
**Hot-rolled steel sheet of higher yield
strength with improved formability**

*Tôles en acier laminées à chaud à limite d'élasticité et aptitude au formage
accrues*



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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 5951 was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 12, *Continuous mill flat rolled products*.

This third edition cancels and replaces the second edition (ISO 5951:1993), which has been technically revised.

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Hot-rolled steel sheet of higher yield strength with improved formability

1 Scope

1.1 This International Standard applies to continuously hot-rolled steel sheet of higher yield strength with improved formability in the grades listed in Table 1. The steel is killed, made according to a fine grain practice and has a suitable chemical composition, which may include microalloying elements, to provide improved formability. The product is intended for applications where parts are to be fabricated requiring better formability than is provided by normal high yield strength steel sheet. It is generally used in the delivered condition.

Because of the combination of higher strength and improved formability, it is possible to obtain savings in mass along with better weldability.

1.2 This product is commonly produced in the range of thicknesses of 1,6 mm and over and widths of 600 mm and over, in coils and cut lengths.

1.3 Hot-rolled sheet less than 600 mm wide may be slit from wide sheet and will be considered as sheet.

NOTE Hot-rolled sheet up to but not including 3 mm in thickness is commonly known as sheet. Hot-rolled sheet 3 mm and over in thickness is commonly known as either "sheet" or "plate".

1.4 This International Standard does not cover steel intended for boilers or pressure vessels, or steels designated as commercial quality or drawing qualities (covered in ISO 3573), or steels designated as weathering steels, having increased atmospheric corrosion resistance, or lower yield strength steels having less formability properties (covered in ISO 4995 and ISO 4996) compared with those included in this International Standard.

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 ISO and IEC maintain registers of currently valid International Standards.

ISO 148:1983, *Steel-Charpy impact test (V-notch)*

ISO 6892:1998, *Metallic materials — Tensile testing at ambient temperature*

3 Terms and definitions

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

3.1

microalloying elements

elements, such as niobium, vanadium, titanium, added singly or in combination to obtain higher strength levels combined with better formability, weldability and toughness as compared with non-alloyed steel produced to equivalent strength levels

3.2

hot-rolled steel sheet

product obtained by rolling heated steel through a continuous-type or reversing-type wide strip hot-rolling mill to the required sheet thickness

NOTE The product has a surface covered with oxide or scale resulting from the hot rolling operation.

3.3

hot-rolled descaled steel sheet

hot-rolled steel sheet from which oxide or scale has been removed, commonly by pickling in an acid solution

NOTE Descaling may also be performed by mechanical means such as grit blasting. Some change in properties may result from descaling.

3.4

mill edge

normal edge without any definite contour produced in hot-rolling

NOTE Mill edges may contain some irregularities such as cracked or torn edges or thin (feathered) edges.

3.5

sheared edge

normal edge obtained by shearing, slitting or trimming a mill edge product

NOTE Normal processing does not necessarily provide a definite positioning of the slitting burr.

3.6

Resquared

Steel sheet that may have received an additional shearing operation after being cut to length in an attempt to approach a true 90° angle at the shear cut

NOTE "Resquared" is referred to as "restricted" in some areas of the world.

4 Conditions of manufacture

4.1 Steelmaking

Unless otherwise agreed upon by the interested parties, the processes used in making the steel and in manufacturing hot-rolled sheet are left to the discretion of the manufacturer. On request, the purchaser shall be informed of the steelmaking process being used.

4.2 Chemical composition

4.2.1 The steel covered by this International Standard may contain microalloying elements. The chemical composition may be agreed between the interested parties at the time of enquiry and ordering.

4.2.2 At the time of choice of grade or chemical composition to be used, attention shall be brought to the welding process to be used (see 4.4).

4.3 Chemical analysis

4.3.1 Heat analysis

A heat analysis of each cast of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus and sulfur, and the contents of other elements giving the specified mechanical strength and formability. On request, this analysis shall be reported to the purchaser or his representative.

4.3.2 Product analysis

A product analysis may be made by the purchaser in order to verify the specified analysis of the semi-finished or finished steel and shall take into consideration any normal heterogeneity. The sampling method and deviation limits shall be agreed upon between the interested parties at the time of enquiry and ordering.

4.4 Weldability

This product is normally suitable for welding if appropriate welding conditions are selected. For underscaled steel, it may be necessary to remove the scale or oxide depending upon the welding method. As the carbon content increases above 0,15 %, spot welding becomes increasingly difficult.

4.5 Application

It is desirable that hot-rolled steel sheet be identified for fabrication by name of the part or by the intended application. Proper identification of the part may include visual examination, prints or description, or a combination of these.

4.6 Mechanical properties

At the time that the steel is made available for shipment, the mechanical properties shall be as stated in Table 1, when they are determined on test pieces in accordance with the requirements of clause 7. Any additional property requirements specified or required are subject to agreement between the interested parties at the time of enquiry and ordering. Such additional requirements may include characterization or prescribed values for properties such as impact for sheet over 6 mm in thickness (see 7.2).

4.7 Surface condition

Oxide or scale on hot-rolled steel sheet is subject to variations in thickness, adherence and colour. Removal of the oxide or scale by pickling or blast cleaning may disclose surface imperfections not readily visible prior to this operation.

The steel shall be supplied as-rolled or pickled and oiled as requested by the purchaser at the time of enquiry and ordering.

4.8 Oiling

As a deterrent to rusting, a coating of oil is usually applied to hot-rolled descaled steel sheet. The oil is not intended as a drawing or forming lubricant and should be easily removable with degreasing chemicals. The product may be ordered not oiled, if required, in which case, the supplier has limited responsibility if oxidation occurs.

Table 1 — Mechanical properties

Grade	R_e min ^a N/mm ²	R_m min (information only) N/mm ²	A min ^{b, c}			
			$e < 3$ mm		$3 \leq e \leq 6$ mm	
			$L_o = 50$ mm	$L_o = 80$ mm	$L_o = 5,65\sqrt{S_o}$	$L_o = 50$ mm
HSF 275	275	350	25	23	28	27
HSF 355	355	420	21	19	24	23
HSF 420	420	480	18	16	21	20
HSF 490	490	540	15	13	18	17
HSF 560	560	610	12	10	15	14

R_e = yield strength
 R_m = tensile strength
 A = percentage elongation after fracture
 L_o = gauge length on test piece
 S_o = original cross sectional area of gauge length
 e = thickness of steel sheet, in millimetres
 $1\text{N/mm}^2 = 1\text{ MPa}$

^a The yield strength can be measured either by 0,5 % elongation proof stress $R_{p0,5}$ (proof stress under load) or by 0,2 % offset $R_{p0,2}$ when a definite yield phenomenon is not present.

^b For thicknesses up to 3 mm, use either $L_o = 50$ mm or $L_o = 80$ mm. For thicknesses 3 mm and over, use $L_o = 5,65\sqrt{S_o}$ or $L_o = 80$ mm. In case of dispute, however, only the results obtained on a proportional test piece will be valid for material 3 mm and over in thickness.

^c For material over 6 mm in thickness, values for elongation are subject to agreement between the manufacturer and the purchaser.

5 Dimensional tolerances

5.1 Dimensional tolerances applicable to hot-rolled steel sheet of higher yield strength with improved formability shall be as given in Tables 2 to 10. Tolerances on thicknesses over 6 mm shall be subject to agreement between the interested parties at the time of enquiry and ordering.

5.2 Restricted thickness tolerances are given in Table 3.

6 Sampling — Tensile test

One representative sample for the tensile test required in Table 1 shall be taken from each lot of sheet for shipment. A lot consists of 50 tonnes or less of sheet of the same designation rolled to the same thickness and condition.

7 Mechanical property tests

7.1 Tensile test

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

7.2 Impact test

While not usually specified, if so agreed at the time of ordering, impact tests may be specified for material over 6 mm in thickness. The test piece shall be in the longitudinal direction and the test shall be carried out in accordance with ISO 148.

8 Retests

8.1 Machining and flaws

If any test piece shows defective machining or develops flaws, it shall be discarded and another piece substituted.

8.2 Elongation

If the percentage elongation of any test piece is less than that specified in Table 1 and if any part of the fracture is outside the middle half of the gauge length as scribed before the test, the test shall be discarded and a retest shall be carried out.

8.3 Additional tests

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

9 Resubmission

9.1 The manufacturer may resubmit for acceptance the products that have been rejected during earlier inspection because of unsatisfactory properties, after he has subjected them to a suitable treatment (selection, heat treatment), which, on request, will be indicated to the purchaser.

In this case, the tests should be carried out as if they applied to a new batch.

9.2 The manufacturer has the right to present the rejected products to a new examination for compliance with the requirements for another grade.

10 Workmanship

The surface condition shall be that normally obtained in a hot-rolled or hot-rolled descaled product.

The steel sheet in cut lengths shall be free from amounts of laminations, surface flaws and other imperfections that are detrimental to subsequent appropriate processing.

Processing for shipment in coils does not afford the manufacturer the opportunity to observe readily or to remove imperfect portions, as can be carried out on the cut length product.

11 Inspection and acceptance

11.1 While not usually required for products covered by this International Standard, when the purchaser specifies that inspection and tests for acceptance be observed 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.

11.2 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 manufacturer shall be notified in order that he may properly investigate.

12 Coil size

When hot-rolled steel sheet is ordered in coils, a minimum inside diameter (I.D.) or range of acceptable inside diameters shall be specified. In addition, the maximum outside diameter (O.D.) and the maximum acceptable coil mass shall be specified.

13 Marking

Unless otherwise stated, the following minimum requirements 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) manufacturer's name or identifying brand;
- b) the number of this International Standard;
- c) the grade designation;
- d) the order number;
- e) the product dimensions;
- f) the lot number;
- g) the mass.

14 Information to be supplied by the purchaser

To adequately specify requirements according to this International Standard, inquiries and orders shall include the following information:

- a) the number of this International Standard, i.e. ISO 5951;
- b) the name, quality, and grade of the material (e.g., hot-rolled steel sheet, higher yield strength with improved formability, grade HSF 355);
- c) the dimensions of the product and the quantity required;
- d) the application (name of part) if possible (see 4.4 and 4.5);
- e) whether pickling or descaling by grit or shot blasting is required [material so specified will be oiled unless ordered not oiled (see 4.8)];
- f) the type of edge (see 3.4 and 3.5);
- g) whether cropped ends are required;
- h) the report of the mechanical properties and/or the cast analysis; if required (see 4.3.1 and 4.6);
- i) limitations on masses and dimensions of individual coils and bundles, if applicable (see clause 12);
- j) inspection and tests for acceptance prior to shipment from the manufacturer's works, if required (see 11.1);
- k) if necessary, additional requirements (see 4.6);
- l) restricted thickness tolerances, if required.

Table 2 — Normal thickness tolerances for coils and cut lengths

Values in millimetres

Grade	Specified width, b	Thickness tolerances ^a for specified thickness, e					
		$1,6 \leq e \leq 2,0$	$2,0 < e \leq 2,5$	$2,5 < e \leq 3,0$	$3,0 < e \leq 4,0$	$4,0 < e \leq 5,0$	$5,0 < e \leq 6,0$
HSF 275	$600 \leq b \leq 1\,200$	$\pm 0,17$	$\pm 0,18$	$\pm 0,20$	$\pm 0,22$	$\pm 0,24$	$\pm 0,26$
	$1\,200 \leq b \leq 1\,200$	$\pm 0,19$	$\pm 0,21$	$\pm 0,22$	$\pm 0,24$	$\pm 0,26$	$\pm 0,28$
	$1\,500 \leq b \leq 1\,800$	$\pm 0,21$	$\pm 0,23$	$\pm 0,24$	$\pm 0,26$	$\pm 0,28$	$\pm 0,29$
	$b > 1\,800$	—	$\pm 0,25$	$\pm 0,26$	$\pm 0,27$	$\pm 0,29$	$\pm 0,31$
HSF 355 and HSF 420	$600 \leq b \leq 1\,200$	$\pm 0,19$	$\pm 0,20$	$\pm 0,22$	$\pm 0,24$	$\pm 0,26$	$\pm 0,29$
	$1\,200 < b \leq 1\,500$	$\pm 0,21$	$\pm 0,23$	$\pm 0,24$	$\pm 0,26$	$\pm 0,29$	$\pm 0,31$
	$1\,500 < b \leq 1\,200$	$\pm 0,23$	$\pm 0,25$	$\pm 0,26$	$\pm 0,29$	$\pm 0,31$	$\pm 0,32$
	$b > 1\,800$	—	$\pm 0,27$	$\pm 0,29$	$\pm 0,30$	$\pm 0,32$	$\pm 0,34$
HSF 490 and HSF 560	$600 \leq b \leq 1\,200$	$\pm 0,21$	$\pm 0,22$	$\pm 0,25$	$\pm 0,27$	$\pm 0,30$	$\pm 0,32$
	$1\,200 < b \leq 1\,500$	$\pm 0,24$	$\pm 0,26$	$\pm 0,27$	$\pm 0,30$	$\pm 0,32$	$\pm 0,35$
	$1\,500 < b \leq 1\,200$	$\pm 0,26$	$\pm 0,29$	$\pm 0,30$	$\pm 0,32$	$\pm 0,35$	$\pm 0,36$
	$b > 1\,800$	—	$\pm 0,31$	$\pm 0,32$	$\pm 0,34$	$\pm 0,36$	$\pm 0,39$

The values specified do not apply to the uncropped ends for a length “ l ” of a mill edge coil.

Length “ l ” would be calculated using the following formula:

$$\text{Length “}l\text{” in metres} = \frac{90}{\text{Thickness in mm}}$$

provided that the result was not greater than 20 m, inclusive of both ends.

More restrictive coil end tolerances should be negotiated at the time of ordering.

^a Thickness is measured at any point on the sheet not less than 40 mm from a side edge. Measurement on an unsheared edge sheet, nearer to an edge than 40 mm and on a sheared edge sheet, nearer to an edge than 25 mm, and values of tolerances shall be subject to negotiation.

NOTE A typical ordering description is as follows:

ISO 5951 hot-rolled steel sheet of higher yield strength with improved formability, grade HSF 355, $3 \times 1\,200 \times 2\,440$ mm, restricted thickness tolerances, 40 000 kg, for Part No. 54321, bumper reinforcement bracket, pickled and oiled, edge trimmed, furnish report of mechanical properties, maximum lift 4 000 kg.

Table 3 — Restricted thickness tolerances for coils and cut lengths

Values in millimetres

Grade	Specified width, b	Thickness tolerances ^a for specified thickness, e					
		$1,6 \leq e \leq 2,0$	$2,0 < e \leq 2,5$	$2,5 < e \leq 3,0$	$3,0 < e \leq 4,0$	$4,0 < e \leq 5,0$	$5,0 < e \leq 6,0$
HSF 275	$600 \leq b \leq 1\,200$	$\pm 0,13$	$\pm 0,14$	$\pm 0,15$	$\pm 0,17$	$\pm 0,19$	$\pm 0,21$
	$1\,200 \leq b \leq 1\,200$	$\pm 0,14$	$\pm 0,15$	$\pm 0,17$	$\pm 0,18$	$\pm 0,21$	$\pm 0,22$
	$1\,500 \leq b \leq 1\,800$	$\pm 0,14$	$\pm 0,17$	$\pm 0,19$	$\pm 0,21$	$\pm 0,22$	$\pm 0,23$
	$b > 1\,800$	—	$\pm 0,20$	$\pm 0,21$	$\pm 0,22$	$\pm 0,23$	$\pm 0,25$
HSF 355 and HSF 420	$600 \leq b \leq 1\,200$	$\pm 0,14$	$\pm 0,15$	$\pm 0,17$	$\pm 0,19$	$\pm 0,21$	$\pm 0,23$
	$1\,200 < b \leq 1\,500$	$\pm 0,14$	$\pm 0,17$	$\pm 0,19$	$\pm 0,21$	$\pm 0,23$	$\pm 0,25$
	$1\,500 < b \leq 1\,200$	$\pm 0,17$	$\pm 0,20$	$\pm 0,21$	$\pm 0,23$	$\pm 0,25$	$\pm 0,26$
	$b > 1\,800$	—	$\pm 0,22$	$\pm 0,23$	$\pm 0,24$	$\pm 0,32$	$\pm 0,27$
HSF 490 and HSF 560	$600 \leq b \leq 1\,200$	$\pm 0,14$	$\pm 0,17$	$\pm 0,20$	$\pm 0,22$	$\pm 0,24$	$\pm 0,26$
	$1\,200 < b \leq 1\,500$	$\pm 0,19$	$\pm 0,21$	$\pm 0,22$	$\pm 0,24$	$\pm 0,26$	$\pm 0,28$
	$1\,500 < b \leq 1\,200$	$\pm 0,21$	$\pm 0,23$	$\pm 0,24$	$\pm 0,26$	$\pm 0,28$	$\pm 0,29$
	$b > 1\,800$	—	$\pm 0,25$	$\pm 0,26$	$\pm 0,27$	$\pm 0,29$	$\pm 0,32$

The values specified do not apply to the uncropped ends for a length " l " of a mill edge coil.
Length " l " would be calculated using the following formula:

$$\text{Length "l" in meters} = \frac{90}{\text{Thickness in mm}}$$

provided that the result was not greater than 20 m, inclusive of both ends.

^a Thickness is measured at any point on the sheet not less than 25 mm from a sheared edge and 40 mm from a mill edge. Points closer than these are subject to negotiation.

Table 4 — Width tolerances for coils and cut lengths
(including descaled material), mill edge

Values in millimetres

Specified width, b	Tolerance ^a
$b \leq 1\,500$	$\begin{smallmatrix} +20 \\ 0 \end{smallmatrix}$
$b > 1\,500$	$\begin{smallmatrix} +25 \\ 0 \end{smallmatrix}$

^a The values specified do not apply to the uncropped ends for a length " l " of a mill edge coil.

The length " l " would be calculated using the formula:

$$\text{Length "l" in metres} = \frac{90}{\text{Thickness in mm}}$$

provided that the result was not greater than 20 m, inclusive of both ends.

**Table 5 — Width tolerances for coils and cut lengths
(including descaled material), sheared edges, not resquared**

Values in millimetres

Specified width, b	Tolerance
$b \leq 1\,200$	$\begin{smallmatrix} +3 \\ 0 \end{smallmatrix}$
$1\,200 < b \leq 1\,500$	$\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$
$b > 1\,500$	$\begin{smallmatrix} +6 \\ 0 \end{smallmatrix}$
NOTE For resquared material more restrictive tolerances are subject to negotiation.	

**Table 6 — Length tolerances for cut lengths
(including descaled material), not resquared**

Values in millimetres

Specified length, l	Tolerance
$l \leq 2\,000$	$\begin{smallmatrix} +10 \\ 0 \end{smallmatrix}$
$2\,000 < l \leq 8\,000$	$+ 0,5 \% \times \text{length}$
$l > 8\,000$	$\begin{smallmatrix} +40 \\ 0 \end{smallmatrix}$
NOTE For resquared material more restrictive tolerances are subject to negotiation.	

**Table 7 — Camber tolerances for coils and cut lengths
(including descaled material), not resquared**

Form	Maximum tolerance
Coils	25 mm in any 5 000 mm length
Cut lengths	$0,5 \% \times \text{length}$
NOTE	
1 For resquared material more restrictive tolerances are subject to negotiation.	
2 The values specified do not apply to the uncropped ends of a mill edge coil for a total length of 7 metres.	
3 Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straight edge as shown in Figure 1.	

**Table 8 — Out-of-square tolerances for cut lengths
(including descaled material), not resquared**

Dimensions	Out-of-square tolerance
All thicknesses and all sizes	1 % × width
NOTE 1 Out-of-square is the greatest deviation of an edge from a straight line at right angles to a side and touching one corner, the measurement being taken as shown in Figure 2. It can also be measured as one-half the difference between the diagonals of the cut length sheet. 2 For resquared material more restrictive tolerances are subject to negotiation.	

**Table 9 — Out-of-square tolerances for resquared material
(including descaled material)**

Values in millimetres

Specified length, l	Specified width, b	Out-of-square tolerance Thickness, $e \leq 6$ mm
$l \leq 3\,000$	$b \leq 1\,200$	$\begin{smallmatrix} +2 \\ 0 \end{smallmatrix}$
	$b > 1\,200$	$\begin{smallmatrix} +3 \\ 0 \end{smallmatrix}$
$l > 3\,000$	All widths	$\begin{smallmatrix} +3 \\ 0 \end{smallmatrix}$
NOTE 1 Out-of-square is the greatest deviation of an edge from a straight line at right angles to a side and touching one corner, the measurement being taken as shown in Figure 2. It can also be measured as one-half the difference between the diagonals of the cut length sheet. 2 When measuring material to resquared tolerances, consideration may have to be given to extreme variations in temperature.		

Table 10 — Standard flatness tolerances for cut lengths

Values in millimetres

Specified thicknesses, e	Specified width, b	Flatness tolerance ^a
$e \leq 2$	$b \leq 1\,200$	32
	$1\,200 < b \leq 1\,500$	38
	$b > 1\,500$	45
$e > 2$	$b \leq 1\,200$	27
	$1\,200 < b \leq 1\,500$	34
	$b > 1\,500$	42
^a Maximum deviation from a flat horizontal surface. With the sheet lying under its own weight on a flat surface, the maximum distance between the lower surface of the sheet and the flat horizontal surface is the maximum deviation from flatness (see Figure 3). NOTE These tolerances are only applicable to sheet up to and including 5 000 mm length. Tolerances for sheet having a length exceeding 5 000 mm shall be subject to agreement. This table also applies to sheet cut to length from coil by the customer when adequate flattening procedures are performed.		