,20	0,2 0,6							1,8 2,3		– 0,08	– 0,004	– 0,008	– 0,001	– 0,01	– 0,022
	ISO-MgAl6Sr2	ISO-MB21520	AJ62	D	min. max.	Rem.	5,5 6,6	– 0,20	0,2 0,6							2,1 2,8		– 0,08	– 0,004	– 0,008	– 0,001	– 0,01	– 0,022
MgAlCa	ISO-MgAl-5Ca2RE2	ISO-MB25120	AE62	D	min. max	Rem.	6,1 6,7	– 0,04	0,13 0,35	2,2 2,8							2,0 2,4	– 0,08	– 0,004	– 0,05	– 0,001	– 0,01	
	ISO-MgAl-6Ca2Sr	ISO-MB25130	AX62	D	min. max	Rem.	5,5 6,5	– 0,10	0,30 0,40							0,20 0,30	1,8 2,5	– 0,10	– 0,004	– 0,001	– 0,001	– 0,01	
MgZnCu	ISO-MgZn-6Cu3Mn	ISO-MB32110	ZC63	S,K,L	min. max.	Rem.	– 0,2	5,5 6,5	0,25 0,75									– 0,20	– 0,05	2,4 3,0	– 0,01	– 0,01	– –
MgZn-REZr	ISO-MgZn-4RE1Zr[c]	ISO-MB35110	ZE41	S,K,L	min. max.	Rem.	– –	3,5 5,0	– 0,15	0,75 1,75	0,4 1,0							– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
	ISO-MgRE3Zn-2Zr[c]	ISO-MB65120	EZ33	S,K,L	min. max.	Rem.	– –	2,0 3,0	– 0,15	2,4 4,0	0,4 1,0							– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
	ISO-MgRE3Zn-Zr[d]	ISO-MB65130	EZ30	S,K,L	min. max.	Rem.	– –	0,10 0,8	– 0,10	2,0 3,7	0,4 1,0						– 0,5	– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
MgREAg-Zr	ISO-MgAg2RE2Zr[e]	ISO-MB65210	QE22	S,K,L	min. max.	Rem.	– –	– 0,2	– 0,15	2,0 3,0	0,4 1,0	2,0 3,0						– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
	ISO-MgRE2Ag-1Zr[e]	ISO-MB65220	EQ21	S,K,L	min. max.	Rem.	– –	– 0,2	– 0,15	1,5 3,0	0,4 1,0	1,3 1,7						– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
MgYREZr	ISO-MgY5RE4Zr[fg]	ISO-MB95310	WE54	S,K,L	min. max.	Rem.	– –	– 0,2	– 0,15	1,5 4,0	0,4 1,0		4,75 5,5		– 0,2			– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
	ISO-MgY4RE3Zr[fg]	ISO-MB95320	WE43	S,K,L	min. max.	Rem.	– –	– 0,2	– 0,15	2,4 4,4	0,4 1,0		3,7 4,3		– 0,2			– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –

Table 2 *(continued)*

Alloy group	Material designation			Composition % mass fraction																			
	Designation by symbols	Designation by numbers	ASTM designation	Casting process	Min. or max.	Mg	Al	Zn	Mn[a]	RE[b]	Zr	Ag	Y	Gd	Li	Sr	Ca	Si	Fe	Cu	Ni	Other each	Fe/Mn
MgG-dYZr	ISO-MgGd7Y6Zr	ISO-MB69110	VW76	K	min. max.	Rem.	– –	– –	– 0,03		0,2 0,5		5,5 6,5	6,5 7,5	– 0,2			– 0,01	– 0,010	– 0,02	– 0,005	– 0,01	– –
	ISO-MgG-d10Y3Zr	ISO-MB69120	VW103	S,K,L	min. max.	Rem.	– –	– 0,2	– –	8,3 10,7	0,4 1,0		2,3 3,7					– 0,01	– 0,01	– 0,03	– 0,005	– 0,01	– –
MgREG-dZr[h]	ISO-MgRE3G-d1Zr	ISO-MB65410	EV31	S,K,L	min. max.	Rem.	– –	0,2 0,5	– 0,03	2,6 3,1	0,4 1,0	– 0,05		1,0 1,7					– 0,01	– 0,01	– 0,002	– 0,01	– –

Table 3 — Mechanical properties of sand-cast magnesium alloys

Alloy group	Material designation			Temper designation	Tensile strength R_m MPa min.	0,2 % proof stress $R_{p0,2}$ MPa min.	Elongation A_{50} % min.	Brinell hardness HBW[<?>]
	Designation by symbols	Designation by numbers	ASTM designation					
MgAlZn	ISO-MgAl9Zn1(A)	ISO-MC21120	AZ91	F	160	90	2	50 to 65
				T4	240	110	6	55 to 70
				T6	240	150	2	60 to 90
	ISO-MgAl6Zn3	ISO-MC21130	AZ63	F	179	76	4	45 to 55
				T4	234	76	7	50 to 60
				T5	179	83	2	50 to 60
				T6	234	110	3	65 to 80
	ISO-MgAl8Zn1	ISO-MC21110	AZ81	T4	234	76	7	50 to 60
MgAlMn	ISO-MgAl10Mn	ISO-MC21240	AM100	T6	241	117	2	60 to80
MgZnCu	ISO-MgZn-6Cu3Mn	ISO-MC32110	ZC63	T6	195	125	2	55 to 65
MgZnREZr	ISO-MgZn4RE1Zr	ISO-MC35110	ZE41	T5	200	135	2,5	55 to 70
	ISO-MgRE3Zn-2Zr	ISO-MC65120	EZ33	T5	140	95	2,5	50 to 60
	ISO-MgRE3ZnZr	ISO-MC65130	EZ30	T6	245[<?>]	140[<?>]	4	65 to 80
MgREAgZr	ISO-MgAg2RE2Zr	ISO-MC65210	QE22	T6	240	175	2	70 to 90
	ISO-MgRE2Ag-1Zr	ISO-MC65220	EQ21	T6	240	175	2	70 to 90
MgYREZr	ISO-MgY5RE4Zr	ISO-MC95310	WE54	T6	250	170	2	80 to 90
	ISO-MgY4RE3Zr	ISO-MC95320	WE43	T6	220	170	2	75 to 90
	ISO-MgRE10Y3Zr	ISO-MC65310	VW103	T6	300[<?>]	220[<?>]	2	90 to 110
MgREGdZr	ISO-MgRE3Gd1Zr	ISO-MC65410	EV31	T6	248[<?>]	145[<?>]	2	70 to 90

NOTE Values given are for separately cast test pieces. The properties of the casting are expected to be 70 % of the values from separately cast test pieces for thicknesses of casting up to 20 mm.

Table 4 — Mechanical properties of permanent-mould cast magnesium alloys

Alloy group	Material designation			Temper designation	Tensile strength R_m MPa min.	0,2 % proof stress $R_{p0,2}$ MPa min.	Elongation A_{50} % min.	Brinell hardness HBW[a]
	Designation by symbols	Designation by numbers	ASTM designation					
MgAlZn	ISO-MgAl9Zn1(A)	ISO-MC21120	AZ91	F	160	110	2	55 to 70
				T4	240	120	6	55 to 70
				T6	240	150	2	60 to 90
	ISO-MgAl8Zn1	ISO-MC21110	AZ81	T4	234	76	7	50 to 60
MgAlMn	ISO-MgAl10Mn	ISO-MC21240	AM100	F	138	69	2	50 to 60
				T4	234	69	6	50 to 60
				T6	234	103	2	60 to80
MgZnCu	ISO-MgZn-6Cu3Mn	ISO-MC32110	ZC63	T6	195	125	2	55 to 65
MgZnREZr	ISO-MgZn4RE1Zr	ISO-MC35110	ZE41	T5	210	135	3	55 to 70
	ISO-MgRE3Zn-2Zr	ISO-MC65120	EZ33	T5	145	100	3	50 to 60
	ISO-MgRE3ZnZr	ISO-MC65130	EZ30	T6	245[b]	140[b]	4	65 to 80
MgREAgZr	ISO-MgAg2RE2Zr	ISO-MC65210	QE22	T6	240	175	2	70 to 90
	ISO-MgRE2Ag-1Zr	ISO-MC65220	EQ21	T6	240	175	2	70 to 90
MgYREZr	ISO-MgY5RE4Zr	ISO-MC95310	WE54	T6	250	170	2	80 to 90
	ISO-MgY4RE3Zr	ISO-MC95320	WE43	T6	220	170	2	75 to 90
	ISO-MgGd7Y6Zr	ISO-MC69110	VW76	T6	300[b]	200[b]	1	110 to 118
MgGdYZr	ISO-MgGd10Y3Zr	ISO-MC65310	VW103	T6	300[b]	220[b]	2	90 to 110
MgREGdZr	ISO-MgRE3Gd1Zr	ISO-MC65410	EV31	T6	248[c]	145[c]	2	70 to 90

[a] These values are for guidance only.

[b] This value applies to both separately cast test pieces and samples cut from castings, for thickness up to 20 mm.

[c] This value applies to both separately cast test pieces and samples cut from castings, for thickness up to 30 mm.

NOTE Values given are for separately cast test pieces. The properties of the casting are expected to be 70 % of the values from separately cast test pieces for thicknesses of casting up to 20 mm.

Table 5 — Mechanical properties of pressure die cast magnesium alloys

Alloy group	Material designation			Temper designation	Tensile strength Rm MPa	0,2 % proof stress Rp0,2 MPa	Elongation A_{50} %	Brinell hardness HBW
	Designation by symbols	Designation by numbers	ASTM designation					
MgAlZn	ISO-MgAl9Zn1(A)	ISO-MC21120	AZ91	F	200 to 260	140 to 170	1 to 9	65 to 85
	ISO-MgAl9Zn-1Ca	ISO-MC21122	AZ91	F	220 to 270	160 to 190	2 to 5	55 to 65
MgAlMn	ISO-MgAl2Mn	ISO-MC21210	AM20	F	150 to 220	80 to 100	8 to 25	40 to 55
	ISO-MgAl5Mn	ISO-MC21220	AM50	F	180 to 230	110 to 130	5 to 20	50 to 65
	ISO-MgAl6Mn	ISO-MC21230	AM60	F	190 to 250	120 to 150	4 to 18	55 to 70
MgAlSi	ISO-MgAl2Si	ISO-MC21310	AS21	F	170 to 230	110 to 130	4 to 14	50 to 70
	ISO-MgAl4Si	ISO-MC21320	AS41	F	200 to 250	120 to 150	3 to 12	55 to 80
MgAlSr	ISO-MgAl5Sr2	ISO-MC21410	AJ52	F	190 to 235	110 to 150	3 to 9	50 to 70
	ISO-MgAl6Sr2	ISO-MC21420	AJ62	F	200 to 260	120 to 160	3 to 10	55 to 80
MgAlCa	ISO-MgAl-5Ca2RE2	ISO-MC25120	AE62	F	225 to 255	160 to 175	5,5 to 8,5	45 to 55
	ISO-MgAl-6Ca2Sr	ISO-MC25130	AX62	F	200 to 250	165 to 185	3 to 6	70 to 80
MgAlRE[a]	ISO-MgAl4RE4	ISO-MC21410	AE44	F	220 to 260	130 to 160	6 to 15	60 to 80

[a] Values given are from separately cast 6 mm round tensile test bars (L_0 = 50 mm)

NOTE 1 The values given in this table are for guidance only, see 5.2.

NOTE 2 Values given are for separately cast test pieces of 20 mm^2 cross-sectional area and a minimum thickness of 2 mm.

Annex A
(informative)

List of ISO and equivalent international alloy designations

Material designation		European (in accordance with EN 1754)		USA	Germany		United Kingdom		France	Japan	China
In accordance with ISO 2092:1981[a]	**In accordance with** EN 1753	**Symbol**	**Number**	**ASTM**	**DIN**	**Previous common designation**	**BS**	**Previous common designation**	**NF**	**JIS**	**SAC**
ISO-MgAl8Zn1	ISO-MC21110	EN-MCMgAl8Zn1	EN-MC21110	AZ81	—	—	—	—	—	—	AZ81
ISO-MgAl9Zn1(A)	ISO-MC21120	EN-MC-MgAl9Zn1(A)	EN-MC21120	AZ91	MgAl9Zn	AZ91	MAG 7	C, AZ91	G-A9Z1	MD1D	AZ91
ISO-MgAl9Zn1(B)	ISO-MC21120	EN-MC-MgAl9Zn1(B)	EN-MC21120	AZ91	—	AZ91	—	AZ91	—	—	AZ91
ISO-MgAl9Zn-1Ca	ISO-MC21122	EN—MC-MgAl9Zn1Ca	—	AZ91	—	—	—	—	—	—	—
ISO-MgAl6Zn3	ISO-MC21130	EN-MC-MgAl6Zn3	EN-MC21130	AZ63	—	—	—	—	—	—	AZ63
ISO-MgAl2Mn	ISO-MC21210	EN-MC-MgAl2Mn	EN-MC21210	AM20	MgAl12Zn	AM20	—	—	—	MD5	AM20
ISO-MgAl5Mn	ISO-MC21220	EN-MC-MgAl5Mn	EN-MC21220	AM50	MgAl5Mn	AM50	—	—	—	MD4	AM50
ISO-MgAl6Mn	ISO-MC21230	EN-MC-MgAl6Mn	EN-MC21230	AM60	MgAl6Mn	AM60	—	—	—	MD2B	AM60
ISO-MgAl10Mn	ISO-MC21240	EN-MC-MgAl10Mn	EN-MC21240	AM100	—	—	—	—	—	MC15	AM100
ISO-MgAl2Si	ISO-MC21310	EN-MCMgAl-2Si	EN-MC21310	AS21	—	AS21	—	—	—	MD6	AS21
ISO-MgAl4Si	ISO-MC21320	EN-MCMgAl-4Si	EN-MC21320	AS41	MgAl4Si	AS41	—	—	G-A4S1	MD3B	AS41
ISO-MgAl5Sr2	ISO-MC21510	EN-MC-MgAl5Sr2	EN-MC21410	AJ52	—	—	—	—	—	—	AJ52
ISO-Mg6Sr2	ISO-MC21520	EN-MC-MgAl6Sr2	EN-MC21420	AJ62	—	—	—	—	—	—	AJ62
ISO-MgAl-5Ca2RE2	ISO-MC25120	EN-MCMgAl-5Ca2RE	—	AE62	—	—	—	—	—	—	—
ISO-MgAl-6Ca2Sr	ISO-MC25130	EN-MCMgAl-6Ca2Sr	—	AJ62	—	—	—	—	—	—	—
ISO-MgAl-4RE4	ISO-MC21410	EN-MCMgAl-4RE4	EN-MC21410	AE44	—	—	—	—	—	—	AE44

[a] Withdrawn in 2002.

Material designation		European (in accordance with EN 1754)		USA	Germany		United Kingdom		France	Japan	China
In accordance with ISO 2092:1981[a]	**In accordance with** EN 1753	**Symbol**	**Number**	**ASTM**	**DIN**	**Previous common designation**	**BS**	**Previous common designation**	**NF**	**JIS**	**SAC**
ISO-MgZn-6Cu3Mn	ISO-MC32110	EN-MCMgZn-6Cu3Mn	EN-MC32110	ZC63	—	—	—	ZC63	—	MCI 111	ZC63
ISO-MgZn-4RE1Zr	ISO-MC35110	EN-MCMgZn-4RE1Zr	EN-MC35110	ZE41	MgZn-4SE1Zr1	RZ5	MAG 5	RZ5	G-Z4TR	MCI 110	ZE41
ISO-MgRE3Zn-2Zr	ISO-MC65120	EN-MC-MgRE3Zn2Zr	EN-MC65120	EZ33	MgSE3Zn-2Zr1	ZRE1	MAG 6	ZRE1	G-TR3Z2	MCI 18	EZ33
ISO-MgRE3Zn-Zr	ISO-MC65130	EN-MC-MgRE3ZnZr	EN-MC65130	EZ30	—	—	—	—	—	—	EZ30
ISO-MgAg2RE2Zr	ISO-MC65210	EN-MCM-gAg2RE2Zr	EN-MC65210	QE22	MgAg-3SE2Zr1	MSR	MAG 12	MSR	G-Ag2,5	MCI 19	QE22
ISO-MgRE2Ag-1Zr	ISO-MC65220	EN-MC-MgRE2Ag1Zr	EN-MC65220	EQ21	—	—	MAG 13	EQ21	—	MCI 114	EQ21
ISO-MgY5RE4Zr	ISO-MC95310	EN-MCM-gY5RE4Zr	EN-MC95310	WE54	—	—	MAG 14	WE54	—	MCI 113	WE54
ISO-MgY4RE3Zr	ISO-MC95320	EN-MCM-gY4RE3Zr	EN-MC95320	WE43	—	—	—	WE43	—	MCI 112	WE43
ISO-MgRE7Y6Zr	ISO-MC69110	EN-MC-MgRE7Y6Zr	EN-MC69110	VW76	—	—	—	—	—	—	VW76S
ISO-MgRE10Y3Zr	ISO-MC65310	EN-MC-MgRE10Y3Zr	EN-MC65310	VW103	—	—	—	—	—	—	VW103Z
ISO-MgRE3Gd1Zr	ISO-MC65410	EN-MC-MgRE3Gd1Zr	EN-MC65410	EV31	—	—	—	—	—	—	EV31A

[a] Withdrawn in 2002.

Annex B
(informative)

Additional information regarding the manganese and iron content

Manganese is added to aluminium-containing magnesium alloys in order to reduce the solubility of iron in the liquid condition to values below the specified maximum content of 0,004 % in the ingots. The necessary content of manganese needed for this purpose depends on the solubility of manganese in the liquid condition at the chosen casting temperature of the specific alloy. At higher casting temperatures, a higher amount of manganese is required. However, it is recommended to keep the manganese content low.

Magnesium alloys are normally processed in equipment made of iron and steel and therefore the casting temperature of the ingots should ideally be chosen to match the temperature in the final casting process in order to achieve the required composition. Use of higher temperatures in the final casting process can lead to enrichment of the iron content in the melt, whereas lower temperatures may force a precipitation of manganese containing particles.

Annex C
(informative)

Additional information regarding maximum content of alloying elements and impurities in ingots and castings

Increased recycling of magnesium alloys requires a strict follow-up on chemical composition. The contents of nickel, copper, silicon, aluminium and zinc in a magnesium alloy melt cannot be reduced except by dilution. While iron is controlled by manganese addition, the contents of nickel, copper and silicon in ingots are kept at a minimum only by careful raw material selection. Specifically, to a avoid deterioration in corrosion properties caused by increased nickel content, nickel-containing processing equipment should be avoided. This leads to a general principle: the maximum contents of the elements that cannot be removed or lowered by normal recycling operations should be the same for both ingots and castings.

Bibliography

[1] ISO 2092:1981[1)], *Light metals and their alloys — Code of designation based on chemical symbols*

[2] EN 1753, *Magnesium and magnesium alloys — Magnesium alloy ingot and castings*

[3] EN 1754, *Magnesium and magnesium alloys — Magnesium and magnesium alloy anodes, ingots and castings — Designation system*

1) This document has been withdrawn.

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