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ISO 3506-7

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Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners —

Part 7: Flat washers with specified grades and property classes

Fixations — Caractéristiques mécaniques des fixations en acier inoxydable résistant à la corrosion —

Partie 7: Rondelles de forme plane de grades et classes de qualité spécifiés

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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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 2, *Fasteners*.

A list of all parts in the ISO 3506 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is issued as an addition to the ISO 3506 series to provide a single point of reference for flat stainless steel washers, in order to standardize market expectations for users, distributors and manufacturers.

For mechanical properties of flat washers made of carbon steel and alloy steel, see ISO 898-3.

Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners —

Part 7:
Flat washers with specified grades and property classes

1 Scope

This document specifies the mechanical and physical properties of flat washers made of corrosion resistant austenitic, ferritic and duplex stainless steels, designed to be used in bolted joints in combination with bolts, screws, studs and nuts with specified grades and property classes in accordance with ISO 3506-1 and ISO 3506-2.

These types of washers are also used with other stainless steel fasteners such as screws forming their own mating thread (see e.g. ISO 3506-4).

ISO 3506-6 provides general rules and additional technical information on suitable stainless steels and their properties (detailed properties of stainless steel grades, corrosion behaviour with regards to pitting, crevice and intergranular corrosion, magnetic properties, etc.)

WARNING — Washers conforming to the requirements of this document are tested at the ambient temperature range of 10 °C to 35 °C and are used in applications ranging from –20 °C to +150 °C. However, these washers are also used outside this range down to –196 °C and up to +300 °C for specific applications. It is possible that they do not retain the specified mechanical and physical properties at lower and/or elevated temperatures. Therefore, it is the responsibility of the user to determine the appropriate choices based on the service environment conditions of the assembly (see also Clauses 6 and 7).

This document applies to the following flat non-captive and captive washers with thickness 0,2 mm to 6 mm (see 5.1):

— plain washers and flat washers (with or without knurls, ribs or chamfers),

— square washers,

— square hole washers,

— shaped plates.

The term “washer” is used in the following for all types of washers and plates within the scope of this document.

This document does not specify requirements for functional properties such as weldability.

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.

ISO 1891-4, *Fasteners — Vocabulary — Part 4: Control, inspection, delivery, acceptance and quality*

ISO 3506-1, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 1: Bolts, screws and studs with specified grades and property classes*

ISO 3506-2, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 2: Nuts with specified grades and property classes*

ISO 3506-6, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 6: General rules for the selection of stainless steels and nickel alloys for fasteners*

ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method*

ISO 16228, *Fasteners - Types of inspection documents*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
stainless steel
steel with at least 10,5 % (mass fraction) of chromium (Cr) and maximum 1,2 % (mass fraction) of carbon (C)

[SOURCE: ISO 3506-1:2020, 3.5]

3.2
austenitic stainless steel
stainless steel (3.1) with high amounts of chromium and nickel, which usually cannot be hardened by heat treatment, providing excellent resistance to corrosion, good ductility, and usually low or non-magnetic properties.

[SOURCE: ISO 3506-1:2020, 3.6]

3.3
ferritic stainless steel
stainless steel (3.1) containing less than 0,1 % carbon and typically 11 % to 18 % chromium, which usually cannot be hardened by heat treatment, and with highly magnetic properties.

[SOURCE: ISO 3506-1:2020, 3.8]

3.4
duplex stainless steel
stainless steel (3.1) with a micro-structure that includes both austenitic and ferritic phases, providing excellent resistance to corrosion, containing a higher amount of chromium and a reduced quantity of nickel compared to austenitic steel, with high strength, and with magnetic properties.

[SOURCE: ISO 3506-1:2020, 3.9]

4 Symbols

F	test force for Vickers hardness determination, N
t_{nom}	nominal thickness of washer, mm
t_{eff}	effective thickness of the material measured on the washer, mm

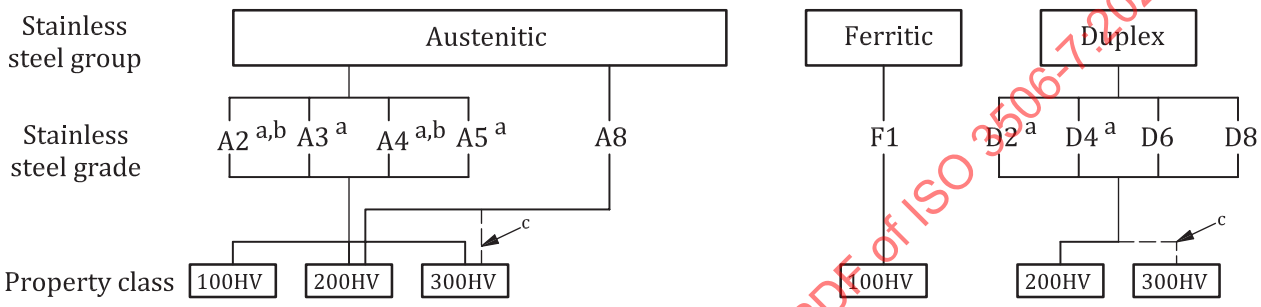
5 Designation system for stainless steel grades and property classes of washers, and combination with bolts, screws, studs and nuts

5.1 General

The designation system for stainless steel washers consists of two blocks, separated by a hyphen: the stainless steel grade and the property class, as specified in Figure 1.

The standard combinations in Figure 1 shall be considered together with Table 1, which shows thickness limits for each combination.

This designation system may be used for sizes outside the limits specified in this document, provided that all applicable chemical, mechanical and physical requirements are met. For non-standard fasteners, it is recommended that a fastener expert be consulted.



[a] Washers made of cold worked material which are subjected to tensile stresses (e.g. when they are used on slotted or enlarged holes) in service environment with chloride are more sensitive to stress corrosion cracking (SCC). For information regarding resistance to stress corrosion cracking, see ISO 3506-6.

[b] For low carbon austenitic stainless steels with carbon content not exceeding 0,030 %, washers shall additionally be designated with the letter "L" just after the grade. Example: A4L-200HV.

[c] Critical availability of flat raw materials in relation to this property class: thickness availability shall be checked between the purchaser and the manufacturer before ordering (see Table 1).

Figure 1 — Designation system for stainless steel washers

Although a great number of stainless steel grades combined with property classes are specified in this document for washers, this does not mean that all combinations are appropriate for all bolts/nuts/washers assemblies: see appropriate combinations in 5.4.

NOTE Martensitic stainless steels and austenitic stainless steel of grade A1 are not included in Figure 1 due to a lack of availability for such flat raw materials on the market.

Table 1 — Washer thickness limits in relation to stainless steel grades and property classes

Property class	Maximum thickness for t_{nom} (mm)									
	Austenitic					Ferritic	Duplex			
	A2	A3	A4	A5	A8	F1	D2	D4	D6	D8
100HV	6	6	6	6	[a]	6	[a]			
200HV	4	4	4	4	6	[b]	6	6	6	6
300HV	3	3	3	3	[c]	[b]	[c]			

[a] Property class 100HV does not apply as raw materials typically result in hardness values above 200 HV.

[b] Property classes 200HV and 300HV does not apply as typical maximum hardness is below 200 HV.

[c] Critical availability of flat raw materials in relation to this property class: thickness availability shall be checked between the purchaser and the manufacturer before ordering.

The achievable thickness for each combination of stainless steel grade and property class specified in Table 1 is limited because the achievable mechanical properties of the washers are limited by the raw material properties and manufacturing processes.

The marking, labelling and designation of washers with the stainless steel grade and the property class shall be as specified in Clause 10.

The combination of washers with bolts, screws, studs and nuts with regards to their stainless steel grades and property classes shall be as specified in 5.4.

5.2 Designation of stainless steel grades (first block)

The designation of the stainless steel grade (first block) consists of one letter, which specifies the stainless steel group:

— **A** for Austenitic steel,

— **F** for Ferritic steel,

— **D** for Duplex steel (austenitic-ferritic),

and

— a digit, which specifies the range of chemical compositions within this stainless steel group.

The chemical compositions of stainless steel groups and grades classified in Figure 1 are specified in Table 3.

5.3 Designation of property classes (second block)

The designation of the property class (second block) consists of two parts as specified in Table 4:

— the number to the left is the minimum Vickers hardness value,

and

— the letters HV to the right represent Vickers hardness.

EXAMPLE 1 **A2-100HV** specifies a washer in austenitic stainless steel of grade A2, with minimum hardness of 100HV.

EXAMPLE 2 **D6-200HV** specifies a washer in duplex stainless steel of grade D6, with minimum hardness of 200HV.

5.4 Combination of washers with bolts, screws, studs and nuts

5.4.1 Stainless steel grade combination

For corrosion resistance purpose, bolts, screws, studs and nuts should be mated with washers of the same stainless steel grade (e.g. bolts and nuts A2 with washers A2, etc.). Other combinations are possible (e.g. washers A2 with bolts D2), providing that:

— the component with the lowest corrosion resistance shall always be taken into account,

— the risk of galling during tightening should be considered, and

— it is strongly recommended that an experienced fastener metallurgist be consulted.

For corrosion resistance, see also 6.3.

5.4.2 Property class combination

Recommended combinations of property classes for stainless steel washers with bolts, screws, studs and nuts are specified in Table 2. RC represents the most suitable combinations with regards to the mechanical properties of the fasteners, however other combinations are possible.

Table 2 — Stainless steel fasteners : combination of property classes with regards to mechanical properties

Threaded fasteners in accordance with ISO 3506-1 or ISO 3506-2		Mating property class for washers		
Steel group	Property class of bolts, screws, studs, regular and high nuts	100HV	200HV	300HV
Austenitic	50	RC	a	a
	70	b	RC	a
	80	c	RC	a
	100	c	b	RC
Ferritic	45	RC	a	a
	60	RC	a	a
Duplex	70	b	RC	a
	80	c	RC	a
	100	c	b	RC

RC = Recommended Combination

[a] This combination can also be used for bolted joints.

[b] This combination can also be used provided that joint design or installation conditions are checked.

[c] Combinations in grey zone shall not be used, because washer hardness is too low in relation to the intended use of bolts, screws, studs and nuts of the related property class.

The recommended combinations for thin nuts is with washers of property class 100HV (however, higher washer property classes can also be used).

6 Materials

6.1 Chemical composition

Table 3 specifies the limits for chemical composition of the stainless steel grades for fasteners. The chemical composition shall be assessed in accordance with the relevant International Standards.

The final choice of the chemical composition within the specified stainless steel grade is at the discretion of the manufacturer, unless otherwise agreed between the purchaser and the manufacturer.

The stainless steel grade suitable for an application shall be selected in accordance with ISO 3506-6. Tables A.1 and A.2 in Annex A also give the most widely used standardized stainless steel materials for washers (see also bibliography for additional material information). For corrosion resistance, see also 6.2 and 6.3.

NOTE When washers are intended to be used in applications outside the range of –20 °C to +150 °C, several factors need to be taken into account (e.g. stainless steel chemical composition, duration of exposure at lower or elevated temperature, the effect of the temperature on the fastener mechanical properties and clamped parts).

Table 3 — Stainless steel grades — Chemical composition

Stainless steel grade		Chemical composition [a] (cast analysis, % by mass) [b]										Other elements and notes
		C	Si	Mn	P	S	Cr	Mo	Ni	Cu	N	
Austenitic	**A2**	0,10	1,00	2,00	0,050	0,030	15,0 to 20,0	— [c]	8,0 to 19,0	4,0	—	[d,e]
	A3	0,08	1,00	2,00	0,045	0,030	17,0 to 19,0	— [c]	9,0 to 12,0	1,00	—	5C ≤ Ti ≤ 0,80 and/or 10C ≤ Nb ≤ 1,00
	A4	0,08	1,00	2,00	0,045	0,030	16,0 to 18,5	2,00 to 3,00	10,0 to 15,0	4,0	—	[e, f]
	A5	0,08	1,00	2,00	0,045	0,030	16,0 to 18,5	2,00 to 3,00	10,5 to 14,0	1,00	—	5C ≤ Ti ≤ 0,80 and/or 10C ≤ Nb ≤ 1,00 [f]
	A8	0,030	1,00	2,00	0,040	0,030	19,0 to 22,0	6,0 to 7,0	17,5 to 26,0	1,50	—	—
Ferritic	**F1**	0,08	1,00	1,00	0,040	0,030	15,0 to 18,0	— [c]	1,00	—	—	[g]
Duplex	**D2**	0,040	1,00	6,0	0,040	0,030	19,0 to 24,0	0,10 to 1,00	1,50 to 5,5	3,00	0,05 to 0,20	Cr+3,3Mo+16 N ≤ 24,0 [h]
	D4	0,040	1,00	6,0	0,040	0,030	21,0 to 25,0	0,10 to 2,00	1,00 to 5,5	3,00	0,05 to 0,30	24,0 < Cr+3,3Mo+16 N [h]
	D6	0,030	1,00	2,00	0,040	0,015	21,0 to 23,0	2,50 to 3,5	4,5 to 6,5	—	0,08 to 0,35	—
	D8	0,030	1,00	2,00	0,035	0,015	24,0 to 26,0	3,00 to 4,5	6,0 to 8,0	2,50	0,20 to 0,35	W ≤ 1,00

[a] According to material standards, values are maximum unless otherwise specified; the number of digits shown is in accordance with usual rules, see e.g. EN 10088-1.

[b] In case of dispute, product analysis applies.

[c] Molybdenum may be present at the discretion of the manufacturer. However, if for some applications limiting of the molybdenum content is essential, this shall be stated at the time of ordering by the purchaser.

[d] If the chromium content is below 17,0 %, the minimum nickel content should be 12,0 %. In case of washers, the minimum nickel content can be reduced to 6 %.

[e] For austenitic stainless steels having a maximum carbon content of 0,030 %, nitrogen may be present but shall not exceed 0,22 %.

[f] At the discretion of the manufacturer, the carbon content may be higher as necessary in order to achieve the specified mechanical and physical properties, but shall not exceed 0,12 %.

[g] Titanium and/or niobium may be included to improve corrosion resistance.

[h] This formula is used solely for the purpose of classifying duplex steels in accordance with this document (it is not intended to be used as a selection criterion for corrosion resistance).

6.2 Surface condition (finish and/or coating)

Unless otherwise specified, washers in accordance with this document shall be supplied clean and bright.

For maximum corrosion resistance, an additional passivation process may be performed, e.g. in accordance with ISO 16048. Additional passivation, if any, shall be required by the purchaser at the time of the order. Washers that are passivated in accordance with ISO 16048 may additionally be referenced on the label with the letter “P” just after the property class symbol (see 10.3).

NOTE 1 Washers with additional passivation do not always show a bright surface finish.

Washers are often used with bolts, screws, studs and nuts in bolted joints where the preload is achieved by torque tightening. Therefore, lubrication of stainless steel fasteners is recommended in order to avoid galling during tightening.

NOTE 2 Several parameters increase the risk of galling for stainless steel fasteners in bolted assemblies during tightening such as thread damage, high preload, high tightening speed.

NOTE 3 For the time being, requirements for surface discontinuities and torque/clamp force properties are not specified in International Standards for stainless steel fasteners.

A controlled torque/clamp force relationship can be obtained for stainless steel fasteners by means of an adequate finish, either just a lubricant or with a coating, top coat and/or sealer including lubricant. Additional lubrication, if any, shall be required by the purchaser at the time of the order. Washers that are lubricated may additionally be referenced on the label with the letters "Lu" (see 10.3). In conjunction, appropriate measures and means of tightening should be selected in order to achieve the required preload.

When other specific requirements are necessary, they shall be agreed between the supplier and the purchaser at the time of the order.

6.3 Corrosion resistance

The stainless steel grade suitable for an application shall be selected in accordance with ISO 3506-6, by taking into account the corrosion resistance in the expected corrosive service environment.

Details on the different types of corrosion (stress corrosion cracking, pitting and crevice corrosion, intergranular corrosion) are given in ISO 3506-6.

Galvanic corrosion (also called contact corrosion) should also be considered when designing a joint where materials with different electrical potentials are assembled (stainless steel fasteners and assembled parts), if the joint is exposed to a wet or humid atmosphere and/or if condensation may occur.

When using stainless steel fasteners with non-stainless steel parts in a joint, e.g. galvanized steels, it is advised that the use of isolation components be considered in order to avoid galvanic corrosion.

6.4 Magnetic properties

Details of magnetic properties are given in ISO 3506-6. Austenitic stainless steel fasteners in annealed condition are usually non-magnetic. Still after work hardening, magnetism can be present.

7 Requirements for mechanical and physical properties

When tested at ambient temperature, washers with specified property class shall meet the requirements specified in Table 4, regardless of which tests are performed during manufacture or final inspection.

Table 4 — Mechanical and physical properties for stainless steel washers

Property class		100HV	200HV	300HV
Vickers hardness, HV	min.	100	200	300
	max.	200 [a]	300	370

[a] Exceeding the maximum hardness up to 250 HV for property class 100HV shall not be cause of rejection.

8 Inspection

8.1 Manufacturer's inspection

Washers produced in accordance with this document shall be capable of conforming to all applicable requirements specified in Clauses 6 and 7, when using the applicable test method specified in Clause 9.

This document does not mandate which of the tests the manufacturer shall perform on each manufacturing lot. It is the responsibility of the manufacturer to apply suitable methods of their choice, such as in-process control or final inspection, to ensure that the manufactured lot does indeed conform to all of the specified requirements. For additional information, see ISO 16426.

In case of dispute, the test method in accordance with Clause 9 shall apply.

8.2 Supplier's inspection

The supplier may control and/or test the washers they provide using methods of their choice (periodic evaluation of the manufacturer, checking of test results from the manufacturer, tests on the washers themselves, etc.), provided the chemical, mechanical and physical properties specified in Clauses 6 and 7 are met.

In case of dispute, the test method in accordance with Clause 9 shall apply.

8.3 Purchaser's inspection

The purchaser may control and/or test the delivered washers by using the test method specified in Clause 9.

In case of dispute, the test method in accordance with Clause 9 shall apply.

8.4 Delivery of test results

If the purchaser requires test results from the supplier, the type of test report shall be agreed upon at the time of order. It shall be established in accordance with ISO 16228, unless otherwise specified. The type of test report (F2.2, F3.1 or F3.2) and any additional or specific test shall also be specified by the purchaser and agreed upon at the time of order.

9 Hardness test

9.1 General

The purpose of this test is to determine that the hardness on the surface of the washer fulfils the requirements specified in Table 4 (minimum and maximum values).

This test applies to all types of washers within the scope of this document.

9.2 Test procedure

Washers shall be tested in the as-received condition.

The hardness test shall be carried out in accordance with ISO 6507-1. The choice of the test force *F* for the Vickers hardness test depends on the washer property class and thickness, see Table 5.

Table 5 — Test forces for Vickers surface hardness on washers

Thickness, t_{eff} mm	**Test force**, F [a]		
	Property class		
	100HV	200HV	300HV
≥ 0,60	HV 10	HV 10	HV 30
0,45 ≤ t_{eff} < 0,60	HV 5		HV 10
0,35 ≤ t_{eff} < 0,45	HV 2	HV 5	
0,30 ≤ t_{eff} < 0,35			HV 5
0,25 ≤ t_{eff} < 0,30	HV 1	HV 2	
0,20 ≤ t_{eff} < 0,25			HV 2
0,15 ≤ t_{eff} < 0,20	—	HV 1	
0,10 ≤ t_{eff} < 0,15		—	HV 1
[a] Based on the formula $F = (t_{eff}^2 \cdot HV)/0,39$			

EXAMPLE Washer of property class 200HV with 1 mm in thickness: test force of HV 10.

For washers with a thickness t_{eff} ≤ 0,5 mm a lower test force may be used but it shall not be less than HV 1.

The hardness shall be determined at the mid-position of the washer face after suitable preparation. The hardness value shall be the mean of at least three readings on the same face of the washer.

In case of dispute, both faces of the washer shall be tested.

9.3 Requirements

The hardness value shall be in accordance with Table 4.

10 Marking and labelling

10.1 General

Stainless steel washers manufactured to the requirements of this document shall be designated in accordance with the designation system specified in Clause 5.

The designation system specified in Clause 5 shall only be used and marking shall only be affixed in accordance with this Clause 10 when all applicable requirements of this document are met:

— chemical composition as specified in Table 3;

and

— mechanical and physical properties specified in Clause 7, when tested in accordance with Clause 9.

Marking on the washers is not required but left to the manufacturer's choice. If marking is performed, it shall be in accordance with 10.2.

Marking of the packages through labelling is always required and shall be in accordance with 10.3.

10.2 Marking on the washers

10.2.1 General

If marking is performed on the washers, the following applies.

The washer marking shall be included during the manufacturing process. Marking shall result in a durable identification on the washers. The marking process (by indentation, laser, spray, etc.) is left to the manufacturer's choice, but embossed marking shall not be used.

Users are advised that indented marking can alter the torque/clamp force relationship of the bolt/nut assembly or can create a stress concentration point susceptible to initiate cracks in the washer.

Marking on the washers includes:

— the stainless steel grade, in accordance with Clause 5, with the letter "L" as relevant (see Figure 1);

— the property class, in accordance with 10.2.2;

— the manufacturer's identification mark, as an option.

A distributor who distributes washers that are marked with their own identification mark shall be considered to be the manufacturer.

10.2.2 Marking of the property class on the washers

Marking of the property class consist in:

— the property class itself, in accordance with Table 6, or;

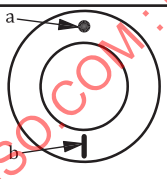
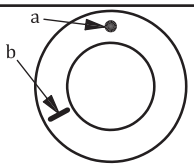
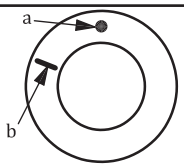
— the property class symbol, in accordance with Table 6, or;

— the property class symbol by using the clock-face marking system, in accordance with Table 7.

Table 6 — Property class marking for stainless steel washers

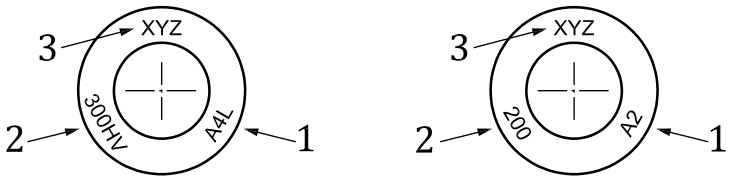
Property class	100HV	200HV	300HV
Property class symbol	100	200	300

Table 7 — Clock-face marking system for stainless steel washers

Property class	100HV	200HV	300HV
Marking symbol	 Dash at 6 o'clock position	 Dash at 8 o'clock position	 Dash at 10 o'clock position
[a] The twelve o'clock position shall be marked by a reference point (or by the manufacturer's identification mark, if any). [b] The property class shall be marked with a dash, its length, width and depth are at the manufacturer's discretion (see also 10.2)			

10.2.3 Examples of marking on the washers

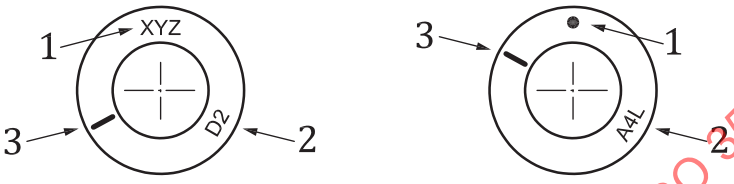
Examples of marking for stainless steel washers are shown in Figure 2 and Figure 3.



Key

1 stainless steel grade
2 property class or property class symbol
3 optional manufacturer's identification mark

Figure 2 — Examples of "full marking" for washers



Key

1 twelve o'clock position by a reference point, or by the optional manufacturer's identification mark
2 stainless steel grade
3 property class dash symbol

Figure 3 — Examples of clock-face marking for washers

10.3 Marking of the packages (labelling)

All packages for all types of washers of all sizes within the scope of this document shall be marked through labelling. The labelling shall include at least:

— the manufacturer's and/or distributor's identification mark and/or name;

— the stainless steel grade;

— the letter "L" (just after the grade) for low carbon austenitic stainless steel, as specified in Clause 5 (see Figure 1, footnote b),

— the property class (after the hyphen) in accordance with Table 6;

— the optional letter "P" (after the property class) when washers have been passivated, as specified in 6.2;

— the optional letters "Lu" (in the last position in the designation) when washers have been lubricated, as specified in 6.2;

and

— the manufacturing lot number, as specified in ISO 1891-4.