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EAST AFRICAN STANDARD

Steel, carbon and high-strength, low alloy hot rolled sheet and cold-rolled sheet-General requirements

EAST AFRICAN COMMUNITY

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Foreword

Development of the East African Standards has been necessitated by the need for harmonizing requirements governing quality of products and services in East Africa. It is envisaged that through harmonized standardization, trade barriers which are encountered when goods and services are exchanged within the Community will be removed.

In order to achieve this objective, the Partner States in the Community through their National Bureaux of Standards, have established an East African Standards Committee.

The Committee is composed of representatives of the National Standards Bodies in Partner States, together with the representatives from the private sectors and consumer organizations. Draft East African Standards are circulated to stakeholders through the National Standards Bodies in the Partner States. The comments received are discussed and incorporated before finalization of standards, in accordance with the procedures of the Community.

East African Standards are subject to review, to keep pace with technological advances. Users of the East African Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

Community P O Box 1096 **Arusha**

Tanzania

Tel: 255 27 2504253/8 Fax:

255-27-2504481/2504255 E-Mail:

eac@eachq.org Web: www.each.org

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Steel, carbon and high-strength, low-alloy hot-rolled sheet and cold-rolled sheet — General requirements

1 Scope

1.1 This specification covers the general requirements for steel sheet in coils and cut lengths. It applies to the following specifications which describe carbon steel and high-strength, low-alloy steel (HSLA) furnished as hot-rolled sheet and cold-rolled sheet.

1.2 This specification is not applicable to hot-rolled, heavy-thickness carbon sheet coils, KS 1513 [1)]

1.3 In case of any conflict in requirements, the requirements of the individual material specification shall prevail over those of the general specification.

1.4 For the purposes of determining conformance with this specification and the various material specifications, values shall be rounded to the nearest unit in the right-hand place of figures used in expressing the limiting values.

2 Description of terms specific to this standard

2.1 Steel types

2.1.1 Carbon steel is the designation for steel when no minimum content is specified or required for aluminium, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any element added to obtain a desired alloying effect, when the specified minimum for copper does not exceed 0.40 %, or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, or copper 0.60.

2.1.2 In all carbon steels small quantities of certain residual elements unavoidably retained from raw materials are sometimes found which are not specified or required, such as copper, nickel, molybdenum, chromium, etc. These elements are considered as incidental and are not normally determined or reported.

2.1.3 High-strength low alloy steel is a specific group of steels in which higher strength, and in some cases additional resistance to atmospheric corrosion or improved formability, are obtained by moderate amounts of one or more alloying elements.

2.2 Product types

2.2.1 Hot-rolled sheet is manufactured by hot rolling slabs in a continuous mill to the required thickness and shall be supplied in coils or cut lengths as given in Table 1.

Table 1 — Hot-rolled coils and cut lengths

Dimensions in millimetres

Width	Thickness
Over 300 to 1200, incl.	1.0[)] to 6.0, excl.
Over 1200	1. 0 to 4.5, excl.

[)] Specification for steel sheet and strip, heavy thickness, coils, carbon hot rolled

2.2.2 Cold-rolled sheet is manufactured form hot-rolled descaled coils by cold reducing to the desired thickness, generally followed by annealing to recrystallize the grain structure. If the sheet is not annealed after cold reduction it is known as full hard with a hardness of 84 HRB minimum and shall be used for certain applications where ductility and flatness are not required.

2.2.3 Cold-rolled carbon sheet is commonly classified by size as given in Table 2.

Table 2 — Cold-rolled carbon sheet

• Dimensions in millimetres

Width	Thickness
50 to 300 incl [a)]	0.35 to 2.0, incl.
Over 300 [b)]	0.35 and Over

[a)] Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses 0.35 to 2.0 mm, incl. Carbon 0.25 % max. by heat analysis.

[b)] When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both, up to and including 600 mm not specified or required.

2.2.3 Cold-rolled high-strength, low-alloy sheet is commonly classified by size as given in Table 3. **Table 3 —**

Cold-rolled high strength, low-alloy carbon sheet

Dimensions in millimetres

Width	Thickness
50 to 300, incl[a)]	0.5 to 2.0, incl
Over 300 [b)]	0.5 and Over

[a)] Cold-rolled sheet coils and cut lengths, slit from wider coils with cut edge (only) and in thicknesses 0.35 to 2.0 mm, incl. Carbon 0.25 % maximum by heat analysis.

[b)] When no special edge or finish (other than matte, commercial bright, or luster finish) or single strand rolling of widths, or both, up to and including 600 mm not specified or required.

3 General requirements for delivery

3.1 Products covered by this specification are produced to metric decimal thicknesses only and metric thickness tolerances shall apply.

3.2 Steel may be produced as ingot-cast or strand-case. When different grades of strand-cast steel are sequentially cast, identification and separation of the transition material shall be required.

4 Manufacture

4.1 Unless otherwise specified, hot-rolled material shall be furnished hot-rolled, not annealed and not pickled.

4.2 Coil breaks, stretcher strains, and fluting can occur during the user's processing of hot-rolled or hot-rolled pickled sheet. When any of these features are detrimental to the application, the manufacturer shall be notified at the time of ordering in order to properly process the sheet.

4.3 Cold-rolled carbon steel sheet may be available as discussed in 9.1.2, 9.3, and as given in Table 4.

4.4 Unless specified as a full-hard product, cold-rolled sheet is annealed after being cold reduced to thickness. The annealed, cold-rolled sheet can be used as annealed last (dead soft) for unexposed end-use applications. When cold-rolled sheet is used for unexposed applications and coil breaks are a hazard in uncoiling, it may be necessary to further process the material. In this case the manufacturer should: be consulted. After annealing, cold-rolled sheet is generally given a light skin pass to impart shape or may be given a heavier skin pass or temper pass to prevent the phenomenon, known as stretcher straining or fluting, when formed Temper passing also provides a required surface texture.

4.5 Temper rolling

4.5.1 Unless otherwise specified, cold-rolled sheet for exposed applications shall be temper rolled and is usually specified and furnished in the strain free condition as shipped (see Annex B).

4.5.2 Cold-rolled sheet for unexposed applications may be specified and furnished "annealed last" or "temper rolled. "Annealed last " shall be produced without temper rolling, but may be lightly temper rolled during oiling or rewinding. Unexposed temper-rolled material may be specified strain-free or nonfluting. Where specific hardness range or limit, or a specified surface texture is required, the application shall be considered as exposed.

NOTE Skin-passed sheet is subject to an aging phenomenon (see Annex B). Unless special killed (non-aging) steel is specified, it is to the user's interest to fabricate the sheet as soon as possible, for optimum performance.

Table 4 — Cold-rolled sheet steel class comparison

Exposed **Unexposed**

Major Imperfections cut lengths coils		Mill rejects Purchaser accepts within the manufacturer's published standards (policy).	Mill rejects Purchaser accepts within the manufacturer's published standards (policy).
Minor imperfections cut lengths		Mill rejections repetitive imperfections. May contain random imperfections which the purchaser accepts within the manufacturer's published standards (policy).	Purchaser accepts all minor imperfections.
Coils		Purchaser accepts within the manufacturer's published standards (policy).	Purchaser accepts all minor imperfections.
Finish		Matte unless otherwise specified. May be specified.	Purchaser accepts all finishes.
Special oils		May be specified.	May not be specified.
Thickness, width and length tolerance	Standard	Will be met.	Will be met.
	Restricted	May not be specified.	May not be specified.
Flatness tolerance	Standard	Will be met.	Will be met (temper rolled), not guaranteed — normally within twice standard (annealed last).
	Stretcher levelled	May be specified.	May not be specified.
Resquaring		May be specified.	May not be specified.
Coil wraps		Purchaser accepts within the manufacturer's published standards (policy).	Purchaser accepts within the manufacturer's published standards (policy).
Coils welds		Purchaser accepts within the manufacturer's published standards (policy).	Purchaser accepts within the manufacturer's published standards (policy).
Outside inspection		May be specified.	May not be specified.
Special Testing		May be specified.	May not be specified.

5 Chemical composition 5.1

Limits

5.1.1 The chemical composition shall be in accordance with the applicable product specification. However, if other compositions are required for carbon steel, they shall be prepared in accordance with Annex A.

5.1.2 Where the material is used for fabrication by welding, care shall be exercised in selection of chemical composition or mechanical properties to assure compatibility with the welding process and its effect on altering the properties.

5.2 Cast or heat (formerly ladle) analysis

5.2.1 An analysis of each cast or heat of steel shall be made by the manufacturer to determine the percentage of elements specified or restricted by the applicable specification.

5.2.2 When requested, cast or heat analysis for elements listed or required shall be reported to the purchaser or to his representative.

5.3 Product, check, or verification analysis

5.3.1 Non-killed steels such as capped or rimmed steels are not technologically suited to product analysis due to the non-uniform character of their chemical composition and therefore, the tolerances in Table 5 shall not apply. Product analysis is appropriate on these types of steel only when misapplication is apparent or for copper when copper steel is specified.

Table 5 — Tolerances for product analysis

Element	**Limit, or max. of specified element, %**	**Tolerance**		**Test methods**
		Under min. limit,	**Over max. limit,**	
Carbon	To 0.15	0.02	0.03	ISO 437
	Over 0.15 to 0.40	0.03	0.04	
	Over 0.40 to 0.80 incusive	0.03	0.05	
	Over 0.80	0.03	0.06	
Manganese	To 0.60 inc	0.03	0.03	ISO 629
	Over 0.60 to 1.15	0.04	0.04	
	Over 1.5 to 1.65	0.05	0.05	
Phosphorus	-	-	0.01	ISO 10714 or EAS 200:2001
Sulfur	-	-	0.01	ISO 671 or EAS 199
Silicon	To 0.30 incl	0.02	0.03	ISO 439:1994 ISO 4829-1:1986 ISO 4829-2:1988
	Over 0.30 to 0.60	0.05	0.05	
Copper		0.02		ISO 4943:1985

5.3.2 For steels other than non-killed (capped or rimmed), product analysis may be made by the purchaser. The chemical analysis shall not vary from the limits specified by more than the amounts in Table 2. The several determinations of any element in a cast shall not vary both above and below the specified range.

5.4 Sampling for product analysis

5.4.1 To indicate adequately the representative composition of a cast by product analysis, it is general practice to select samples to represent the steel, as fairly as possible, from a minimum number of pieces as follows: 3 pieces for lots up to 15 Mg incl. and 6 pieces for lots over 15 Mg (see ISO 14284).

5.4.2 When the steel is subject to tension test requirements, samples for product analysis may be taken either by drilling entirely through the used tension test specimens themselves, or as covered in 5.4.3.

5.4.3 When the steel is not subject to tension test requirements, the samples for the analysis shall be taken by milling or drilling entirely through the sheet in a sufficient number of places so that the samples are representative of the entire sheet or strip. The sampling may be facilitated by folding the sheet both ways, so that several samples shall be taken at one drilling. Steel subjected to certain heating operations by the purchaser may not give chemical analysis results that properly represent its original composition. Therefore users shall analyze chips taken from the steel in the condition in which it is received from the steel manufacturer.

5.5 Specimen preparation

Preparation — Drillings or chips shall be taken without the application of water, oil, or other lubricant, and shall be free of scale, grease, dirt, or other foreign substances. They shall not be overheated during cutting to the extent of causing decarburization. Chips shall be well mixed and those too coarse to pass a 2.0 mm sieve size or too fine to remain on a 600 urn sieve size are not suitable for proper analysis.

NOTE Sieve sizes are in accordance with ISO 3310-1.

5.6 Test methods

In case a referee analysis is required and agreed upon to resolve a dispute concerning the results of a chemical analysis, the procedure of performing the referee analysis shall be in accordance with the latest issues of test methods given in Table 5, unless otherwise agreed upon between the manufacturer and the purchaser.

6 Mechanical requirements

6.1 The mechanical property requirements, number of specimens and test locations and specimen orientation shall be in accordance with the applicable product specification.

6.2 Unless otherwise specified in the applicable specification, test specimens shall be prepared in accordance with EAS 194-1.

6.3 Mechanical tests shall be conducted in accordance with appropriate methods of test.

6.4 To determine conformance with the product specification, a calculated value should be rounded to the nearest 5 MPa tensile strength and yield point or yield strength, and to the nearest unit in the right hand place of figures used in expressing the limiting value for other values.

6.5 Structural sheet steels are commonly fabricated by cold bending. There are many interrelated factors that affect the ability of given steel to cold form over a given radius under shop conditions. These factors include thickness, strength level, degree of restraint, relationship to rolling direction, chemistry and microstructure. Each of the appropriate product specifications lists minimum inside radius for cold bending. These radii should be used as minima for 90° bends. They presuppose "hard way" bending (bend axis parallel to rolling direction) and reasonably good shop forming practices. Where possible, the use of large radii or "easy way" bends are recommended for improved performance.

6.6 Fabricators should be aware that cracks may initiate upon bending a sheared or burned edge. This is not considered to be a fault of the steel but is rather a function of the induced cold work or heat-affected zone.

7 Dimensions, tolerances, and allowances

7.1 Dimensions, tolerances, and allowances applicable to products covered by this specification are contained in Tables 6 through 24. The appropriate tolerance tables shall be identified in each individual specification.

7.2 Flatness tolerances are not applicable to "annealed last" cold-rolled sheet, but that product will normally be within two times standard flatness when shipped in cut lengths and after removal of coil set when shipped in coils.

Table 6 — Thickness tolerances of hot-rolled sheet (carbon steel)

Specified width		**Thickness tolerance, over only, mm for specified minimum thickness**			
Over	Through	Through 2.0	Over 2.0 to 2.5 ind	Over 2.5 to 4, incl	Over 4 to 5, incl
300	600	0.30	0.30	0.35	0.407
600	1200	0.30	025	0.40	0.45
	1500	0.35	0.35	0.40	
	1800	0.35	0.40	0.40	
1800		0-35	0.40	0.40	

NOTE 1 Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coils.
NOTE 2 The specified thickness range captions also apply when sheets specified to a nominal thickness and the tolerances are divided equally over and under.

Table 7 —Thickness tolerances of hot-rolled sheet (High strength low-alloy steel) (coils and cut lengths, including pickled)

Specified width		Thickness tolerances, over only, mm, for specified minimum thickness			
Over	Through	Through 2.0	Over 2.0 to 2.5, ind	Over 2.5 to 4.5, incl	Over 4.5 to 6.0, incl
300	600	0.30	0.35	0.40	0.40
600	1 200	0.35	0.40	0.45	0.50
1 200	1 500	0.35	0.40	0.50	
1 500	1 800	0.40	0.45	0.55	
1 800	2 000	0.40	0.45	0.60	
2 000			0.50	0.60	

NOTE 1 Thickness is measured at any point across the width not less than 10 mm from a cut edge and not less than 20 mm from a mill edge. This table does not apply to the uncropped ends of mill edge coiis.

NOTE 2 The specified thickness range captions also apply when sheet F specified to a nominal thickness and the tolerances are divided equally, over and under.

Table 8 — Width tolerances[a)] of hot-rolled mill edge sheet (carbon and high-strength low alloy steel) (coils and cut lengths, including pickled)

Specified width		**Width tolerance, over only**	
Over	Through	Carbon	HSLA
300	600	16	16
600	1200	26	28
1200	1500	32	38
1500	1800	35	45
1800		48	50

a) The above tolerances do not apply to the uncropped ends of mill edge coils.

Table 9 — Width tolerances of hot-rolled cut edge sheet and cold-rolled sheet (carbon and high-strength low-alloy steel) (Not resquared coils and cut lengths, including pickled)

Specified width		**Width tolerance, over only**
Over	Through	
300	600	3
600	1200	5
1200	1500	6
1500	1800	8
1800		10

Table 10 — Length tolerances of hot-rolled sheet (carbon and high-strength low-alloy steel)

(Cut lengths not resquared, including pickled)

Specified length		Length tolerance, Over only
Over	to	
300	600	6
600	900	8
900	1500	12
1500	3000	20
3000	4000	25
4000	5000	35
5000	6000	40
6000		45

Table 11 — Diameter tolerances of circles from hot-rolled sheet (including pickled) and cod rolled sheet (over 300 mm width)

Specified thickness[a)]		Tolerances over specified diameter (no tolerances under) Diameters		
Over	Through	Through 600	Over 600 to 1200 incl	Over 1200
	1.5	1.5	3.0	5.0
1.5	2.5	2.5	4.0	5.5
2.5		3.0	5.0	6.5
[a)] 1.8 mm min. thickness for hot-rolled high-strength low-alloy steel sheet.				

Table 12 — Camber tolerances [a)] for hot-rolled (including pickled) and cold-rolled sheet (over 300 mm width) (carbon and high-strength low-ally steel)

(Cut lengths, not resquared)

Cut length, mm		**Camber tolerances[a)] mm**
Over	Through	
	1200	4
1200	1800	5
1800	2400	6
2400	3000	8
3000	2700	10
3700	4300	13
4300	4900	16
4900	5500	19
5500	6000	22
6000	9000	32
9000	12200	38
NOTE 1 Camber is the greatest deviation *of* a side edge from a straight *line,* the measurement being taken on the concave side with a straightedge.		

The camber tolerance for coils is 25.0 mm in any 6000 mm.

Table 13 — Out-of-square tolerances of hot-rolled cut-edge (including pickled) and cold-rolled sheet (over 300 mm width carbon and high-strength low-alloy steel) (cut lengths not resquared)

Out-of-square is the greatest deviation of an end edge from a straight line at right angle to a side and touching one comer. It is also obtained by measuring the difference between the diagonals of the cut length. The out-of-square deviation is one half of that difference. The tolerance for all thicknesses and all sizes is 1.0 mm/100 mm of width or fraction thereof.

Table 14 — Resquared tolerances of hot-rolled (including pickled) and cold-rolled sheet (over 300 mm width) (carbon and high-strength low-alloy steel)

(cut lengths)

When cut lengths are specified resquared, the width and the length are not less than the dimensions specified. *The individual* tolerance *for over-width,* over-length. camber, or out of-square should not exceed 1.6 mm up to and inducting 7, 200 mm in width and up to and inducting 3, 000 mm in length. For cut lengths wider or longer, the applicable tolerance is 3.2 mm.

Table 15 — Flatness Tolerances [a)] of hot-rolled sheet including pickled cut lengths not specified to stretcher-leveled standard of flatness (Carbon and high strength low-alloy steel)

Specified thickness, mm			Flatness tolerance[b)], mm specified yield point, min, MPa[c)], [d)]	
Over	Through	Specified width mm,	Under 310	310 to 345 MPa Yield Point Min MPa
1.2	1.5	To 900, incl	15	
		Over 900 to 1500, incl	20	
		Over 1500	25	
1.5	4.5	To 1500 incl	15	20
		Over 1500 to 1800, incl	20	30
		Over 1800	25	40
44.5	6.0 excl	To 1200, incl	15	20

Table 16 — Flatness tolerances of Hot-rolled sheet including pickled cut lengths specified to stretcher-leveled standard of flatness (carbon and high-strength low-alloy steel)

Specified thickness mm		Specified width	Specified length	Flatness tolerance[a)] mm specified yield point, min. MPa[b)]	
Over	Through	mm	mm	Under 310	310 to 345 Mpa[c)]
1.2	4.5	Through 1 200	Through 2 400	3	
		wider or longer	wider or longer	6	c)
4.5	6.0	Through 1 200	Through 2 400	3	
		Longer	Longer	6	c)

Maximum deviation from a horizontal flat surface.

1.8 mm minimum thickness for HSLA.

Tolerances for high-strength, low-alloy steel are subject to negotiation.

[a)] The above tolerances also apply to cut lengths from coils by the consumer when adequate flattening operations are performed.
[b)] Maximum deviation from a horizontal flat surface.
[c)] Tolerances for high-strength, low-alloy steels with specified minimum yield point in excess of 345 Mpa are subject to negotiation.
[d)] 1.8 minimum thickness.

Table 17 — Allowances in width and length of hot-rolled sheet (carbon-steel) and cold-rolled sheet (carbon and high-strength low-alloy steel)

(Cut length sheets specified to stretcher-leveled standard of flatness, not resquared, including pickled)

Dimensions in millimetres

Specified length		Allowance over specified dimensions		
		Width	Length	
Over	Through		Specified "grip or entry marks outside specified length"	Specified "grip or entry marks inside specified length"
	3 000	20	100	75
3 000	4 000	25	100	75
4 000		30	125	100

NOTE 1 When cut lengths are specified to stretcher-leveled standard of flatness and not resquared, the allowances over specified dimensions in width and length given in the following table apply. Under these conditions the allowances for width and length are added by the manufacturer to the specified width and length and the tolerances given in Tables 5, 6, 7, 17, 18, and 19 apply to the new size

established. The camber tolerances in Table 10 do not apply.
NOTE 2 When cut lengths are not to have grip or entry marks within the specified length, the purchaser should specify "gap entry marks outside specified length" When cut lengths may have grip or entry marks within the specified length the purchaser should specify "grip or entry marks inside specified length".

Table 18 — Thickness tolerances of cold-rolled sheet (carbon and high-strength low-alloy steel)

Dimensions in millimetres

Specified width		**Thickness tolerances, over only, mm, for specified minimum thickness**				
Over	Through	Through 0.4	Over 0.4 to 1.0, incl	Over 1.0 to 1.2, incl	Over 1.2 to 2.5, incl	Over 2.5 to 4.0, incl
50	1 800	0.10	0.15	0.20	0.25	0.30[b)]
1 800	2 000		0.15	0.20	0.30	0.35
2 000			0.30	0.30	0.35	0.40

[a)] **0.50 mm minimum thickness for high-strength low-alloy.**
[b)] **Not applicable to widths under 300 mm.**

Table 19 — Length tolerances of cold-rolled sheet (carbon and high-strength low-alloy steel)
(cut lengths over 300 mm in width, not resquared)

Specified length		Tolerance over specified length (no tolerance under)
Over	**Through**	
300	**1 500**	**6**
1 500	**3 000**	**20**
3 000	**6 000**	**35**
6 000		**45**

Table 20 — Length tolerances of cole-rolled sheet (carbon and high-strength low-alloy steel) (cut length sheets, 50 to 300 mm in width and 0.35 to 2.0 mm in thickness, not resquared)

Dimensions in millimetres

Specified length		Tolerance over specified length (no tolerance under)
Over	**Through**	
600	**1 500**	**15**
1 500	**3 000**	**20**
3 000	**6 000**	**25**

NOTE This table applies to widths produced by slitting from wider sheets.

Table 21 — Width tolerances for cold-rolled sheet (carbon and high-strength low-alloy steel)[a]
(coils and cut lengths 50 to 300 mm in width, not resquared, and 0.35 to 2.0 mm in thickness)

Dimensions in millimetres

Specified width		**Width tolerance, (over and under)**
Over	Through	
50	100	0.3
100	200	0.4
200	300	0.8

NOTE This table applies to widths produced by slitting from wider sheet.
[a)] 0.50 mm thickness for high-strength low-alloy.

Table 22 — Camber tolerances of cold-rolled sheet in coils (carbon and high-strength low-alloy steel 0.35[a)] to 2.0 mm in thickness)

Width, mm	**Camber tolerances**
50 through 300, incl	5.0 mm in any 2 000 mm

NOTE 1 Camber is the greatest deviation of a side edge from a straight line the measurements being taken on the concave side with a straightedge.
NOTE 2 This table applies to widths produced by slitting from wider sheet.

Table 23 — Flatness tolerances of cold-rolled sheet (carbon and high-strength low-alloy steel)[a)]
(cut lengths over 300 mm in width, not specified to stretcher levelled standard or flatness)

Specified thickness, mm	Specified width, mm		Flatness tolerance, mm specified yield point, min, MPa	
	Over	Through	Under 310 MPa	310 to 345 MPa[b)]
Through 1.0		900	10	20
	900	1 500	15	30
	1 500		20	40
Over 1.0		900	8	20
	900	1 500	10	20
	1 500	1 800	15	30
	1 800		20	40

NOTE 1 This table does not apply when product is ordered full hard, to a hardness range or "annealed last" (dead soft).

NOTE 2 This table also applies to lengths cut from coils by the consumer when adequate flattening measures are performed.
Maximum deviation from a horizontal flat surface.

b) Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 345 MPa are subject to negotiation.

Table 24 — Flatness tolerances of cold-rolled sheet (carbon and high-strength low-alloy steel)[a)]
(cut lengths specified to stretcher-level standard of flatness)

Specified thickness, mm	Specified width, mm	Specified length, mm	Flatness tolerance, mm specified yield point, min. MPa	
			Under 310 MPa	**310 to 345 MPa[b)]**
0.35 to 0.8, incl	Through 900	Through 3 000	8	10
	Wider or longer	Wider or longer	10	15
Over 0.8	Through 1 200	Through 3 000	5	5
	Wider or longer	Wider or longer	8	10

a) Maximum deviation from a flat surface.
b) Tolerances for high-strength, low-alloy steel with specified minimum yield point in excess of 345 MPa are subject to negotiation.

8 Finishes and condition

8.1 Hot-rolled sheet has a surface with an oxide or scale resulting from the hot-rolling operation. The oxide or scale can be removed by pickling or blast cleaning when required for presswork operations or welding. Hot-rolled and hot-rolled descaled sheet is not generally used for exposed parts where surface is of prime importance.

8.1.1 Hot-rolled sheet can be supplied with mill edges or cut edges as specified mill edges are the natural edges resulting from the hot-rolling operation. They do not conform to any particular contour. They may also contain some edge imperfections, the more common types of which are cracked edges, thin edges (feather), and damaged edges due to handling or processing and which should not extend in beyond the ordered width. These edge conditions are detrimental where joining of the mill edges by welding is practiced. When the purchaser intends to shear or to blank a sufficient width allowance should be made when purchasing to assure obtaining the desired contour and size of the pattern sheet. The manufacturer may be consulted for guidance. Cut edges are the normal edges, which result from the shearing, slitting, or trimming of mill-edge sheet.

8.1.1.1 The ends of plain hat-rolled mill-edge coils are irregular in shape and are referred to as uncropped ends. Where such ends are not acceptable, the purchaser's order should so specify. Processed coils such as pickled or blast cleaned are supplied with square-cut ends.

8.2 Cold-rolled carbon sheet (exposed) is intended for those applications where surface appearance is of primary importance. This class will meet requirements for controlled surface texture, surface quality, and flatness. It is normally processed by the manufacturer to be free of stretcher strain and fluting. Subsequent user roller levelling immediately before fabrication will minimize strain resulting from aging.

8.2.1 Cold rolled carbon sheet, when ordered for exposed applications, can be supplied in the following finishes:

8.2.1.1 Matte finish is a dull finish, without luster, produced by rolling on rolls that have been roughened by mechanical or chemical means to various degrees of surface texture depending upon application. With some surface preparation matte finish is suitable for decorative painting. It is not generally recommended for bright plating.

8.2.1.2 Commercial bright finish is a relatively bright finish having a surface texture intermediate between that of matte and luster finish. With some surface preparation commercial bright finish is suitable for decorative painting of certain plating applications. If sheet is deformed in fabrication the surface may roughen to some degree and areas so affected will require surface preparation to restore surface texture to that of the undeformed areas.

8.2.1.3 Luster finish is a smooth bright finish produced by rolling on ground rolls and is suitable for decorative painting or plating with additional special surface preparation by the user. The luster may not be retained after fabrication; therefore, the formed parts will require surface preparation to make them suitable for bright plating.

8.3 Cold-rolled carbon sheet, when intended for unexposed applications, is not subject to limitations on degree and frequency of surface imperfections, and restrictions on texture and mechanical properties are not applicable. When ordered as "annealed last," the product will have coil breaks: and a tendency toward fluting and stretcher straining. Unexposed cold-rolled sheet may contain more surface imperfections than exposed cold-rolled sheet because steel applications, processing procedures, and inspection standards are less stringent.

8.4 Cold-rolled high-strength low-alloy sheet is supplied with a matte finish, unless otherwise specified.

8.5 The cold-rolled products covered by this specification are furnished with cut edges and square cut ends, unless otherwise specified.

8.6 Oiling

8.6.1 Plain hot-rolled sheet is customarily furnished not oiled. Oiling shall be specified, when required.

8.6.2 Hot-rolled pickled or descaled sheet is customarily furnished oiled. If the product is not to be cited it shall be so specified since tile-cleaned surface is prone to rusting.

8.6.3 Cold-rolled products covered by this specification can lie furnished oiled or not oiled as specified.

8.7 Sheet steel in coils or cut lengths may contain surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser.

9 Workmanship and surface conditions

9.1 Workmanship

9.1.1 Cut lengths shall have a workmanlike appearance and shall not have imperfections of a nature of degree for the product, the grade, class, and the quality ordered that will be detrimental to the fabrication of the finished part.

9.1.2 Coils may contain some abnormal imperfections that render a portion of the coil unusable since the inspection of coils does not afford the producer the same opportunity to remove portions containing imperfections as in the case with cut lengths.

9.2 Surface conditions

9.2.1 Exposed cold-rolled sheet is intended for application where surface appearance is of primary importance, that is, exposed applications. Unexposed or annealed cold rolled sheet is intended for applications where surface appearance is not of primary importance, that is, unexposed applications.

9.2.2 Cut lengths for exposed applications shall not include individual sheets having major surface imperfections (holes, loose slivers, and pipe) and repetitive minor surface imperfections. Cut lengths may contain random minor surface imperfections that can be removed with a reasonable amount of metal finishing by the purchaser. These imperfections shall be acceptable to the purchaser within the manufacturer's published standards.

9.2.3 For coils for exposed applications, it is not possible to remove the surface imperfections listed in 9.2.2. Coils will contain such imperfections, which shall be acceptable to the purchaser within the manufacturer's published standards. Coils contain more surface imperfections than cut lengths because the producer does not have the same opportunity to sort portions containing such imperfections as is possible with cut lengths.

9.2.4 Cut lengths for unexposed applications shall not include individual sheets having major surface imperfections such as holes, loose slivers, and pipe. In addition, unexposed cut lengths can be expected to contain more minor imperfections such as pits, scratches, sticker breaks, edge breaks, pinchers, cross breaks, roll marks, and other surface imperfections than exposed. These imperfections shall be acceptable to the purchaser without limitation.

9.2.5 For coils for unexposed applications, it is not possible to remove the surface imperfections listed in 9.2.4. Coils will contain surface imperfections that are normally not repairable. Minor imperfections shall be acceptable to the purchaser within the manufacturer's published standards. Unexposed coils contain more surface imperfections than exposed coils.

10 Retests

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

10.2 If the percent elongation of any test specimen is less than that specified and any part of the fracture is more than 20 mm from the centre of the gage length of a 50-mm specimen or is outside the middle half of the gage length of a 200-mm specimen, as indicated by scribe scratches marked on the specimen before testing, a retest is allowed.

10.3 If a bend specimen fails, due to conditions of bending more severe than required by the specification, a retest is permitted either on a duplicate specimen or on a remaining portion of the failed specimen.

11 Inspection

11.1 When purchaser's order stipulates that inspection and tests (except product analyses) for acceptance on the steel be made prior to shipment from the mill, the manufacturer shall afford the purchaser's inspector all reasonable facilities to satisfy him that the steel is being produced and furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with he manufacturer's operation.

12 Rejection and rehearing

12.1 Unless otherwise specified, any rejection shall be reported to the manufacturer within a reasonable time after receipt of material by the purchaser.

12.2 Material that is reported to be defective subsequent to the acceptance at the purchaser's works shall be set aside adequately protected, an investigation may be initiated.

12.3 Samples that are representative of the rejected material shall be made available to the manufacturer. In the event that the manufacturer is dissatisfied with the rejection, may request a rehearing.

13 Product marking

13.1 As a minimum requirement, the material shall be identified by having the manufacturer's name designation, weight, purchaser's order number, and material identification legibly stenciled on top of each lift or shown or a tag attached to each coil or shipping unit.

13.2 When specified in the contract order and for direct procurement or direct shipment, marking for shipment in addition to requirements specified in the contract or order, shall be as agreed upon between the manufacturer and the purchaser.

14 Packaging and package marking

14.1 When coils are ordered, it is customary to specify a minimum or range of inside diameter, maximum outside diameter, and a maximum coil weight, if required. The ability of manufacturers to meet the maximum coil weights depends upon individual mill equipment. When required minimum coil weights are subject to negotiation.

14.2 In addition to 14.1, when specified in the contract or order, and for direct procurement or direct shipment, preservation, packaging, and packing shall be as agreed upon between the manufacturer and the purchaser.

Standard chemical ranges and limits

A.1 Standard chemical ranges and limits are prescribed for carbon steels in Tables A.1 and A.2.

Annex A
(normative)

Table A.1 — Standard steel - carbon sheet steel compositions

Steel designation SAE or AISI No.	Chemical composition limits, %			
	C	Mn	P max.	S max.
1006	0.08 max.	0.45 max.	0.040	0.050
1008	0.10 max.	0.50 max.	0.040	0.050
1009	0.15 max.	0.60 max.	0.040	0.050
1010	0.08-0.13	0.30-0.60	0.040	0.050
1012	0.10-0.15	0.30-0.60	0.040	0.050
1015	0.12-0.18	0.30-0.60	0.040	0.050
1016	0.12-0.18	0.60-0.90	0.040	0.050
1017	0.14-0.20	0.30-0.60	0.040	0.050
1018	0.14-0.20	0.60-0.90	0.040	0.050
1019	0.14-0.20	0.70-1.00	0.040	0.050
1020	0.17-0.23	0.30-0.60	0.040	0.050
1021	0.17-0.23	0.60-0.90	0.040	0.050
1021	0.17-0.23	0.70-1.00	0.040	0.050
1023	0.19-0.25	0.30-0.60	0.040	0.050
1025	0.22-0.28	0.30-0.60	0.040	0.050
1026	0.22-0.28	0.60-0.90	0.040	0.050
1030	0.27-0.34	0.30-0.90	0.040	0.050
1033	0.29-0.36	0.70-1.00	0.040	0.050
1035	0.31-0.38	0.60-0.90	0.040	0.050
1037	0.31-0.38	0.70-1.00	0.040	0.050
1038	0.34-0.42	0.60-0.90	0.040	0.050
1039	0.36-0.44	0.70-1.00	0.040	0.050
1040	0.36-0.44	0.60-0.90	0.040	0.050
1042	0.39-0.47	0.60-0.90	0.040	0.050
1043	0.39-0.47	0.70-1.00	0.040	0.050
1045	0.42-0.50	0.60-0.90	0.040	0.050
1046	0.42-0.50	0.70-1.00	0.040	0.050
1049	0.45-0.53	0.60-0.90	0.040	0.050
1050	0.47-0.55	0.60-0.90	0.040	0.050
1055	0.52-0.60	0.60-0.90	0.040	0.050
1060	0.55-0.66	0.60-0.90	0.040	0.050
1064	0.59-0.70	0.50-0.80	0.040	0.050
1065	0.59-0.70	0.60-0.90	0.040	0.050
1070	0.65-0.75	0.60-0.90	0.040	0.050
1074	0.69-0.80	0.50-0.80	0.040	0.050
1078	0.72-0.86	0.30-0.60	0.040	0.050
1080	0.74-0.88	0.60-0.90	0.040	0.050
1084	0.80-0.94	0.60-0.90	0.040	0.050
1085	0.80-0.94	0.70-1.00	0.040	0.050
1086	0.80-0.94	0.30-0.50	0.040	0.050
1090	0.84-0.98	0.60-0.90	0.040	0.050
1095	0.90-1.04	0.30-0.50	0.040	0.050
1524	0.18-0.25	1.30-1.65	0.040	0.050
1527	0.22-0.29	1.20-1.55	0.040	0.050
1536	0.30-0.38	1.20-1.55	0.040	0.050
1541	0.36-0.45	1.30-1.65	0.040	0.050
1548	0.43-0.52	1.05-1.40	0.040	0.050
1552	0.45-0.55	1.20-1.55	0.040	0.050

NOTE When silicon is required, the following ranges and limits are commonly used:

To 1015, excl 0.10 max.

1015 to 1 025, incl 0.10 max. 0.10-0.25 or 0.15-0.30

Over 1 025 0.10-0.25 or 0.15-0.30

Table A.2 — Standard chemical ranges and limits

Element	Carbon steels only, cast or heat analysis		
	Minimum of specified element, %	**Range**	**Lowest max.**
Carbon (see Note)	To 0.15 incl	0.05	0.08
	Over 0.15 to 0.30 incl	0.06	
	Over 0.30 to 0.40	0.07	
	Over 0.40 to 0.60	0.08	
	Over 0.6 to 0.80	0.11	
	Over 0.80 to 1.35	0.14	
Manganese	To 0.50 incl	0.20	0.40
	Over 0.50 to 1.15 incl	0.30	
	Over 1.15 to 1.65	0.35	
Phosphorus	To 0.08 incl	0.03	0.40[a)]
	Over 0.08 to 0.15	0.05	
Sulfur	To 0.08 incl	0.03	0.05[a)]
	Over 0.08 to 0.15 incl	0.05	
	Over 0.15 to 0.23	0.07	
	Over 0.23 to 0.33 incl	0.10	
Silicon	To 0.15 incl	0.08	0.10
	Over 0.15 to 0.30	0.15	
	Over 0.30 to 0.60 incl	0.30	
Copper	When copper is required 0.20 mm is commonly specified		

NOTE The carbon ranges shown in the column headed "Range" apply when the specified maximum limit for manganese does not exceed 1.00 %. When the maximum manganese limit exceeds 1.00 %, add 0.01 to the carbon ranges shown below.

Certain individual specifications provide for lower standard limits for phosphorus and sulfur.

Effect of aging of cold-rolled carbon steel sheet on drawing and forming B.1

Commercial quality and drawing quality

B.1.1 Cold-rolled sheet is usually temper rolled after annealing. Maximum ductility and minimum hardness exist in cold-rolled sheet in the annealed or dead soft conditions (not temper rolled); however, such sheet is not suitable for most formations due to the fact that it will flute or stretcher strain. A certain amount of cold work (temper rolling) will prevent these conditions from occurring, but the effect of temper rolling, is only temporary due to the phenomenon commonly known as aging.

B.1.2 Effective roller levelling of temper-passed steel immediately prior to fabrication will minimize the tendency of the sheet to stretcher strain and to flute, but such levelling will not restore softness and ductility. In fact, roller levelling further work hardens the sheet and hence further reduces ductility. Rotation of stock by fabricating the oldest material first is important. Stocking material for extended periods of time should be avoided.

B.2 Special killed, drawing quality

B.2.1 Special killed steel is essentially non-aging. It will not stretcher strain or flute or suffer loss of ductility with elapsed time when suitably temper rolled after annealing. This quality should be ordered when stretcher strains or fluting during fabrication are objectionable and the user does not have roller levelling equipment. This quality also should be ordered when the user plans to store sheet over an extended period of time without experiencing adverse changes due to aging.

B.2.2 Drawing quality, special killed steel has its maximum ductility in the annealed or dead-soft conditions, but in this state it is subject to stretcher straining or fluting during fabrication.

B.2.3 The superiority of special killed steel is not limited to the fact that it is essentially non-aging. It also has the exceptional ductility required for draws that cannot be made of drawing quality.

Procedure for determining breakage allowance levels

(applicable to carbon steel sheet only)

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C.1 In spite of the many extra precautions exercised in making sheet for drawing purposes, certain manufacturing variables may be encountered, all beyond the manufacturer's reasonable control, which may contribute to breakage in fabrication and shall be considered as part of the normal hazard of the purchaser's use. The manufacturer will undertake to establish with the purchaser's concurrence a breakage allowance level.

C.2 Breakage, for the purpose of this proposal, is defined as un-repairable parts broken during drawing and classed as scrap. Parts showing laminations, resulting from pipe, may be excluded provided they are separately identified. Broken parts that can be salvaged are not covered in this procedure.

C.3 This procedure is intended to establish a breakage allowance without the need for reinspection of each broken stamping. It will apply to overall breakage on a given part (as calculated by the method outlined below) in excess of 1 % up to and including 8 %. Inherent variations in steel sheet and normal variables in the stamping operation preclude 100 % satisfactory performance. Therefore, it is accepted that practical perfection is attained when 99 % of the stampings are produced without breakage. When the overall breakage is in excess of 8 %, it is considered to be the result of abnormal stamping conditions, and this method does not apply.

C.4 When there are two or more suppliers, the recommended procedure for determining a breakage allowance for an identified part is based on the average percentage of breakage of at least 75 % minimum is to be included in the calculation starting with the best performance. The average breakage thus determined shall be considered the allowance for the part.

C.4.1 Example

Vendor	Parts produced	Parts scrap	% scrap
A	32 466	630	1.94
B	27 856	579	2.08
C	67 120	1 477	2.20
D	56 200	1 349	2.40
E	40 900	1 125	2.75
F	850	60	7.05
All	225 392 total	5 220 total	2.32 avg.

C.4.2 Seventy-five percent of 225 392 equals to 169 044; there, it is necessary to include the total production of vendors A, B, C and D (A + B + C + D = total production of 183 642 parts) since the total of A, D, and C is only 127 442; which is less than 75 % of the total. Total production of 183 642 parts (A + B + C + d) with 4035 parts being rejected, results in a percentage allowance of 2.20 %. On this basis, vendors D, E and F exceed the allowance.

Procedures for determining the extent of plastic deformation encountered in forming or drawing

D.1 Introduction

There preferred method for determining plastic grain is the circle grid and forming limit curve. The scribed square and change in thickness methods may also be used to evaluate deformation during the forming of a flat sheet into the desired shape.

D.2 Circle grid method

D.2.1 The test system employs photographic or electrochemically etched circle patterns on the surface of a sheet metal blank of known "quality" and a forming limit curve for the evaluation of strains developed by forming in press operations. It is useful in the laboratory and in the pressroom. Selection from the various steels that are commercially available can be done effectively by employing this technique. In addition, corrective action in die or part design to improve performance is indicated.

D.2.2 The forming limit curve in Figure D.1 has been developed from actual measurements of the major (e_1) and associated minor (e_2) strains found in critical areas of production type stampings. Strain combinations that locate below this curve are safe, while those that fail above the curve are critical. For analysis of metal strain on production stampings, one shall recognize that day-to-day variations of material, lubrication and die settings will affect the strain level. To ensure trouble-free press performance a zone below the forming limit curve bounded by the dashed and solid lines is designated as the "safety band". Therefore, strain combinations falling below the dashed lines should not exceed the forming limit curve in normal production operations. The left of zero portion of the curve defines the limiting biaxial tension-compression strain combination while the right side defines the forming limit curve. Because the production stampings used to develop for forming limit curve represented all qualities of low-carbon light-gage sheet steel, this single forming limit curve can be used successfully for these products.

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D.2.3 The circle grid method can also be used for other low-carbon sheet categories if the following adjustments to the forming limit curve are made:

D.2.3.1 Material Thickness

As the metal thickness increases the forming limit curve shifts upwards in a parallel manner, 0.2 % ($e_{1)}$ strain for each 0.025 mm increase in metal thickness above 0.75 mm.

D.2.3.2 Material properties

When material properties are considerably different from that of conventional low-carbon sheet steel (for example, higher strength-low ductility), the forming limit curve is lower. The magnitude of the downgrade displacement is specific to each material; therefore, current material information should be consulted to determine placement of the forming limit curve

D.3 Procedure

D.3.1 Obtain a sheet sample of "known quality", the sheet quality being established by either supplier designation, consumer purchase order, or most preferred tensile data obtained from a companion sheet sample.

D.3.2 Obtain or prepare a negative on stencil with selected circles in a uniform pattern. The circles may be 2.5 to 25.0 mm in diameter; the most convenient diameter is 5.0 mm because it is easy to read and the gage spacing is short enough to show the maximum strain in a specific location on the part.

D.3.3 The sheet metal blanks should be cleaned to remove excess oil and dirt; however, some precoated sheets can be etched without removing the coating. The areas to be etched should be determined from observation of panels previously formed; generally, the area that has a split problem is selected for etching. Normally, the convex side of the radius is gridded. If sufficient time is available, the entire blank may be etched, since valuable information can be obtained about the movement of metal in stamping a part when strains can be evaluated in what may appear to be non-critical areas. Additionally, for complex shapes it may be desirable to etch both surfaces of blanks so that the strains that occur in reverse draws can be determined.

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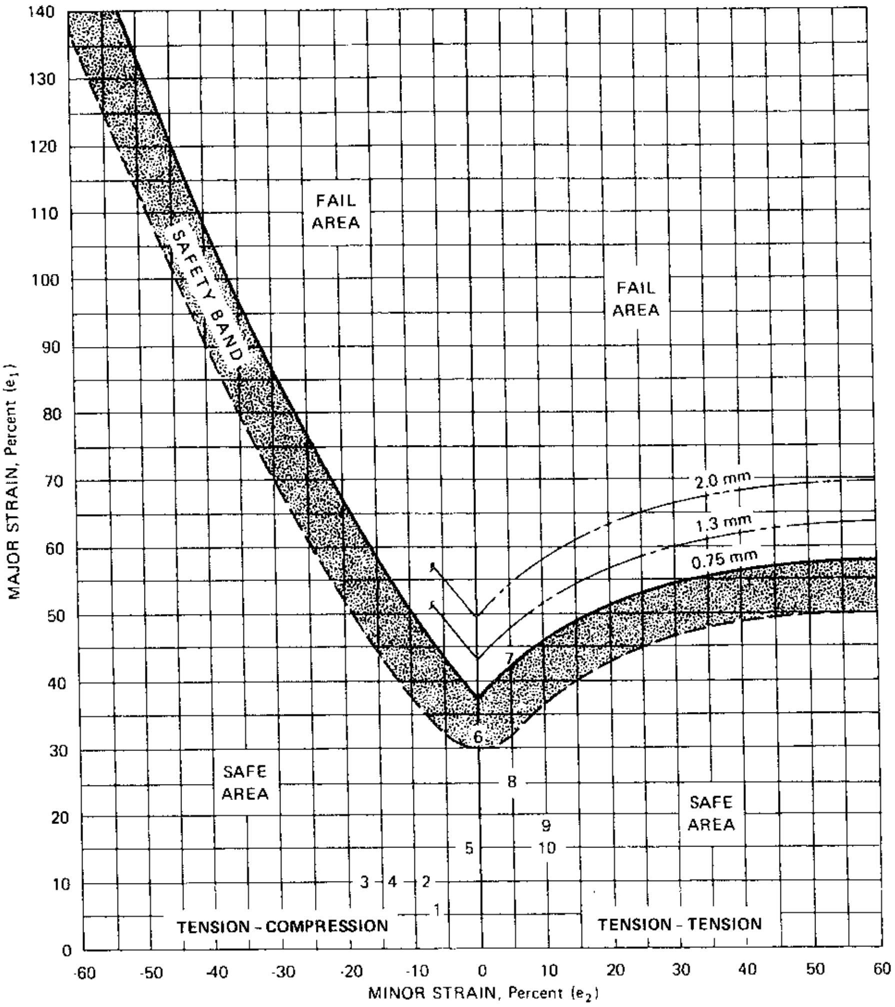

Figure D.1 — Forming limit curve

D.3.4 The sheet metal blanks may be etched by a photographic or electrochemical method. In the former method a photosensitive solution, for example, 50 % Kodak Photo Resist (KPR) emulsion and 50 % Q KPR-thinner, is sprayed onto the sheet. The emulsion is dried by baking the sheet at 65 °C for 15 min or by just standing it for several hours at room temperature in a dark room. The latter should be employed in materials that age and hence, become stronger when baked at 65 °C. The negative is placed on the emulsion, held intimately in contact with the sheet, and exposed to a strong ultraviolet light source for 1 to $1^1/_2$ min. The sheet is developed for 30 to 45 s in KPR developer, rinsed with water, and sprayed with alcohol to set the resist. It is again rinsed with water and then sprayed with KPR black dye to reveal the etched circles.

D.3.5 In the electrochemical method, the etch pad is saturated with an appropriate electrolyte. Various electrolytes are available from suppliers of the etching equipment. Some electrolytes are more effective than others for etching certain surfaces, such as terne plate and other metallic coated sheets. A rust-inhibiting solution is preferred for steel sheets.

D.3.6 A ground clamp from the transformer of suitable amperage (10 to 50.4 is usually used) is fastened to the blank and the second lead is attached to the etch pad. Although the current may be turned on at this time, caution should be taken not to lay the pad on the sheet blank as it will arc. It is advisable to refrain from touching the metal of the etch pad and the grounded sheet blank.

D.3.7 The stencil is placed with the plastic coating against the sheet surface in the area to be etched. Wetting the stencil with a minimum amount of electrolyte will assist in smoothing out the wrinkles and gives a more uniform etch. The etch pad is now positioned on the stencil and the current turned, on, if it is not already on. Apply suitable pressure to the pad. Only the minimum time necessary to produce a clear etched pattern should be used. The etching time will vary with the amperage available from the power source and the stencil area, as well as the pad area in contact with the stencil.

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Rocker-type etch pads give good prints and require less amperage than flat-surfaced pads. Excessive current causes stencil damage.

D.3.8 The etching solution activates the surface of the, metal and may cause rusting unless it is inhibited. After the desired area has been etched, the blank should be wiped or rinsed, dried, and neutralized.

D.3.9 The etched blank is now ready for forming. The lubricants and press conditions should simulate production situations. If a sequence of operations is used in forming a part, it is desirable to etch sufficient blanks so that each operation can be studied.

D.4 Measurement of strain after forming

D.4.1 After forming, the circles are generally distorted (into elliptical shapes (Figure D.2). These ellipses have major, and minor strain axes. The major strain (e_1) is always defined to be the direction in which the greatest positive strain has occurred without regard to original blank edges or the sheet rolling direction. The minor strain (e_2) is defined to be 90° the major strain direction.

D.4.2 There are several methods for determining the major and minor strains of the formed panel. Typical tool: are a pair of dividers and a scale ruled in 0.5 mm. For sharp radii, a thin plastic scale that can follow the contour of the stamping can be used to determine the dimensions of the ellipses. (Scales are available to read the percent strain directly).

D.5 Evaluation of strain measurements

D.5.1 The strain is always positive while the e_2 strain may be zero, positive, or negative, as indicated on the forming limit curve chart (Figure D.1). The maximum e_1 and associated 2, values measured in critical areas on the formed part are plotted on the graph paper containing the formic: limit curve by locating the point of intersection of the e_1, e_1 strains.

D.5.2 If this point is on or below the "safety band" of the forming limit curve, the strain should not cause breakage. Points further below the curve indicate that a less ductile material of a lower grade may be applied. Points above the safety band show that fabrication has induced strains that could result in breakage. Therefore, in evaluation on stampings exhibiting these strains, efforts should be made to provide an e_1, e_2 strain combination that would lie on or below the "safety band" of the forming limit curve. A different e_1, e_2 strain combination can be obtained through changes of one or more of the forming variables such as die conditions, lubricants, blank size, thickness, or material grade: it should be: noted at this time that these conclusions are derived from a reference base being the steel "quality" used to

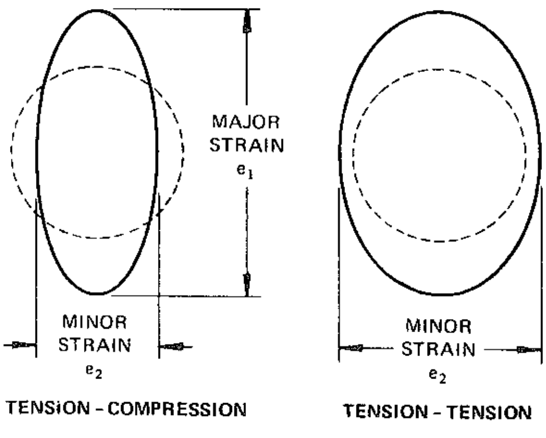

Figure D.2 — Major and minor strain axes

fabricate the grid stamping.

D.5.3 When attempting to change the relationship of e_1 and e_2 strains, it should be noted that on the forming limit curve the most severe condition for a given e_1 strain is at 0 % e_2. This means the metal works best when it is allowed to deform into two dimensions, e_1 and e_2, rather than being restricted in one dimension. A change in e_2 to decrease the severity can be made by changing one of the previously mentioned forming variables of the die design, for example, improving lubrication on the tension-tension side will increase e_1 and decrease the severity.

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D.5.4 In addition to the forming limit curve, the e_2 strain measurements may be used to evaluate the material requirements on the basis of strain gradients, as illustrated in Figure D.3, or by plotting contours of equivalent strain levels on the surface of the formed part. Even when the level of strain is relatively low, parts in which the e_1 strain is changing rapidly either in magnitude or direction over a short span on the surface may require more ductile grades of sheet metal, change in lubrication, or change in part design.

D.6 Example of major and minor strain distribution

D.6.1 A formed panel (Figure D.4) with a cross section as shown in Figure D.3 is used to illustrate major and minor strain combinations. A plot of the major strain distribution should be made by finding the ellipse with the largest major strain (circle 7) and measuring both the major and minor strains in the row of ellipses running in the direction of the major strain. The solid dots (Figure D.3) are the measured major strains for each ellipse. The Xs are the critical major strains as determined from the forming limit curve at the corresponding minor strain (intersection of the measured minor strain and the severity curve).

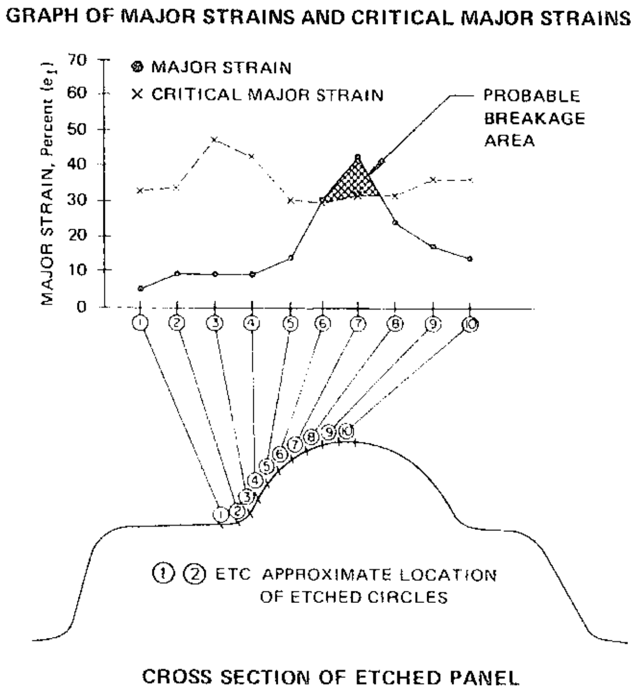
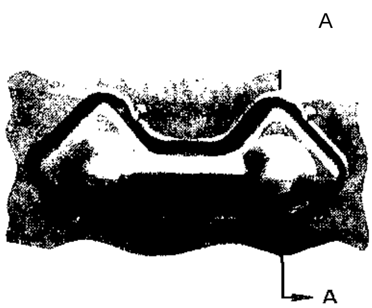


Figure D.3 — Graph of major strains and critical major strains and cross section of etched panel

D6.2 Usually a single row of ellipses will suffice to determine the most severe strain distribution. The resulting strain distribution plot (Figure D.3) illustrates both severity of the strain compared to the critical strain limits and the



1 = Final Contour 2 = First Revision 3 = Original Contour

Figure D.4 — Formed panel and cross section

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concentration of strain in the stamping. Steep strain gradients should be avoided because they are inherent to fracture sites.

D.7 Example for reducing splitting tendency

D.7.1 In an area such as that represented in Figure D.3, the splitting tendency can be reduced as follows:

D7.1.1 If the radius of the pan in the region of circle 1 is increased, some strain can be induced to take place in this area which will allow the major strain in circle 7 to be reduced sufficiently to bring the strain combination below the critical limit. Thus course of action requires no binding or reshaping of the punch, only grinding in the radius.

D.7.1.2 The total average major strain required to make this formation is only 17.5 %; yet in a 5.0 mm circle the strain is as high as 40 %. The strain distribution curve puts forth graphically the need to distribute the strain over the length of the line by some means as described above.

D.7.1.3 Change in lubrication can also improve the strain distribution of a stamping. If the strain over the punch is critical, the amount of stretch (strain) required to make the shape can be reduced by allowing metal to flow in over the punch by decreasing the friction through the use of a more effective lubricant in the hold-down area.

D.7.1.4 If the part is critical, a change in material may help. That is, a material having a better uniform elongation will distribute the strain more uniformly or a material having a higher "r" value will make it possible to "draw" in more metal from the hold-down area so that less stretch is necessary to form the part.

D.8 Scribed square method

D.8.1 The basic technique is to draw a panel from a blank that has been scribed both longitudinally and transversely with a series of parallel lines spaced at 25.0 mm intervals. The lines on the panel are measured after drawing and the stretch or draw calculated as the percent increase in area of a 25.0 mm square. This is a fairly simple procedure for panels having generous radii and fairly even stretch or draw. Many major panels fall in this category, and in these instances it is quite easy to pick out the square area exhibiting the greatest increase.

D.8.2 If the square or line to be measured is no longer a flat surface, place a narrow strip of masking (or other suitable tape) on the formed surface and mark the points, which are to be measured. Remove the tape, place on a plane surface, and determine the distance between the points with a steel scale.

D.8.3 There will be cases of minor increase in area with major elongation in the one direction. In these instances, the percent elongation should be recorded.

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D.9 Thickness method

D9.1 There are instances when the maximum stretch is continued to an area smaller than 645 mm^2 or the shape of the square has been distorted irregularly, making measurement difficult and calculation inaccurate. When either of these conditions exists, an electronic thickness gage may be used at the area in question or this area may be sectioned and the decrease in metal thickness measured with a ballpoint micrometer. The increase in unit area can be calculated by dividing the original thickness by the final thickness.

D.9.2 Example

Assuming the blank thickness to be 0.80 rnm and the final thickness to be 0.60 mm, the increase in unit area would be a [(0.80 - 0.60)/0.80] x 100 = 25 % increase.

Bibliography

EAS 194 *Steel and steel products — Part 1: Location and preparation of samples and test pieces for mechanical testing*

EAS 199 *Steel and cast iron* *Combustion titrimetric method*
Determination of sulphur content

EAS 200 *Steel and cast iron — Determination of phosphorus content — Phosphovanadomolybdate spectrophotometric method*

ISO 437 *Steel and cast iron — Determination of total carbon content — Combustion gravimetric method*

ISO 439 *Steel and iron — Determination of total silicon content — Gravimetric method*

ISO 629 *Steel and cast iron — Determination of manganese content — Spectrophotometric method*

ISO 671 *Steel and cast iron — Determination of sulphur content — Combustion titrimetric method*

ISO 4829-1 *Steel and cast iron — Determination of total silicon content — Reduced molybdosilicate spectrophotometric method — Part 1: Silicon contents between 0.05 and 1.0 %*

ISO 4829 *Steel and iron — Determination of total silicon content — Reduced molybdosilicate spectrophotometric method — Part 2: Silicon contents between 0.01 and 0.05 %*

ISO 4943 *Steel and cast iron — Determination of copper content — Flame atomic absorption spectrometric method*

ISO 10714 *Steel and iron — Determination of phosphorus content — Phosphovanadomolybdate spectrophotometric method*

ISO 14284 *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

KS 1513 *Specification for steel sheet and strip, heavy thickness coils, carbon, hot-rolled*

ISO 3310-1 *Test sieves — technical requirements and testing — Part 1: Test sieves of metal wire cloth*

