



**BEML LIMITED
BANGALORE**

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**STAINLESS STEEL
SPECIFICATION FOR
METRO CARS**

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3	Page 11 of 13	Revised	1.0 mm max. Camber for strips & 42-48 Kgf/mm ² proof stress for strips.	06.06.18
4	Page 5 of 14	Revised	In Para.4.1, 2J finish added.	07.05.19
4	Page 6 of 14	Revised	In Para 6, Freedom from defects 2 J finish also added	07.05.19
4	Page 12 of 14	Revised	In Para.14, Surface protection 2J finish also added	07.05.19
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5	Page 5 of 14	Revised	In Para.4.1, No 1D, 2D added & Dull finish updated.	17.02.2020
5	Page 10 of 14	Revised	In Para.13.1, 13.3 & 13.4 Tolerances for above 4thk added.	17.02.2020
5	Page 13 of 14	Revised	In Para.14, Surface protection for dull finish added.	17.02.2020

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1. Scope

- 1.1. This document details the technical specification of Cold rolled austenitic Stainless Steel (SS) sheets, strips and coils, to grade SUS 301L in different cold rolled tempers of LT, DLT, ST and HT and Hot rolled stainless steel to grade SUS 304L / AISI 304L used for the fabricated structures of carbody of Metro cars.
- 1.2. The SS raw material covered under this specification shall be supplied with guaranteed mechanical properties, formability, weldability and adequate corrosion resistance against varying temperature, humidity and exposure to environmental conditions experienced during service in all regions of the country.
- 1.3. The stainless steels shall be produced through established manufacturing process and quality assurance procedures.
- 1.4. All the sheets and strips shall be supplied in Trimmed conditions, unless otherwise specified in the order.
- 1.5. During vendor approval stage, M/s.SAIL & M/s.JSL Stainless submitted a series of samples of every grade and thickness and BEML conducted the chemical, mechanical, formability, weldability & corrosion resistance tests and finally obtained DMRC approval for the 2 vendors for supply of indigenous SS raw material required for the fabrication of carbody of Metro cars. The requirements specified in this Specification are broadly based on the results obtained during the vendor approval stage.

2. Applied standard.

JIS G 4305, JIS G 4304, ASTM A240 and the related standards unless otherwise specifically mentioned in this specification.

3. Material Symbols

The temper rolled symbols are as under

- LT : Low Tensile
- DLT : Deadlite Tensile
- ST : Special Tensile
- HT : High Tensile

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4. Surface finish

4.1. The surface of sheets, strips and coils shall be finished with one of the following finishes.

NO.1D : Hot Rolling followed by Annealing and Pickling.

NO 2D : Cold Rolling followed by Annealing and Pickling.

NO.2B : Finished by light cold rolling on polish rolls after cold rolling, annealing and pickling to obtain bright smooth finish.

NO.4 : Polished with No.150-180 grit abrasives as specified in JIS R 6001.

NO.3 : Polished with No. 100-120 grit abrasives as specified in JIS R 6001.

2J : Process route as per EN10088-2, Table.6

Surface Roughness(Ra) : 0.15 - 0.2 micrometers in both the directions.

Surface Glossiness / Reflectivity value for 2J finish:

At 60 deg. in transverse Direction 90 to 110 GU

At 60 deg. in rolling Direction 96 to 120 GU

At 85 deg. in transverse Direction 80 to 90 GU

At 85 deg. in rolling Direction 87 to 110 GU

Dull finish : Surface condition having lower reflectivity by cold rolling with etched rollers and is applicable for the DLT grade. Glossiness (%) 23 - 26 (compared with 60 degree reflectivity standard sample) & surface roughness (in microns) : 2.2 - 2.5 Ra.

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Due care shall be taken to ensure uniformity of the surface finish and the uniformity between each manufacturing lot. All the sheets, strips and coils shall be supplied in the 2B finish unless otherwise specified in the order.

4.2. The surfaces shall be protected with coating film as given in section 13 of this standard.

5. Process

Steel shall be produced in Electric/ Induction furnace and refined by AOD/VOD secondary refining process to ensure freedom from harmful gases, inclusions and other undesirable constituents.

6. Freedom from defects

The raw material shall be of uniform quality consistent with good manufacturing and inspection practices. Stainless Steel sheets, strips and coils shall be rolled to the dimensions and tolerances specified. Raw material shall be free from cracks, slivers, shells, laminations, deep scratches, pits, roll stop marks on No 4 / No 3 /2J finish, severe stains and any other harmful defects detrimental to the end use.

7. Chemical composition

7.1.1. Ladle Analysis

The ladle analysis of the stainless steel, SUS 301L, SUS304L / AISI 304L shall conform to Table-1

Table.1: Chemical composition of SUS 301L, SUS 304L / AISI 304L (wt %)

Designation	C	Si	Mn	P	S	Ni	Cr	N	Others
SUS 301L	0.030 max.	1.0 max.	2.0 max.	0.045 max.	0.030 max.	6.0 ~ 8.0	16.0 ~ 18.0	0.20 max.	-
SUS304L / AISI304L	0.030 max.	1.0 max.	2.0 max.	0.045 max.	0.030 max.	8.0 ~ 12.0	18.0 ~ 20.0	-	-

7.1.2. Product Analysis

Product analysis shall be carried out in the finished product. Permissible variation in product analysis on the limits specified in Table-1 shall be as given

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in Table-2.

Table.2: Permissible variation in product analysis of SUS 301L (wt %)

Element	C	Si	Mn	P	S	Ni	Cr	N
Permissible variation	+0.005	+0.05	+0.04	+0.005	+0.005	±0.10	±0.20	+0.02
Percent								-0.01

Elements not specified in Table-1 shall not be added to the steel except where agreed to, other than for the purpose of finishing the heat. All appropriate precautions are to be taken to avoid the addition of such elements from scrap and other materials used in production. Limit of all trace elements like Cu, Mo, Ti, Nb, Co, put together shall not exceed 1.0 wt % max.

8. Mechanical Properties :

8.1. Mechanical properties of the sheets, strips and coils shall conform to Table-3.

Tensile test shall be carried out both in longitudinal and transverse directions. Tensile strength shall be determined with a tensile machine cross head speed of 5 meter per minute up to yield strength and after yield, with 20 meter per minute.

Table.3: Mechanical Properties of SUS 301L, SUS 304L / AISI 304L

Stainless Steel Grade	Proof Stress (N/mm ²)		Tensile Strength (N/mm ²)		Elongation (%), (on 50mm GL)	Bend test	
	Min.	Max.	Min.	Max.		Bend angle	Inside Radius
SUS 301L-LT	215	375	550	860	45	180°	½ t
SUS 301L-DLT	345	485	690	860	40	180°	½ t
SUS 301L-ST	410	550	760	930	35	180°	¾ t
SUS 301L-HT	685	825	930	1140	20	135°	2 t
SUS 304L / AISI 304L	170		480		40		

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For mechanical testing, extensometer shall be used and the yield stress shall be measured through Offset Methods at 0.2 % yield.

9. Bend test :

The bend test specimen shall be cut transverse to the direction of rolling and the test made so that bending axis is parallel to the direction of rolling. The bend radius shall be as specified in table-3. The bend test shall be carried out as per JIS Z 2248. The bent specimen shall show no cracks on the bent surface when viewed visually or at low magnification of 5X-15X.

10. Metallography test :

10.1. Inclusion Rating

Inclusion rating shall be determined by microscopic method as per ASTM E 45 and the results shall conform to Table-4

Table.4: Inclusion rating limits

Type A (max.)		Type B (max.)		Type C (max.)		Type D (max.)	
Fine	Thick	Fine	Thick	Fine	Thick	Fine	Thick
1.0	0.5	1.0	0.5	1.0	1.0	1.0	1.0

10.2. Grain size

Average Grain size determined as per ASTM E112 shall be ASTM No.7 or finer

10.3. Microstructure

LT & DLT grade: Pre-dominantly equiaxed grains of austenite and there shall be no carbide precipitation.

ST & HT grades: Elongated grains of austenite with some Strain Induced Martensite and there shall be no carbide precipitation at grain boundaries. Traces of carbides in the matrix may be permitted.

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11. Inter Granular Corrosion (IGC) resistance test

11.1. LT & DLT grade :

Inter Granular Corrosion (IGC) resistance test in the sensitized condition shall be carried out for all thicknesses of the LT & DLT grade as per ASTM A262 with 10% Oxalic acid etch test - Practice A. Step structure as per Practice-A is preferred. In some cases, dual structure is permitted. Nothing beyond step & dual structure is acceptable. After practice- A, practice-E as per ASTM A262 shall be carried out. The samples shall be bent through 180° on a mandrel of diameter equal to the thickness of the specimen. The bent specimen shall show no cracks.

11.2. ST & HT grade:

Inter Granular Corrosion (IGC) resistance test in the sensitized condition shall be carried out for all thicknesses of the ST & HT grade as per ASTM A262 with copper-copper sulphate-16% sulphuric acid test - Practice E. ST grades shall be bent through 180° on a mandrel of diameter equal to the thickness of the specimen and HT grades shall be bent through 135° on a mandrel of diameter equal to twice the thickness of the specimen. The bent test results shall be submitted.

12. Weldability:

The sheets, strips & coils shall be suitable for MIG, TIG & spot welding using recommended consumables.

The supplier shall submit samples with identity along with MTC for weldability test. BEML shall carry out the tests and give clearance.

13. Dimensional Tolerances

13.1. Thickness tolerance

The thickness tolerance for sheets, strips and coils shall conform to table-5

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Table-5: Thickness tolerance

Sheet thickness (in mm)	Tolerance (in μm)
Below 1.6	± 20
1.6-2.5	± 25
2.5-4.0	± 30
4.0-5.0	± 45
5.0-6.0	± 50
6.0-8.0	± 60
8.0-10.0	± 70

Note: Thickness of the sheets shall be measured with micrometer for every 100 mm in the width direction starting from 50 mm from the edge.

13.2. Width tolerance

Tolerance on the Width of the sheets shall be as given in Table 6.

Table -6: Width tolerance

Thickness (mm)	Tolerance (mm) for $1000 < W < 1500$
Below 1.0	± 0.75
1.0-1.6	± 0.90
1.6-2.5	± 1.05
2.5 & above	± 1.20

Tolerance on the Width of the strip shall be as given in Table 7.

Table 7: Width tolerance for strips

Thickness (mm)	Width tolerance (mm)				
	Under 160	$160 \leq W < 250$	$250 \leq W < 400$	$400 \leq W < 630$	$630 \leq W < 1000$
$0.60 \leq t < 1.0$	± 0.20	± 0.25	± 0.25	± 0.30	± 0.50
$1.0 \leq t < 1.60$	± 0.20	± 0.30	± 0.30	± 0.40	± 0.60
$1.6 \leq t < 2.5$	± 0.25	± 0.35	± 0.35	± 0.50	± 0.70
$2.5 \leq t < 4.0$	± 0.30	± 0.40	± 0.40	± 0.50	± 0.80
$4.0 \leq t < 5.0$	± 0.35	± 0.45	± 0.45	± 0.55	± 0.90

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13.3. Length tolerance

Tolerance on the length of the sheets and strips shall be as given in Table 8.

Table 8: Length tolerance

Thickness (mm)	Length (mm)	
	L<3500	3500<L<=6000
Under 5.0	+10	+15
	0	0
5.0 - 10.0	+10	+15
	0	0

13.4. Flatness tolerance

The maximum values for flatness of sheets and strips shall be as given in Table 9.

Table 9: Maximum values for flatness of sheets & strips

Symbol	Thickness (mm)	Flatness (mm)
LT, DLT, ST	-	Below 6
HT	4.5	Below 15.0
304L	Up to 10	Below 20.0

Note: Table 9 applies to an arbitrary length of 4000 mm and in case of under 4000 mm length sheets and strips, it applies to the overall length.

13.5. Camber

Permissible value of camber in sheets shall be 3.0 mm max. per unit length of 2400 mm.

For strips supplied in cut lengths the camber shall be 1.0 mm max for full length. If the camber cannot be achieved by slitting, alternate methods like laser cutting may be adopted.

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 strips to be cut from the raw material of proof stress range 42-48 kgf/mm², however the SUS301L-ST proof stress specified range is 42 to 56 Kgf/mm².

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13.6. Squareness of sheets :

Squareness in the direction of width of sheets shall be 2.5 mm max. per 1250 mm in width.

Out of square is the greatest deviation of an end edge from a straight edge of a square placed at right angles to a side and touching one corner as shown in Fig.1

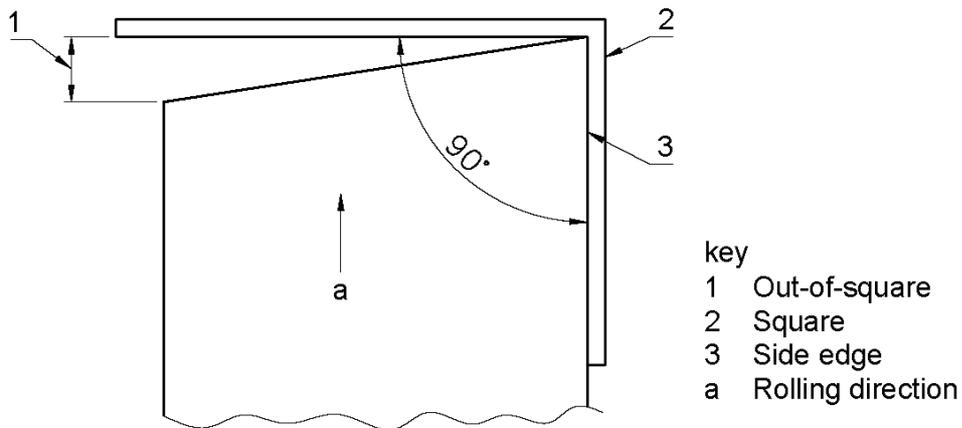


Fig.1: Measurement of out-of-squareness

Alternatively, the out of squareness may also be measured by taking the difference between the diagonal lengths. The diagonal difference divided by 2 shall not exceed 2.5mm.

13.7. Wave tolerance of coil: Shall be as given in table 10.

Table 10: Wave tolerance of coil

Symbol	Wave tolerance
LT, DLT, ST, HT	5 mm / 20 m

13.8. Straightness of coil: Shall be as given in table 11.

Table 11: Straightness of coil

Symbol	Straightness
LT, DLT, ST, HT	5 mm / 20 m

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14. Surface Protection

All sheets, strips & coils shall be provided with PVC/Plastic protection film with a thickness of 90±10microns, on the No.4 / No 3 / 2J finish surface and on one side of 2B finish surface.

The Dull Finish sheets (DLT Grade) shall be provided with PVC vinyl film covering with a minimum cover thickness of 120±10 microns on the dull finish surface for protection.

The films are intended to protect the surface of the stainless steel from scratches and damage during transportation, storage, handling and further processing of the components. Subsequently, the film will be removed from the component before/after installation. Hence, the films shall have good adhesion and weatherability and shall be easy to remove without tearing and with no residual glue on the surface.

15. Tests

All the tests and test methods shall generally be as detailed at clause 11 of JIS G4305 unless otherwise specifically mentioned in this standard.

16. Inspection, Marking & Report

Inspection : The general requirements for inspection shall conform to JIS G0303 (General rules for inspection of steel)

The test results on chemical composition, mechanical properties, corrosion resistance, surface finish appearance, shape and dimensions shall conform to the requirements specified in respective clauses of this specification.

Report: The manufacturer shall submit the inspection report of the sheets, plates & coils, stating the results of inspection as per this specification, quantity, delivery conditions etc.

Marking: Each sheet/ coil shall be marked with a permanent marker with details of stainless steel grade and temper (LT/ DLT/ ST/ HT), heat no. & coil no.,

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thickness, width & length, surface finish symbol and manufacturer's name. Similar details for Dull finish, No 3, No.4 & 2J finish sheets shall be marked with a permanent marker / Sticker on the PVC, and other side of the No3, No.4, 2J & Dull finish.

17. Re-tests

If the samples for the materials do not conform to clause 10 & 11, the same sample shall be retested to confirm the results. If the sample on retesting does not conform to the clause 10 & 11, the material shall be rejected. No New sampling shall be permitted.

For all other tests, if any of the first selected test pieces do not pass the tests specified in this specification, two further samples shall be selected from the same lot in the same manner. If the test pieces from both these additional samples pass, then the material represented by the test samples shall be deemed to comply with the requirements of that particular test. Should the test pieces from either of these additional samples not pass, the material represented by the test samples shall be deemed to be not conforming to this specification.

18. Packing

Sheets & coils shall be provided with reasonable packing, with metal strapping for handling during transit and storage.

Due care shall also be taken to avoid mechanical damage and corrosion during transit.