
**Cold-reduced carbon steel sheet for
vitreous enamelling**

*Tôles en acier au carbone laminées à froid pour émaillage par
vitrification*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 5001 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 12, *Continuous mill flat rolled products*.

This fifth edition cancels and replaces the fourth edition (ISO 5001:2007), which has been technically revised.

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Cold-reduced carbon steel sheet for vitreous enamelling

1 Scope

This International Standard applies to cold-reduced carbon steel sheet of commercial and drawing qualities for vitreous enamelling, where the surface of the sheet and chemical composition of the base metal are of prime importance.

2 Normative references

The following referenced documents are indispensable for the application 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 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 16162, *Cold-rolled steel sheet products — Dimensional and shape tolerances*

3 Terms and definitions

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

3.1

steel sheet for vitreous enamelling

product obtained from cold-reduced steel sheet having a matte finish and for which proper chemical composition and processing are selected by the producer to prepare the sheet for both fabrication and vitreous enamelling.

NOTE It is produced in thicknesses of 0,35 mm and thicker (commonly up to 3 mm) and in widths of 600 mm and wider in coils and cut lengths. Sheet for vitreous enamelling less than 600 mm wide may be slit from wide sheet and will be considered sheet.

3.2

skin pass

final light cold rolling of cold-reduced fully processed sheet

NOTE The purpose of the final light cold rolling is one or more of the following:

- to temporarily minimize the occurrence of stretcher strains (Lüders' lines) or fluting during fabrication of finished parts;
- to obtain the required surface finish for vitreous enamelling;
- to control shape.

3.3

stabilized interstitial steel

extra-low-carbon steel in which all interstitial elements are combined with titanium and/or equivalent elements

3.4 Types for vitreous enamelling

3.4.1

type 1

sheet steel suitable for two-coat enamelling

NOTE The base metal of this type loses strength after firing the enamel, and if this is a problem, the producer should be consulted.

3.4.2

type 2

very-low-carbon sheet steel suitable for direct cover coat (one coat) enamelling and also for two-coat enamelling for special applications (sag resistance)

NOTE It should be noted that this type loses strength after firing and, if this should be a problem, the producer should be consulted. See Table 1 footnote "a" for other special application details.

3.4.3

type 3

interstitial-free sheet steel with extremely low carbon content and excellent formability, suitable for one- or two-coat enamelling

3.5

lot

a lot consisting of 50 tonnes or less of the same quality rolled to the same thickness and condition

4 Quality designations for steel sheets for vitreous enamelling

4.1 Commercial-quality sheet (VE01) is intended for general fabricating purposes where sheet is used in the flat form, or for bending or moderate forming.

4.2 Drawing-quality sheet (VE02, VE03, VE04 and VE05) is intended for drawing and severe forming. It is furnished according to all requirements of this International Standard or, by agreement when ordered, to fabricate an identified part, in which case the mechanical properties of Table 4 do not apply. If strain ageing is to be minimized, grade VE04 or VE05 should be specified.

Drawing qualities are identified as follows:

VE02 – drawing quality;

VE03 – deep-drawing quality;

VE04 – deep-drawing quality aluminium-killed;

VE05 – extra-deep-drawing quality (stabilized interstitial-free).

4.3 The designations in 4.1 and 4.2 include the qualities of sheet steel for vitreous enamelling. The designation VE represents "vitreous enamelling" similar to CR "cold reduced". The numbers 01, 02, 03, 04 and 05 are common to other standards, indicating the qualities of commercial, drawing, deep-drawing, deep-drawing aluminium-killed and extra-deep-drawing interstitial-free.

5 Conditions of manufacture

5.1 Steelmaking

The processes used in making the steel and in manufacturing sheet for vitreous enamelling are left to the discretion of the producer. When requested, the purchaser shall be informed of the steelmaking process being used.

5.2 Chemical composition

The chemical composition (heat analysis) shall not exceed the values given in Tables 1 and 2.

Table 1 — Chemical composition

Element	Composition, max. % (mass fraction)		
	Vitreous enamelling types and quality designations		
	Type 1	Type 2 ^a	Type 3
		Aluminium-killed	Stabilized interstitial-free
Carbon	0,05	0,02	0,008
Manganese	0,50	0,50	0,40
Phosphorus	0,040	0,040	0,040
Sulfur	0,040	0,030	0,030
Nb, Ti, Va		b	0,15 ^c

a For some one-coat applications, the carbon content must be reduced to less than 0,01 % by means of appropriate annealing practices to obtain satisfactory enamelling performance. In such cases, since the decarburization process occurs after the melting process, heat analysis is not appropriate and product analysis can be used to check the carbon content. When supplied from interstitial-free steel, quality applications VE03 and VE04 can also qualify for enamelling application requiring reduced carbon levels.

b Microalloys are permitted to meet special customer requirements.

c Niobium, titanium and vanadium, or in various combinations, are made to combine with the carbon and nitrogen to produce interstitial-free steel.

Table 2 — Limits on additional chemical elements, % (mass fraction)

Element	Cu ^a max.	Ni ^a max.	Cr ^{ab} max.	Mo ^{ab} max.	Nb ^c max.	V ^{cd} max.	Ti ^d max.
Heat analysis	0,20	0,20	0,15	0,06	0,008	0,008	0,008
Product analysis	0,23	0,23	0,19	0,07	0,018	0,018	0,018

Each of the elements listed in this table shall be included in the report of the heat analysis. When the amount of copper, nickel, chromium or molybdenum present is less than 0,02 %, the analysis result may be reported as < 0,02 %.

a The sum of copper, nickel, chromium and molybdenum shall not exceed 0,50 % on the heat analysis. When one or more of these elements are specified, the sum does not apply, in which case, only the individual limits on the remaining elements apply.

b The sum of chromium and molybdenum shall not exceed 0,16 % on heat analysis. When one or more of these elements are specified, the sum does not apply; in which case, only the individual limits on the remaining elements apply.

c For interstitial-free steels only, the value of 0,15 % titanium, and 0,10 % maximum for niobium and vanadium, are acceptable to ensure that the carbon and nitrogen are fully stabilized.

d Heat analysis greater than 0,008 % (mass fraction) may be supplied after agreement between the producer and purchaser.

5.3 Chemical analysis

5.3.1 Heat analysis

An analysis of each heat of steel shall be made by the manufacturer to determine compliance with the requirements given in Tables 1 and 2. When requested, this analysis shall be reported to the purchaser or his representative.

5.3.2 Product analysis

A product analysis may be made by the purchaser to verify the specified analysis of the semi-finished or finished steel and shall take into consideration any normal heterogeneity. Non-killed steels (such as rimmed or capped) are not technologically suitable for verification analysis.

For killed steels, the sampling method shall be agreed between the manufacturer and the purchaser at the time of ordering. The product analysis tolerances shall be in accordance with Table 3.

Table 3 — Product analysis tolerances, % (mass fraction)

Element	Maximum of specified element	Tolerance over maximum specified
C	0,008	0,001
	0,02	0,005
	0,05	0,01
Mn	0,50	0,03
P	0,04	0,01
S	0,02	0,01
Ti or Nb or Va	0,15	0,01

NOTE The above maximum tolerance is the allowable excess over the specified requirement and not the heat analysis.

5.4 Weldability

The product is easily welded. Certain precautions may be advisable due to the very low hardness of VE02, VE03, VE04 and VE05 material.

5.5 Application

Steel sheet for vitreous enamelling shall be identified for fabrication by the name of the part or by the intended application. Steel sheet of drawing quality (VE02, VE03, VE04 or VE05) may be produced to make an identified part previously agreed upon between the manufacturer and purchaser. In this case, the part name, the details of fabrication, the vitreous enamelling practice and any special requirements (freedom from stretcher strain or fluting) shall be specified, and the mechanical properties of Table 4 do not apply.

5.6 Mechanical properties

Except when ordered as an identified part as explained in 5.5, the mechanical properties of the steel, at the time the steel is made available for shipment, shall be as stated in Table 4. The properties shall be determined on test pieces obtained in accordance with the requirements of Clause 7. Prolonged storage of the sheet can cause a change in mechanical properties (increase in hardness and decrease in elongation, leading to a decrease in drawability). To minimize this effect, quality VE04 or VE05 should be specified.

Table 4 — Mechanical property requirements^a

Base metal quality		R_m^b max. MPa	A^c min. %		\bar{r}^d min.	\bar{n}^e min.
			$L_0 = 80$ mm	$L_0 = 50$ mm		
Designation	Name					
VE01	Commercial ^f	410	27	28	—	—
VE02	Drawing	370	30	31	—	—
VE03	Deep-drawing	350	34	35	—	—
VE04	Deep-drawing	350	36	37	—	—
VE05	Extra-deep-drawing	350	38	38	1,6	0,20

NOTE 1 MPa = 1 N/mm².

^a R_m tensile strength
 A percent elongation after fracture
 L_0 gauge length on test piece
 \bar{r} plastic strain ratio (indicator of the drawability of the product)
 \bar{n} tensile strain hardening exponent (indicator of the stretchability of the product)

^b For qualities VE02, VE03 and VE04, the minimum tensile strength would normally be expected to be 270 MPa. All tensile strength values are determined to the nearest 10 MPa. For design purposes, the lower limit of R_e may be assumed to be 140 MPa for VE01, VE02, VE03 and VE04 and 120 MPa for VE05.

^c For material up to and including 0,6 mm in thickness, the elongation values in this table shall be reduced by 1.

^d \bar{r} can also be written as r bar.

^e \bar{n} can also be written as n bar.

^f Mechanical properties are not generally determined for commercial-quality products and the values in this table are for information only.

5.7 Strain ageing

Steel sheet for vitreous enamelling in qualities VE01, VE02 and VE03 supplied in the skin-passed condition tends to strain age and this may lead to the following:

- surface markings from stretcher strain (Lüders' lines) or fluting when the steel is formed;
- deterioration in ductility.

Steel sheet for vitreous enamelling in quality VE04 supplied in the skin-passed condition may be subject to strain ageing under certain conditions.

Strain ageing can be caused by either carbon or nitrogen atoms which exist in a supersaturated solid solution and diffuse to dislocation sites, this diffusion depending on time and temperature. The addition of aluminium in sufficient quantities causes the removal of nitrogen from solid solution as particles of aluminium nitride. This practice tends to minimize room-temperature ageing due to nitrogen and results in the general understanding that cold-rolled aluminium-killed steel is free of ageing concerns generally associated with VE04. However, carbon, which is usually not retained in solid solution with the slow cooling typical of batch annealing, can be retained in solid solution during the continuous-annealing process. If the annealing process and steel chemistry are not properly controlled, such material with carbon remaining in solid solution after continuous annealing may result and such material will strain age at room temperature and the problems noted above can occur. Chemical stabilization, as with VE05, prevents this problem as does proper processing with VE04 material.

Because of these factors, it is essential that the period between final processing at the mill and fabrication be kept to a minimum. Rotation of stock, by using the oldest material first, is important. Stocking of such steels for extended periods of time should be avoided and for optimum performance should not exceed six weeks.

For skin-passed sheet in qualities VE01, VE02 and VE03, and with due regard to the foregoing precautions, reasonable freedom can be achieved by effective roller levelling immediately prior to fabrication at the

purchaser's plant. Freedom from stretcher strain and fluting for a period of six months can be achieved by the supply of skin-passed non-ageing steels. Qualities VE04 or VE05 shall be specified in such cases where Lüders' lines are not acceptable and where roller levelling is not possible.

5.8 Surface condition

The surface of steel sheet for vitreous enamelling shall be reasonably free of imperfections that would affect the appearance of the enamelled product.

5.9 Surface finish

Steel sheet for vitreous enamelling is produced in a matte finish with a degree of roughness depending on the end application.

5.10 Surface quality

5.10.1 General

Products shall be supplied with either surface quality A or surface quality B.

5.10.2 Surface quality A (unexposed)

Imperfections such as pores, slight imperfections, small marks, minor scratches and slight colouring which do not affect the formability or the application of surface coatings are permitted.

5.10.3 Surface quality B (exposed)

The better surface shall be free of imperfections which might affect the uniform appearance of quality coating. The other surface shall at least conform to surface quality A.

In the case of delivery of coil and slit coil, the percentage of defects may be greater than in the case of delivery in sheet or cut lengths. This shall be taken into account by the purchaser, and the percentage of admissible surface defects may be agreed at the time of the enquiry and order. Unless otherwise agreed, one of the surfaces of the product shall comply with the specified requirements. The other surface shall be such that, during subsequent treatment, it does not have a deleterious effect on the better surface.

5.11 Oiling

As a deterrent to rusting, a coating of oil is usually applied to the product. The oil is not intended as a drawing or forming lubricant and shall be easily removable using degreasing chemicals. The product may be ordered unoiled, if required, in which case the supplier shall have limited responsibility if oxidation occurs.

6 Dimensional and shape tolerances

Dimensional tolerances applicable to steel sheet for vitreous enamelling shall be as given in ISO 16162.

7 Tensile test sampling

When ordered according to mechanical properties, one representative sample for the tensile test required in Table 1 shall be taken from each lot of sheet for shipment.

8 Tensile test requirements

The tensile test shall be carried out in accordance with ISO 6892-1. Transverse test pieces shall be taken mid-way between the centre and edge of the sheet as rolled.

9 Retests

If a test does not give the specified results, two more tests shall be carried out on samples taken at random from the same lot. Both retests shall conform to the requirements of this International Standard; otherwise, the lot may be rejected.

10 Resubmission

Products that have been rejected during an earlier inspection because of unsatisfactory properties may be resubmitted by the manufacturer after the manufacturer has subjected them to a suitable treatment (for example -selection, heat treatment) which, on request, will be indicated to the purchaser. In this case, testing shall be carried out as if it applied to a new lot. The manufacturer also has the right to present the rejected product to a new examination for compliance with the requirements for other types, qualities or applications.

11 Workmanship

Steel sheet for vitreous enamelling in cut lengths shall be free from amounts of laminations, surface flaws and other imperfections that would be detrimental to subsequent appropriate processing. Processing for shipment in coils does not afford the manufacturer the opportunity to readily observe or remove defective portions, as can be done with the cut-length product.

12 Inspection and acceptance

While not usually required for products covered by this International Standard, when the purchaser specifies that inspection and tests for acceptance be carried out prior to shipment from the manufacturer's works, the manufacturer shall afford the purchaser's inspector all reasonable facilities to determine that the steel is being furnished in accordance with this International Standard.

Steel that is reported to be defective after arrival at the user's works shall be set aside, properly and correctly identified and adequately protected. The supplier shall be notified in order that he may properly investigate.

13 Coil size

When steel sheet for vitreous enamelling is ordered in coils, a minimum inside diameter (ID) or range of acceptable IDs shall be specified. In addition, the maximum outside diameter (OD) and maximum acceptable coil mass shall be specified.

14 Marking

Unless otherwise stated, the following minimum information for identifying the steel shall be legibly stencilled on the top of each lift or shown on a tag attached to each coil or shipping unit:

- a) the manufacturer's name or identifying brand;
- b) the number of this International Standard, i.e. ISO 5001;
- c) the quality designation number;
- d) the type;
- e) the order number;
- f) the product dimension;
- g) the lot number;
- h) the mass.