International Standard 5951

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

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

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

First edition — 1980-09-15

UDC 6669.14-415 **Ref. No. ISO 5951-1980 (E)**

Descriptors : steels, metal sheets, iron and steel products, hot rolled products, high yield strength steels, manufacturing, mechanical properties, dimensional tolerances, form tolerances, tests, marking, user supplier-relations.

Price based on 12 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 5951 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in November 1978.

It has been approved by the member bodies of the following countries:

Australia	France	Portugal
Austria	Germany, F.R.	Romania
Belgium	India	South Africa, Rep. of
Brazil	Italy	Spain
Bulgaria	Japan	Sweden
Canada	Korea, Dem. P. Rep. of	Switzerland
Czechoslovakia	Korea, Rep. of	Turkey
Denmark	Netherlands	United Kingdom
Egypt, Arab Rep. of	Poland	USSR

No member body expressed disapproval of the document.

Printed in Switzerland

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

1 Scope and field of application

1.1 This International Standard applies to hot-rolled steel sheet of higher yield strength with improved formability in the grades listed in table 1. The steel is killed, made to a fine grain practice and has suitable chemical composition, which may include microalloying elements, to provide improved formability. It 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 the combination of higher strength and improved formability, it is possible to obtain savings in mass along with better weldability (see 1.4).

1.2 This product is commonly produced in a 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 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 steels intended for boilers or pressure vessels, or steels designated as commercial quality or drawing qualities (covered in ISO 3573), or steels to be rerolled to cool-reduced products (covered in ISO 3576), or steels designated as weathering steels, having increased atmospheric corrosion resistance, or yield strength steels having less formability properties (covered in ISO 4995 and ISO 4996) compared with those included in this document.

NOTE — Approximate conversions into inches are given in annex A.

2 References

ISO 82, *Steel — Tensile testing.*

ISO/R 85, *Bend test for steel.*

ISO 86, *Steel — Tensile testing of sheet and strip less than* 3 mm *and not less than* 0,5 mm *thick.*

ISO/R 87, *Simple bend testing of steel sheet and strip less than* 3 mm *thick.*

ISO 148, *Steel — Charpy impact test (V-notch)*[1].

3 Definitions and other information

3.1 microalloying elements : Elements, such as niobium, vanadium, titanium, etc., 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 : A product obtained by rolling heated steel through a continuous-type or reversing-type wide strip mill to the required sheet thickness. 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. Descaling may also be performed by mechanical means such as grit blasting. Some change in properties may result from descaling.

As a deterrent to rusting, a coating of oil is usually applied to hot-rolled descaled steel sheet, but sheet may be furnished not oiled if required. The oil is not intended as a forming lubricant

1) At present at the stage of draft. (Revision of ISO/R 148.)

and shall be easily removable with degreasing chemicals. On request, the manufacturer shall advise the purchaser which type of oil has been used.

3.4 mill edge : A normal side edge produced in hot rolling. Mill edges may contain some irregularities such as cracked or torn edges or thin (feathered) edges.

3.5 edge trimmed : A normal edge obtained by shearing, slitting or trimming a mill edge product.

3.6 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.

4 Conditions of manufacture

4.1 Steelmaking

Unless otherwise agreed 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 Cast analysis

A cast analysis of each cast of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, phosphorus and sulphur, 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 Verification analysis

A verification 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. 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 undescaled 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 the name of the part or by the intended application, which shall be compatible with the grade specified.

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 7.3).

4.7 Surface condition

The steel shall be supplied as rolled or pickled and oiled as requested by the purchaser at the time of enquiry and ordering (see 3.3).

5 Dimensional tolerances

Dimensional tolerances applicable to hot-rolled steel of higher yield strength with improved formability shall as given in tables 2 to 9 inclusive. Tolerances on thicknesses over 6 mm shall be subject to agreement between the interested parties at the time of enquiry and ordering.

6 Sampling

6.1 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 grade rolled to the same thickness and condition.

6.2 Bend test

One representative sample for the bend test shall be taken from each lot of sheet for shipment. A lot consists of all sheet of the same grade 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 82 and ISO 86. Transverse test pieces shall be taken midway between the centre and edge of the sheet as rolled.

7.2 Bend test

The transverse bend test piece shall withstand being bent, through 180° in the direction as shown in figure 1, around an inside diameter as shown in table 1, without cracking on the outside of the bent portion. The bend test shall be carried out at ambient temperature and as specified in ISO/R 85 and ISO/R 87.

Table 1 — Mechanical properties[1)]

Grade	R_e min.[2)] N/mm²	R_m min. (information only) N/mm²	A min. %[3) 5)]				180° [4) 5)] bend mandrel diameter (flat on itself)
			$e < 3$ mm		$3 \leqslant e \leqslant 6$ 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	0
HSF 355	355	420	21	19	24	23	0,5 *a*
HSF 420	420	480	18	16	21	20	1 *a*
HSF 490	490	540	15	13	18	17	1,5 *a*
HSF 560	560	610	12	10	15	14	1,5 *a*

1) 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
a = thickness of bend test piece
e = thickness of steel sheet, in millimetres
1 N/mm² = 1 MPa

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

3) 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 $L_o = 50$ 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.

4) The bend mandrel diameters in table 1 are for specimens prepared for laboratory testing. Conditions during fabrication may be more severe and not simulate those during laboratory testing. (See annex B).

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

Small cracks on the edges of test pieces and cracks which require magnification to be visible shall be disregarded.

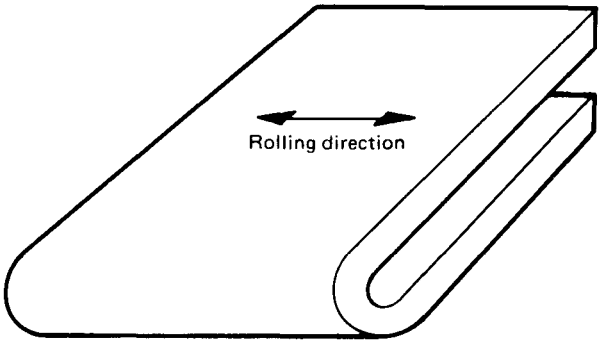

Figure 1 — Transverse bend test piece (after bending)

7.3 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 test 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 shall 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 defective 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 or range of acceptable inside diameters (I.D.) 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) the 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 specify adequately requirements under this International Standard, inquiries and orders shall include the following information :

a) the number of this International Standard;

b) the name, quality and grade of the material (for example, hot-rolled steel sheet, higher yield strength with improved formability, grade HSF355);

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 3.3);

f) the type of edge (see 3.4 and 3.5);

g) whether cropped ends are required;

h) the report of mechanical properties and/or cast analysis, if required (see 4.6 and 4.3.1);

j) if necessary, additional requirements (see 4.6);

k) limitations on masses and dimensions of individual coils and bundles, if applicable (see clause 12);

m) inspection and tests for acceptance prior to shipment from the manufacturer's works, if required (see 11.1).

NOTE — A typical order description is as follows :

International Standard 5951 hot-rolled steel sheet of higher yield strength with improved formability, grade HSF355, 3 × 1,200 × 2,440 mm, 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 2 — Thickness tolerances for coils[1] and cut lengths, in grades HSF275, HSF355 and HSF420 (including descaled material)

(For grades HSF490 and HSF560, increase the thickness tolerances by 25 % applying normal rounding-off procedures)

NOTE — See table 10 for approximate inch conversions.

Values in millimetres

Specified widths	Thickness tolerances[2], over and under, for specified thicknesses				
	1,6 up to and including 2,0	over 2,0 up to and including 2,5	over 2,5 up to and including 3,0	over 3,0 up to and including 4,0	over 4,0 up to and including 6,0
600 up to and including 1 200	0,23	0,25	0,26	0,29	0,34
Over 1 200 up to and including 1 500	0,25	0,28	0,29	0,31	0,35
Over 1 500 up to and including 1 800	0,28	0,30	0,31	0,33	0,36
Over 1 800	–	0,33	0,34	0,35	0,38

1) 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 :

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

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

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

Table 3 — Width tolerances for coils and cut lengths (including descaled material), mill edge

NOTE — See table 11 for approximate inch conversions.

Values in millimetres

Specified widths	Tolerance[1)]
Up to and including 1 200	+ 30 0
Over 1 200 up to and including 1 500	+ 35 0
Over 1 500 up to and including 1 800	+ 40 0
Over 1 800	+ 50 0

1) 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 :

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

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

Table 4 — Width tolerances for coils and cut lengths (including descaled material), cut edges, not resquared

NOTE — See table 12 for approximate inch conversions.

Values in millimetres

Specified widths	Tolerance
Up to and including 1 200	+ 6 0
Over 1 200 up to and including 1 500	+ 8 0
Over 1 500	+ 10 0

Table 5 — Length tolerances (including descaled material), not resquared

NOTE — See table 13 for approximate inch conversions.

Values in millimetres

Specified lengths	Tolerance
Up to and including 3 000	+ 20 0
Over 3 000 up to and including 6 000	+ 30 0
Over 6 000	+ 0,5 % × length 0

Table 6 — Camber tolerances for coils and cut lengths (including descaled material), not resquared

NOTE — See table 14 for approximate inch conversions.

Form	Maximum tolerance
Coils	25 mm in any 5 000 mm length
Cut lengths	0,5 % × length

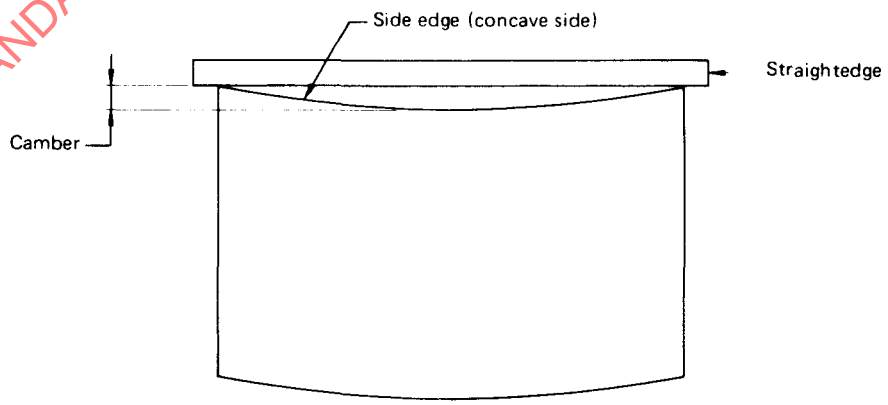

Figure 2 — Measurement of camber

Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

Table 7 — Out-of-square tolerances for cut lengths (including descaled material), not resquared

Dimensions	Out-of-square tolerance
All thicknesses and all sizes	1 % X width

Table 8 — Out-of-square[1] tolerances for resquared[2] material (including descaled material)

NOTE — See table 15 for approximate inch conversions.

Values in millimetres

Specified lengths	Specified widths	Out-of-square tolerance
		Up to and including 6 mm thickness
Up to and including 3 000	Up to and including 1 200	$^{+2}_{0}$
	Over 1 200	$^{+3}_{0}$
Over 3 000	All widths	$^{+3}_{0}$

1) See figure 3.

2) When measuring material to resquared tolerances, consideration may have to be given to extreme variations in temperature.

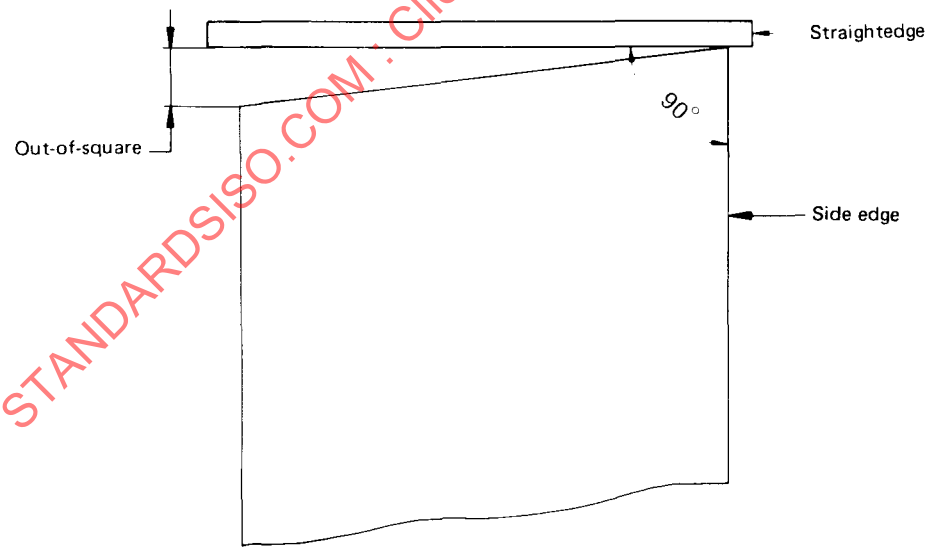

Figure 3 — Measurement of out-of-square

Out-of-square is the greatest deviation of an end edge from a straight line at right angles to a side and touching one corner, the measurement being taken as shown in figure 3. It can also be measured as one-half the difference between the diagonals of the cut length sheet.

Table 9 — Standard flatness tolerances[1] for cut lengths

NOTE — See table 16 for approximate inch conversions.

Values in millimetres

Specified thicknesses	Specified widths	Flatness tolerance[2]
Up to and including 2	Up to and including 1 200	36
	Over 1 200 up to and including 1 500	48
	Over 1 500	56
Over 2	Up to and including 1 200	29
	Over 1 200 up to and including 1 500	38
	Over 1 500	48

1) 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.

2) Maximum deviation from a flat horizontal surface. With the sheet lying under its own mass 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 4).

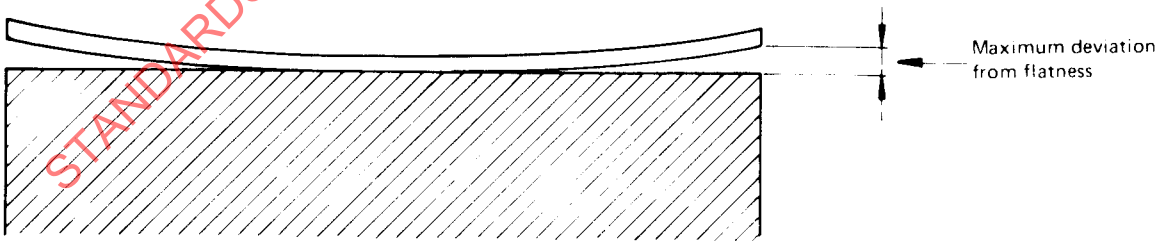

Figure 4 — Measurement of flatness

Annex A

Approximate inch conversions

(Forms part of the Standard)

A.1 Scope and field of application

This annex gives the approximate inch conversions of the dimensional data in this International Standard, based on the following *conversion factors*.

mm	in
1,6	0.063
3,0	0.118
6,0	0.236
600	24

Table 10 — Thickness tolerances for coils[1] and cut lengths, in grades HSF275, HSF355 and HSF420 (including descaled material)

(For grades HSF490 and HSF560 increase the thickness tolerances by 25 % applying normal rounding-off procedures)

Values in inches (approximate conversions of table 2)

Specified widths	**Thickness tolerances[2], over and under, for specified thicknesses**				
	0.063 up to and including 0.079	over 0.079 up to and including 0.098	over 0.098 up to and including 0.118	over 0.118 up to and including 0.158	over 0.158 up to and including 0.236
24 up to and including 48	0.009	0.010	0.010	0.011	0.014
Over 48 up to and including 60	0.010	0.011	0.011	0.013	0.014
Over 60 up to and *including* 71	0.011	0.011	0.013	0.013	0.014
Over 71	–	0.013	0.014	0.014	0.015

1) 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 :

$$\text{Length } l \text{ in feet} = \frac{12}{\text{Thickness in inches}}$$

provided that the result was not greater than 65 ft, inclusive of both ends.

2) Thickness is measured at any point on the sheet not less than 1.5 in from a side edge. Measurement on an untrimmed edge sheet nearer to an edge than 1.5 in and on a trimmed edge sheet nearer to an edge than 1 in and values of tolerances shall be subject to negotiation.