भारतीय मानक **IS 18384 : 2023**

Indian Standard

पाइपलाइन परिवहन तंत्र में युक्त वेल्डेड इस्पात पाइप के लिए तप्त-वेल्लित इस्पात की पत्ती, चद्दर और प्लेटें — विशिष्टि

Hot-Rolled Steel Strip, Sheet and Plates for Welded Steel Pipe for Pipeline Transportation Systems — Specification

ICS 77.140.50

भारतीय मानक ब्यूरो
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Wrought Steel Products Sectional Committee, MTD 04

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Wrought Steel Products Sectional Committee had been approved by the Metallurgical Engineering Division Council.

Steel pipes used in pipeline transportation systems in petroleum and natural gas industry require stringent quality norms due to the criticality of application. Although the hot-rolled strips and plates for welded pipes used in oil and gas transportation have been manufactured in India for over two decades, there is no specific standard available for the hot rolled steel strips and plates for the manufacture the welded steel pipes that are used for transportation of oil and natural gas.

A need was then felt to have a standard for hot-rolled steel strips and plates that are used for manufacturing welded line pipes.

Based on the experience gained over the years, the chemical composition and the mechanical properties of the steels used in two product specification levels PSL 1 and PSL 2 have been kept in line with ISO 3183 : 2019 requirements. It has also been noted by the Committee that the mechanical properties of the steel strips or plates may or may not be the same across the thickness range as those obtained on the pipes made from this steel. Therefore, based on their experience and pipe manufacturing process (ERW, Helical SAW, L-SAW etc), the pipe manufacturers may require more stringent mechanical properties for steel strips, sheets and plates than those required on the steel pipes. Accordingly, it was agreed that steels with more stringent mechanical properties can be mutually agreed between the steel manufacturer and the user or the pipe manufacturer.

Supply of pipelines for oil manufacturing companies involve multi-layered third-party inspections from the stage of steel production till pipe manufacturing. On the account, vast data generated over the years having supply of line pipes for various projects involving most of the manufacturers was consolidated and utilized for validating the requirements stipulated in the standard.

The Committee also recognized that the petroleum and natural gas industries often specify additional requirements for particular applications. In order to accommodate such needs, additional requirements for special applications are available, as follows:

a) PSL 2 pipe ordered for sour service (*see* Annex B); and

b) PSL 2 pipe ordered for offshore service (*see* Annex C).

For all the tests specified in this standard (chemical/physical/others), the method as specified in relevant ISO standard may also be followed as an alternate method.

The composition of the Committee responsible for formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

HOT-ROLLED STEEL STRIP, SHEET AND PLATES FOR MANUFACTURE OF WELDED LINE PIPES — SPECIFICATION

1 SCOPE

This standard covers requirements for hot-rolled steel strips, sheets and plates intended for the manufacture of welded steel pipe for pipeline transportation systems in the petroleum and natural gas industries.

2 REFERENCES

The standards listed in Annex A contain provisions, which through references in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards.

3 TERMINOLOGY

For the purpose of this standard, IS 1956 (various parts) and the following definitions shall apply.

3.1 Micro-Alloying Elements —Elements, such as niobium, vanadium and titanium or boron (for steel with YS > 690 Mpa) added singly or in combination to obtain high strength combined with better toughness, formability and weldability.

3.2 Weldability — A metallic substance is considered to be weldable by a given process and for the given purpose, when metallic continuity to a stated degree can be obtained by welding using a suitable procedure, so that the joints comply with the requirements specified in regard to both their local properties and their influence on the construction of which they form apart.

3.3 As Rolled — The normal rolling of steel with no specific control of rolling temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region (above the Ar3 temperature) of the steel. The strength and toughness properties of steel produced by this process are generally less than steel rolled with other temperature controlled advanced rolling processes.

3.4 Controlled Rolling — A hot rolling process in which the temperature of the steel and its reduction ratio are controlled in order to achieve fine grain microstructure and optimum mechanical properties.

3.5 Normalizing Rolling — A hot rolling process in which the final deformation is carried out within a certain temperature range equivalent to normalizing temperature, leading to a material condition equivalent to that obtained after normalizing, such that the specified mechanical properties would still be met in the event of any subsequent normalizing.

3.6 Thermo-Mechanical Controlled Processing (TMCP) — A hot rolling process in which the final deformation is carried out in a certain temperature range leading to a material condition with certain properties which cannot be achieved or repeated by heat treatment alone, and such deformation is followed by cooling, possibly with increased cooling rates with or without tempering, self-tempering included.

NOTE — Subsequent heating above 580 °C typically can lower the strength values.

3.7 Normalizing — A normalizing heat treatment consist of heating steel from an appropriate temperature below the transformation range to the proper temperature above the transformation range, holding for a sufficient time to effect the desired transformation and then subsequent cooling the steel in air. The process improves the mechanical properties of as-rolled steel by refining the austenitic grain size, provided that the steel is produced by fine austenitic grain size practice.

3.8 Quenching and Tempering (QT) — Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above Ac_3 to austenitising temperature of steel and then cooled with an appropriate quenching media for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the Ac_1 to restore toughness properties by improving the microstructure.

4 ABBREVIATED TERMS

CE_{IIW}	Carbon equivalent, based upon the International Institute of Welding equation
CE_{Pcm}	Carbon equivalent, based upon the chemical portion of the Ito-Bessyo carbon equivalent equation
CVN	Charpy V-notch
DWT	Drop-weight tear
HBW	Brinell hardness
HIC	Hydrogen-induced cracking

HRC	Rockwell hardness, C scale
HV	Vickers hardness
PSL	Product specification level
SSC	Sulphide stress cracking

5 CLASSIFICATIONS OF GRADES

5.1 Product Specification Level (PSL)

This specification establishes requirements for two product specification levels (PSL 1 and PSL 2). The PSL designations define different standard technical requirements. PSL 1 shall be at the discretion of the manufacturer unless a specific delivery condition is specified in the purchase order. PSL 1 provides a standard quality level for line pipe. PSL 2 shall have mandatory technical requirements for the product which may include specific technical parameters viz, chemical composition, carbon equivalent values, Charpy V-notch impact toughness, minimum and maximum range for yield strength and tensile strength etc.

5.2 Steel Grade and Delivery Condition

5.2.1 The steel grade for PSL 1 shall be as given in Table 1. It consists of an alpha or alphanumeric designation that identifies the yield strength level of the steel.

5.2.2 The steel grade for PSL 2 shall be as given in Table 1 and consists of an alpha or alphanumeric designation that identifies the yield strength level of the steel. The steel name includes a suffix that consists of a single letter (R, N, Q or M) that identifies the delivery condition.

NOTE — Steels for sour service (*see* Annex B) and steels for offshore service (*see* Annex C).

Table 1 Steel Grades and Acceptable Delivery Conditions

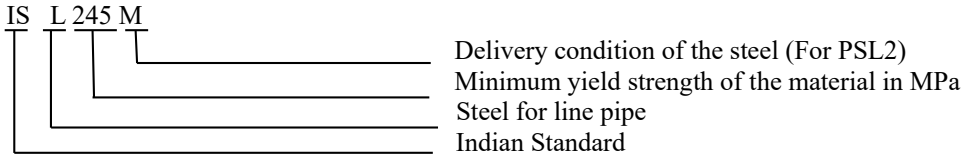
(*Clause* 5.2.1 *and* 5.2.2)

Sl No.	PSL	Delivery Condition of the Steel	Steel Grade[1)]
(1)	(2)	(3)	(4)
i)	PSL 1	As-rolled, normalizing rolled and normalized	ISL 175 ISL 210
		As-rolled, normalizing rolled, thermo-mechanical controlled processing (TMCP), normalized, normalized and tempered; or, if agreed, quenched and tempered	ISL 245 ISL 290 ISL 320 ISL 360 ISL 390 ISL 415 ISL 450 ISL 485
ii)	PSL 2	As-rolled	ISL 245R ISL 290R
		Normalizing rolled, normalized, normalized and tempered	ISL 245N ISL 290N ISL 320N ISL 360N ISL 390N ISL 415N

Table 1 (*Concluded*)

Sl No.	PSL	Delivery Condition of the Steel	Steel Grade[1)]
(1)	(2)	(3)	(4)
		Quenched and tempered	ISL 245Q ISL 290Q ISL 320Q ISL 360Q ISL 390Q ISL 415Q ISL 450Q ISL 485Q ISL 555Q ISL 625Q ISL 690Q ISL 830Q
		Thermo-mechanical controlled processing (TMCP)	ISL 245M ISL 290M ISL 320M ISL 360M ISL 390M ISL 415M ISL 450M ISL 485M ISL 555M ISL 625M ISL 690M ISL 830M
[1] For intermediate grades, the steel grade shall be in one of the following formats: the word ISL followed by the specified minimum yield strength in MPa and, for PSL 2, the letter describing the delivery condition (R, N, Q or M) consistent with the above formats.			

5.2.3 Nomenclatures of the grade is as below:



6 INFORMATION TO BE SUPPLIED BY THE PURCHAER

6.1 General Information

The purchase order shall include the following information:

a) Dimensions and quantity;
b) PSL (1or 2);
c) Steel grade and delivery condition; and
d) HR strip, cut to length sheets and plates.

6.2 Additional Information

The purchase order shall indicate which of the following provisions apply for the specific order:

a) Items that are subject to mandatory agreement, if applicable:

1) Chemical composition for intermediate grades;
2) Chemical composition for steel with $t > 25.0$ mm;

3) Carbon equivalent limits for PSL 2 steel in Grade ISL 415 N; and

4) Carbon equivalent limits for PSL 2 steel in Grade ISL 555 Q, ISL 625 Q, ISL 690 Q and ISL 830 Q.

b) Items that apply as prescribed, unless otherwise agreed:

1) Delivery condition;
2) Chemical composition limits for PSL 1 steel;
3) Chemical composition limits for PSL 2 steel;
4) Yield/tensile ratio for grades ISL 690 and ISL 830; and
5) Estimation and reporting of Charpy shear area.

c) Items that apply, if agreed:

1) Delivery condition;
2) Supply of quenched and tempered PSL 1 Grade ISL 245;
3) Supply of intermediate grades;
4) CVN impact test temperature lower than 0 °C;
5) DWT test temperature lower than 0 °C;
6) PSL 2 steel for sour service, in which case, Annex B shall apply;
7) PSL 2 steel for offshore service, in which case, Annex C shall apply;
8) Ultrasonic inspection of plate for laminar imperfections; and
9) Any other additional or more stringent requirements.

7 MANUFACTURE

7.1 The steel shall be made in basic oxygen or electric arc furnace only in combination with a secondary ladle refining process and shall be continuously cast. The steel shall be fully killed and fine grained. The steel may be vacuum degassed and micro-alloyed.

7.2 The steel may be calcium treated for inclusion shape control.

7.3 The hot-rolled strip, sheet and plates made of PSL 2 quality steel shall not contain any repair by welding.

7.4 For steel with delivery condition M, critical variables of the strip/sheet/plate rolling practice (for example re-heating time and temperature, rolling and cooling temperatures and tolerances) shall be defined and controlled to ensure that the mechanical properties throughout the length are suitably uniform considering:

a) Strip/sheet/plate characteristics and variability;
b) Sensitivity of properties to rolling practice;
c) Appropriate cropping of strip/sheet/plate ends;
d) Change in tensile properties after pipe forming; and
e) The permissible ranges of critical variables for strip/sheet/plate rolling practice shall be documented.

7.5 Hot rolling practice process deviations from the manufacturer's documented limits shall be qualified through documented practices in the hot-rolled material by mechanical testing to defined limits by designating that material as a new test unit.

8 CHEMICAL COMPOSITION

8.1 For PSL 1 steel with, $t \leq 25.0$ mm, the chemical composition for standard grades shall be as given in Table 2, and the chemical composition for intermediate grades shall be as agreed, but consistent with those given in Table 2.

8.2 For PSL 2 steel with, $t \leq 25.0$ mm, the chemical composition for standard grades shall be as given in Table 3 and the chemical composition for intermediate grades shall be as agreed, but consistent with those given in Table 3.

8.3 The chemical composition based on the requirements of Tables 2 and 3 may be applied for pipe with, t > 25.0 mm. Otherwise the chemical composition shall be as agreed between the purchaser and manufacturer.

8.4 For PSL 2 steel with a product analysis carbon content ≤ 0.12 percent, the carbon equivalent, CE_{Pcm}, shall be determined using equation (1):

$$CE_{Pcm} = C + Si/30 + Mn/20 + Cu/20 + Ni/60 + Cr/20 + Mo/15 + V/10 + 5B \quad \ldots\ldots (1)$$

Where the symbols for the chemical elements represent the mass fraction in percent (*see* Table 3). If the ladle analysis for boron is less than 0.0 005 percent, then it is not necessary for the product analysis to include boron, and the boron content may be considered to be zero for the CE_{Pcm} calculation.

For PSL 2 steel with a product analysis carbon content greater than 0.12 percent, the carbon equivalent, CE_{IIW}, shall be determined using equation (2):

$$CE_{IIW} = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15 \ldots\ldots (2)$$

Where the symbols for the chemical elements represent the mass fraction in percent (*see* Table 3).

Table 2 Chemical Composition for PSL 1 Steel Grade with t ≤ 25.0 mm

(*Clause* 8.1)

Sl No.	Steel Grade	Mass Fraction, Based upon Product Analyses[a, f] Percent, *Max*						
		C[b]	Mn[b]	P	S	V	Nb	Ti
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	ISL175	0.21	0.60	0.030	0.030	—	—	—
ii)	ISL210	0.22	0.90	0.030	0.030	—	—	—
iii)	ISL245	0.26	1.20	0.030	0.030	c, d	c, d	d
iv)	ISL290	0.26	1.30	0.030	0.030	d	d	d
v)	ISL320	0.26	1.40	0.030	0.030	d	d	d
vi)	ISL360	0.26	1.40	0.030	0.030	d	d	d
vii)	ISL390	0.26	1.40	0.030	0.030	d	d	d
viii)	ISL415	0.26[e]	1.40[e]	0.030	0.030	d	d	d
ix)	ISL450	0.26[e]	1.45[e]	0.030	0.030	d	d	d
x)	ISL485	0.26[e]	1.65[e]	0.030	0.030	d	d	d

[a] Cu ≤ 0.50 percent; Ni ≤ 0.50 percent; Cr ≤ 0.50 percent and Mo ≤ 0.15 percent

[b] For each reduction of 0.01 percent below the specified maximum for carbon, an increase of 0.05 percent above the specified maximum for manganese is permissible, up to a maximum of 1.65 percent for grades ≥ ISL245 but ≤ ISL360; up to a maximum of 1.75 percent for grades > ISL360, but < ISL485; and up to a maximum of 2.00 percent for Grade ISL485.

[c] Unless otherwise agreed, the sum of the niobium and vanadium contents shall be ≤ 0.06 percent.

[d] The sum of the niobium, vanadium and titanium contents shall be ≤ 0.15 percent.

[e] Unless otherwise agreed.

[f] No deliberate addition of B is permitted and the residual B ≤ 0.001 percent.

NOTE — Restricted chemical composition may be mutually agreed to between the purchaser and the supplier.

Table 3 Chemical Composition for PSL 2 Steel with t ≤ 25.0 mm

(*Clause*s 8.2 *and* 8.4)

Sl No.	Steel Grade	Mass Fraction, Based Upon Ladle and Product Analyses[k] Percent, *Max*									Carbon Equivalent[a] Percent, *Max*	
		C[b]	Si	Mn[b]	P	S	V	Nb	Ti	Other	CE_{IIW}	CE_{Pcm}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	As-rolled and normalized rolled or normalized											
i)	ISL245R	0.24	0.40	1.20	0.025	0.015	[c]	[c]	0.04	[e, k]	0.43	0.25
ii)	ISL290R	0.24	0.40	1.20	0.025	0.015	0.06	0.05	0.04	[e, k]	0.43	0.25
iii)	ISL245N	0.24	0.40	1.20	0.025	0.015	[c]	[c]	0.04	[e, k]	0.43	0.25
iv)	ISL290N	0.24	0.40	1.20	0.025	0.015	0.06	0.05	0.04	[e, k]	0.43	0.25
v)	ISL320N	0.24	0.40	1.40	0.025	0.015	0.07	0.05	0.04	[d, e, k]	0.43	0.25
vi)	ISL360N	0.24	0.45	1.40	0.025	0.015	0.10	0.05	0.04	[d, e, k]	0.43	0.25
vii)	ISL390N	0.24	0.45	1.40	0.025	0.015	0.10[f]	0.05	0.04	[d, e, k]	0.43	0.25
viii)	ISL415N	0.24	0.45[f]	1.40 [f]	0.025	0.015	0.10[f]	0.05[f]	0.04[f]	[g, h, k]	As agreed	
	Quenched and tempered											
ix)	ISL245Q	0.18	0.45	1.40	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
x)	ISL290Q	0.18	0.45	1.40	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
xi)	ISL320Q	0.18	0.45	1.40	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
xii)	ISL360Q	0.18	0.45	1.50	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
xiii)	ISL390Q	0.18	0.45	1.50	0.025	0.015	0.07	0.05	0.04	[d, e, k]	0.43	0.25
xiv)	ISL415Q	0.18	0.45[f]	1.70[f]	0.025	0.015	[g]	[g]	[g]	[h, k]	0.43	0.25
xv)	ISL450Q	0.18	0.45[f]	1.70[f]	0.025	0.015	[g]	[g]	[g]	[h, k]	0.43	0.25
xvi)	ISL485Q	0.18	0.45[f]	1.80[f]	0.025	0.015	[g]	[g]	[g]	[h, k]	0.43	0.25
xvii)	ISL555Q	0.18	0.45[f]	1.90[f]	0.025	0.015	[g]	[g]	[g]	[i, k]	As agreed	
xviii)	ISL625Q	0.18	0.55[f]	1.90	0.025	0.015	[g]	[g]	[g]	[i, k]	As agreed	
xix)	ISL690Q	0.18	0.55[f]	1.90	0.025	0.015	[g]	[g]	[g]	[i, j]	As agreed	

Table 3 (*Continued*)

Sl No.	Steel Grade	Mass Fraction, Based Upon Ladle and Product Analyses[k] Percent, *Max*									Carbon Equivalent[a] Percent, *Max*	
		C[b]	Si	Mn[b]	P	S	V	Nb	Ti	Other	CE_{IIW}	CE_{Pcm}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
xx)	ISL830Q	0.18	0.55[f]	2.10[f]	0.025	0.015	[g]	[g]	[g]	[i, j]	As agreed	
	Thermomechanical controlled processing (TMCP)											
xxi)	ISL245M	0.22	0.45	1.20	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
xxii)	ISL290M	0.22	0.45	1.30	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
xxiii)	ISL320M	0.22	0.45	1.30	0.025	0.015	0.05	0.05	0.04	[e, k]	0.43	0.25
xxiv)	ISL360M	0.22	0.45	1.40	0.025	0.015	[d]	[d]	[d]	[e, k]	0.43	0.25
xxv)	ISL390M	0.22	0.45	1.40	0.025	0.015	[d]	[d]	[d]	[e, k]	0.43	0.25
xxvi)	ISL415M	0.12[f]	0.45[f]	1.60[f]	0.025	0.015	[g]	[g]	[g]	[h, k]	0.43	0.25
xxvii)	ISL450M	0.12[f]	0.45[f]	1.60[f]	0.025	0.015	[g]	[g]	[g]	[h, k]	0.43	0.25
xxviii)	ISL485M	0.12[f]	0.45[f]	1.70[f]	0.025	0.015	[g]	[g]	[g]	[h, k]	0.43	0.25
xxix)	ISL555M	0.12[f]	0.45[f]	1.85[f]	0.025	0.015	[g]	[g]	[g]	[i, k]	0.43[f]	0.25
xxx)	ISL625M	0.10	0.55[f]	2.10[f]	0.020	0.010	[g]	[g]	[g]	[i, j]	—	0.25
xxxi)	ISL690M	0.10	0.55[f]	2.10[f]	0.020	0.010	[g]	[g]	[g]	[i, j]	—	0.25
xxxii)	ISL830M	0.10	0.55[f]	2.10[f]	0.020	0.010	[g]	[g]	[g]	[i, j]	—	0.25

[a] The CE_{IIW} limits apply if C > 0.12 percent and the CE_{Pcm} limits apply if C ≤ 0.12.

[b] For each reduction of 0.01 percent below the specified maximum for carbon, an increase of 0.05 percent above the specified maximum for manganese is permissible, up to a maximum of 1.65 percent for grades ≥ ISL 245, but ≤ ISL360; up to a maximum of 1.75 percent for grades >ISL360, but < ISL485; up to a maximum of 2.00 percent for grades ≥ ISL485, but ≤ ISL555; and up to a maximum of 2.20 percent for grades > ISL555.

[c] Unless otherwise agreed, the sum of the niobium and vanadium contents shall be ≤ 0.06 percent.

[d] The sum of niobium, vanadium and titanium content shall be ≤ 0.15 percent.

[e] Unless otherwise agreed, 0.50 percent maximum for copper, 0.30 percent maximum for nickel, 0.30 percent maximum for chromium and 0.15 percent maximum for molybdenum.

[f] Unless otherwise agreed.

Table 3 (*Concluded*)

Sl No.	Steel Grade	Mass Fraction, Based Upon Ladle and Product Analyses[k] Percent, *Max*									Carbon Equivalent[a] Percent, *Max*	
		C[b]	Si	Mn[b]	P	S	V	Nb	Ti	Other	CE_{IIW}	CE_{Pcm}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

[g] Unless otherwise agreed, the sum of the niobium, vanadium and titanium contents shall be ≤ 0.15 percent.

[h] Unless otherwise agreed, 0.50 percent maximum for copper, 0.50 percent maximum for nickel, 0.50 percent maximum for chromium and 0.50 percent maximum for molybdenum.

[I] Unless otherwise agreed, 0.50 percent maximum for copper, 1.00 percent maximum for nickel, 0.50 percent for chromium and 0.50 percent maximum for molybdenum.

[j] 0.004 percent maximum for boron.

[k] For PSL 2 steel grades except those grades to which foot note j) already applies, the following applies unless otherwise agreed no intentional addition of B is permitted and the residual B ≤ 0.001percent.

NOTE — Restricted chemical composition may be mutually agreed to between the purchaser and the supplier.

9 TENSILE PROPERTIES

9.1 For PSL 1 steel, the tensile properties shall be as given in Table 4.

9.2 For PSL 2 steel, the tensile properties shall be as given in Table 5.

Table 4 Requirements for Tensile Tests for PSL 1 Steel

(*Clause* 9.1)

Sl No.	Steel Grade	Yield Strength[a] $R_{t0.5}$[c] MPa *Min*	Tensile Strength[a] R_m MPa *Min*	Elongation GL = 50 mm Percent *Min*
(1)	(2)	(3)	(4)	(5)
i)	ISL175	175	310	[b]
ii)	ISL 210	210	335	[b]
iii)	ISL 245	245	415	[b]
iv)	ISL 290	290	415	[b]
v)	ISL 320	320	435	[b]
vi)	ISL 360	360	460	[b]
vii)	ISL 390	390	490	[b]
viii)	ISL 415	415	520	[b]
ix)	ISL 450	450	535	[b]
x)	ISL 485	485	570	[b]

[a] For intermediate grades, the difference between the specified minimum tensile strength and the specified minimum yield strength for the steel shall be as given in the Table for the next higher grade.

[b] The specified minimum elongation shall be as determined using the following equation:

$$A = C \left[\frac{B^{0.2}}{U^{0.9}} \right]$$

where

A = the minimum elongation in 50 mm or 2 in, expressed in percent, rounded to the nearest percent;

C = 1940 for calculations using SI units and 625 000 for calculations using USC units;

B = the applicable tensile test piece cross-sectional area, expressed in square millimeters (square inches), as follows:

a) For circular cross-section test pieces, 130 mm^2 (0.20 in^2) for 12,5 mm (0.500 in) and 8,9 mm (0.350 in) diameter test pieces; and 65 mm^2 (0.10 in^2) for 64 mm (0.250 in) diameter test pieces;

b) For full-section test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2); and

c) For strip test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2).

U = the specified minimum tensile strength, expressed in mega pascal (pounds per square inch).

[c] $R_{t0.5}$ = yield strength (0.5 percent total extension), expressed in mega pascals (pounds per square inch).

NOTE — More stringent tensile properties can be mutually agreed between the steel producer and pipe manufacturer.

Table 5 Requirements for Tensile Tests for PSL 2 Steel

(*Clause*s 9.2)

Sl No.	Steel Grade	Yield Strength[a] $R_{t0.5}$[c] MPa		Tensile Strength[a] R_m MPa		Ratio[a], $R_{t0.5}/R_m$	Elongation GL = 50 mm Percent
		Min	*Max*	*Min*	*Max*	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i) ii) iii) iv)	ISL245R ISL245N ISL245Q ISL245M	245	450	415	655	0.93	[b]
v) vi) vii) viii) ix)	ISL290R ISL290N ISL290Q ISL290M	290	495	415	655	0.93	[b]
x) xi) xii)	ISL320N ISL320Q ISL320M	320	525	435	655	0.93	[b]
xiii) xiv) xv)	ISL360N ISL360Q ISL360M	360	530	460	760	0.93	[b]
xvi) xvii) xviii)	ISL390N ISL390Q ISL390M	390	545	490	760	0.93	[b]
xix) xx) xxi)	ISL415N ISL415Q ISL415M	415	565	520	760	0.93	[b]
xxii) xxiii)	ISL450Q ISL450M	450	600	535	760	0.93	[b]
xxiv) xxv)	ISL485Q ISL485M	485	635	570	760	0.93	[b]
xxvi) xxvii)	ISL555Q ISL555M	555	705	625	825	0.93	[b]
xxviii) xxix)	ISL625M ISL625Q	625	775	695	915	0.95 0.97[d]	[b]
xxx) xxxi)	ISL690M ISL690Q	690	840	760	990	0.97[e]	[b]

Table 5 (*Concluded*)

Sl No.	Steel Grade	Yield Strength[a] $R_{t0.5}$[c] MPa		Tensile Strength[a] R_m MPa		Ratio[a], $R_{t0.5}/R_m$	Elongation GL = 50 mm Percent
		Min	*Max*	*Min*	*Max*	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
xxxii) xxxiii)	ISL830M ISL830Q	830	1 050	915	1 145	0.99[e]	[b]

[a] For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength shall be as given in the Table for the next higher grade, and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in the Table for the next higher grade.

For intermediate grades lower than Grade ISL555, the maximum tensile strength shall be ≤ 760 MPa. For intermediate grades higher than Grade ISL555, the maximum permissible tensile strength shall be obtained by interpolation. For SI units the calculated value shall be rounded to the nearest 5 Mpa.

[b] The specified minimum elongation shall be as determined using the following equation:

$$A = C \left[\frac{B^{0.2}}{U^{0.9}} \right]$$

where

A = the minimum elongation in 50 mm or 2 in ,expressed in percent, rounded to the nearest percent;

C = 1940 for calculations using SI units and 625 000 for calculations using USC units;

B = the applicable tensile test piece cross-sectional area, expressed in square millimeters (square inches), as follows:

a) For circular cross-section test pieces, 130 mm^2 (0.20 in^2) for 12,5 mm (0.500 in) and 8, 9 mm (0.350 in) diameter test pieces; and 65 mm^2 (0.10 in^2) for 6, 4 mm (0.250 in) diameter test pieces;

b) For full-section test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2); and

c) For strip test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2).

U = the specified minimum tensile strength, expressed in mega pascals (pounds per square inch).

[c] $R_{t0.5}$ = yield strength (0.5 percent total extension), expressed in mega pascals (pounds per square inch).

[d] For grade ISL 625Q. Lower values of $R_{t0.5}/R_m$ may be specified by agreement.

[e] For grades ISL 690 and ISL 830, $R_{p0.2}/R_m$ applies. Lower values of $R_{p0.2}/R_m$ may be specified by agreement.

where

$R_{p0.2}$ = yield strength (0.2 percent non-proportional extension), expressed in megapascals (pounds per square inch).

NOTE — More stringent tensile properties can be mutually agreed between the steel producer and pipe manufacturer.

10 BEND TEST

10.1 Steel Grades Up to ISL 485 (PSL 1 and PSL 2)

The internal diameter/insert thickness of the bend for the different grades of material shall be 2 *t* (*t* = thickness of strip/sheet/plate). The test piece shall be bend cold through 180°. The test piece shall be deemed to have passed the test, if the outer convex surface is free from cracks/opening.

10.2 Steel Above ISL 485 (PSL 2)

The internal diameter/insert thickness of the bend for the different grades of material shall be 3 *t* (*t* = thickness of strip/sheet/plate). The test piece shall be bend cold through 180°. The test piece shall be deemed to have passed the test, if the outer convex surface is free from cracks/opening.

11 HARDNESS TEST

11.1 The limits for hardness for PSL 1 steel grades may be mutually agreed to between the manufacturer and the purchaser.

11.2 PSL 2 Steels

For steel grades up to ISL 485, hardness of the steels shall be 248 HV10, *Max*. For steel grades above ISL 485 and up to ISL 555, hardness of the steels shall be 275 HV10, *Max*. For steel grades above ISL 555, limits for hardness may be mutually agreed to between the manufacturer and the purchaser.

12 CVN IMPACT TEST FOR PSL 2 STEEL GRADE

12.1 General

12.1.1 If sub size test pieces are used, the required minimum average (set of three test pieces) absorbed energy values shall be the required values for full-size test pieces times the ratio of the specified thickness of the sub size test piece to the specified thickness of the full-size test piece, with such derived values rounded to the nearest joule.

12.1.2 Individual test values for any test piece shall be ≥ 75 percent of the required minimum average (set of three test pieces) absorbed energy values.

12.1.3 Tests conducted at temperatures lower than the specified test temperature shall be acceptable if the applicable requirements for energy absorption and shear fracture area are met at such lower temperatures.

12.2 Impact Test

12.2.1 The minimum average (set of three test pieces) absorbed energy for each test shall be as given in Table 6, based upon full-size test pieces and a test temperature of 0 °C or, if agreed, a lower test temperature.

12.2.2 If agreed, the minimum average (set of three test pieces) shear fracture area for each test shall be ≥ 85 percent, based upon a test temperature of 0 ºC or, if agreed, a lower test temperature.

12.2.3 If **12.2.2** does not apply for the order item, the shear fracture area should be estimated and reported for information purposes, unless otherwise agreed.

13 DWT TEST (FOR PSL 2 STEEL GRADE)

13.1.1 For each test (set of two test pieces), the average shear fracture area shall be ≥ 85 percent, based on test temperature of 0 °C or, if agreed, at a lower test temperature. For thickness > 25.4 mm, DWT test acceptance requirements shall be by agreement between manufacturer and purchaser.

NOTES

1 Such shear fracture area ensures sufficiently ductile fracture at or above the test temperature.

2 Sufficient shear fracture area in combination with sufficient CVN absorbed energy is essential in steel properties to ensure the avoidance of brittle fracture propagation and the control of ductile fracture propagation in gas pipelines.

13.1.2 Tests conducted at temperatures lower than the specified test temperature shall be acceptable if the applicable requirements for shear fracture area are met at such lower temperatures.

14 INSPECTION AND TEST METHODS

14.1 Test Frequency

Test frequency of each test shall be as per Table 7.

Table 6 CVN Absorbed Energy Requirements for PSL 2 Steel

(*Clause* 12.2.1)

Sl No.	Steel Grade	≤ ISL 415	> ISL 415 ≤ ISL450	>ISL450 ≤ ISL555	> ISL 555 ≤ ISL625	> ISL 625 ≤ ISL690	> ISL 690 ≤ ISL830
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Full size CVN absorbed average energy, *Min,* J	40	54	68	81	95	108

Table 7 Test Frequency

(*Clause* 14.1)

Sl No.	Characteristic	Sample Orientation	Test Frequency
(1)	(2)	(3)	(4)
i)	Chemical analysis (ladle & product)	—	One sample per heat
ii)	Tensile test	Transverse to rolling direction	One sample per heat
iii)	Bend test	Transverse to rolling direction	One sample per heat
iv)	Charpy impact test	Transverse to rolling direction	One set of three specimens per heat
v)	DWT test	Transverse to rolling direction	One set of two specimens per heat
vi)	Hardness test	Transverse to rolling direction	One sample per heat

NOTE — If agreed between supplier and purchaser at the time of order, tensile test may be conducted at a different orientation.

14.2 Test Methods

14.2.1 *Product Analysis*

Unless otherwise agreed between the manufacturer and purchaser at the time of order, the product analysis shall be carried out either by the method specified in the relevant part of IS 228 or any other established instrumental/chemical method. In cases of dispute, the procedure given in the relevant part of IS 228 shall be the referee method.

14.2.2 *Tensile Test*

The tensile test shall be carried out in accordance with IS 1608 (Part 1). The yield strength ($R_{t0.5}$), the tensile strength, the yield to tensile ratio and the percentage elongation after fracture shall be determined. The percentage elongation after fracture shall be reported with reference to a gauge length of 50 mm.

For test pieces having a gauge length less than 50 mm, the measured elongation after fracture shall be converted to a percentage elongation in 50 mm in accordance with IS 3803 (Part 1).

14.2.3 *CVN Impact Test*

The Charpy test shall be carried out in accordance with IS 1757 (Part 1).

14.2.4 *Drop-Weight Tear Test*

14.2.4.1 The drop-weight tear test shall be carried out as per **10.2.4.4** of IS/ISO 3183.

14.2.4.2 Samples for DWTT test are to be drawn from the strip, cut to length plates from strip and plates in transverse to rolling direction.

14.2.5 *Bend Test*

The bend test shall be carried out in accordance with IS 1599.

14.2.6 *Hardness Test*

The hardness tests shall be carried out in accordance with IS 1501 (Part 1), IS 1500 (Part 1) or IS 1586 (Part 1).

15 RETEST

15.1 If any mechanical test does not satisfy the results, two additional tests shall be carried out at random on the same lot of production heat. Both retests shall conform to the specified requirements of this standardthen the heat shall be accepted except the coil/plate from which initial specimen was taken.

15.2 If one or both of the retested specimens fail to conform to the specified requirements, at the option of the manufacturer, either heat shall be rejected orindividual coil/plate of the heat shall be tested. The individual coil/plate test which conforms to the specified requirements shall be accepted and the coil/plate test which fails to meet the specified requirements shall be rejected.

16 SURFACECONDITIONS, IMPERFECTIONS AND DEFECTS

16.1 All finished steel shall be well and cleanly rolled to the specified dimensions. The finish material shall be reasonably free from surface flaws, laminations, rough/jagged and imperfect edges and all other harmful defects. Minor surface defects may be removed by the manufacturer/supplier by grinding provided that thickness is not reduced locally below the lower thickness tolerance.

16.2 Laminar Imperfection in Hot-Rolled Plates

The hot-rolled plates may be subjected to non-destructive testing like UT (ultrasonic testing) as per IS 4225 or any other established method to determine the soundness of material, subject to mutual agreement between the purchaser and the manufacturer/supplier.

17 DIMENSIONS

Nominal dimensions and thickness of hot-rolled steel strip/sheet/plate may be as specified in IS 1730. Sizes other than those specified in IS 1730 may also be supplied by mutual agreement between purchaser and manufacturer.

18 TOLERANCES

Unless otherwise agreed to between the purchased and the manufacturer, the rolling and cutting tolerances for steel products conforming to this standard shall be those specified in IS/ISO 16160 and IS1852 for sizes and tolerances not covered in IS/ISO 16160.

19 MARKING

19.1 Each strip shall carry a stencil marking, metal tag or adhesive label/sticker bearing the cast number or identification mark or lot number traceable to the cast number and manufacturer's name or trade-mark or shall be legibly marked at top. Marking should also include size, grade and mass of strip.

19.2 Plates and sheet (including cut to length from strip) may be supplied in bundles. Each bundle shall carry a metal tag or adhesive label/sticker bearing the cast number or identification mark or lot number traceable to the cast number and manufacturer's name or trade-mark. Alternatively, top sheet/plate shall be legibly marked with cast number or identification mark or lot number traceable to the cast number and manufacturer's name or trade-mark

19.3 BIS Certification Marking

The products(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the *Bureau of Indian Standards Act*, 2016 and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

20 CHARACTERISTICS OF THE MANUFACTURING PROCEDURE SPECIFICATION

Before production commences or at the manufacturer's risk from the initial production run, the manufacturer shall supply the purchaser with summary information or identification of the control documents, as applicable, on the main characteristics of the manufacturing procedure. This information shall include at least the following:

a) Steelmaking and casting:
   1) Name/location of manufacturing facility;
   2) Equipment and process description including steelmaking method, heat size, deoxidation practice, inclusion shape control practices (where applicable), and casting method;
   3) Chemical composition ranges including each element intentionally added;
   4) Steelmaking and casting process control;
   5) Hydrogen control practices for slabs used to make plate/coil greater than 20 mm thick;
   6) Product identification and traceability practices;
   7) Product rework/retest/release controls for non-conformances with manufacturer's documented practices including grade intermixes/transitions and process/chemistry deviations; and
   8) Centerline segregation controls and acceptance criteria, as applicable.

b) Hot rolling:
   1) Name/location of manufacturing facility;
   2) Equipment and process description including heat treatment method (N or Q) if applicable;
   3) Applicable rolling practice control temperature tolerances (reheating, rolling, and cooling);
   4) Applicable time tolerances (reheating, rolling, and cooling);
   5) Applicable non-destructive inspection methods and practices for the coil/plate including instrument standardization practices;
   6) Dimensional and mechanical property control limits;
   7) End cropping practices;
   8) Product traceability practices from slab receipt to plate/coil delivery;
   9) Product rework/retest/release controls for non-conformances with manufacturer's documented practices (includingprocess, chemical/ mechanical, and dimensional deviations); and
   10) Storage, handling, loading, and shipping practices.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
IS 228 (all parts)	Methods for chemical analysis of steels
IS 1500 (Part 1) : 2019/ISO 6506-1 : 2014	Metallic materials — Brinell hardness test: Part 1 Test method (*fifth revision*)
IS 1501 (Part 1) : 2020/ISO 6507-1 : 2018	Metallic Materials — Vickers Hardness Test Part 1 Test Method (*fifth revision*)
IS 1586 (Part 1) : 2018/ISO 6508-1 : 2016	Metallic materials — Rockwell hardness test: Part 1 Test method (*fifth revision*)
IS 1599 : 2019/ ISO 7438 : 2016	Metallic Materials — Method for bend test (*fourth revision*)
IS 1608 (Part 1) : 2022/ISO 6892-1 : 2019	Metallic materials — Tensile testing: Part 1 Method of test at room temperature (*fifth revision*)
IS 1730 : 1989	Steel plates, sheets, strips and flats for structural and general engineering purposes — dimensions (*second revision*)
IS 1757 (Part 1) : 2020/ISO 148-1 : 2016	Metallic materials — Charpy pendulum impact test: Part 1 Test method (*fourth revision*)
IS 1852 : 1985	Rolling and cutting tolerances for hot rolled steel products (*fourth revision*)
IS 1956 (all parts)	Glossary of terms relating to iron and steel
IS/ISO 3183 : 2019	Petroleum and natural gas industries — Steel pipe for pipeline transportation systems (*second revision*)
IS 3803 (Part 1) : 2023/ISO 2566-1 : 2021	Steel — Conversion of elongation values: Part 1 Carbon and low-alloy steels (*third revision*)
IS 4225 : 2021/ ISO 17577 : 2016	Steel — Ultrasonic testing of steel flat products of thickness equal to or greater than 6 mm (*third revision*)
IS 4748 : 2021/ ISO 643 : 2019	Steel — Micrographic determination of the apparent grain size (*third revision*)
IS 8910 : 2022/ ISO 404 : 2013	Steel and steel products — General technical delivery requirements(*second revision*)
IS/ISO 14284 : 1996	Steel and iron-sampling and preparation of samples for the determination of chemical composition
IS/ISO 16160 : 2012	Hot-rolled steel sheet products — Dimensional and shape tolerances (*first revision*)
ISO 15156-2 : 2020	Petroleum and natural gas industries —Materials for use in H_2S containing environments in oil and gas production — Part 2: Cracking-resistant carbon and low alloy steels, and the use of cast irons

ANNEX B

(*Foreword and clause* 6.2)

STEEL FOR SOUR SERVICE

B-1 INTRODUCTION

This annex specifies additional provisions that apply for PSL 2 steel that is ordered for sour service.

B-2 ADDITIONAL INFORMATION TO BE SUPPLIED BY THE PURCHASER

The purchase order shall indicate which of the following provisions apply for the specific order item:

a) Steel casting method for HR strip (including cut to length plates from strip) or plate used;

b) Ultrasonic inspection of plate for laminar imperfections;

c) Chemical composition for intermediate grades;

d) SSC test for manufacturing procedure qualification;

e) HIC test method and associated acceptance criteria; and

f) Photomicrographs of reportable HIC cracks.

B-3 MANUFACTURING

B-3.1 Steel Manufacturing

The steel shall be made to a clean steel practice using either the basic oxygen steel making process or the electric furnace process and shall be fully killed and fine grained.

B-3.1.2 Vacuum degassing or alternative processes to reduce the gas content of the steel shall be used.

B-3.1.3 The molten steel shall be treated for inclusion shape control. If agreed at the time of order, inclusion content may be determined by the manufacturer as per ISO 4967. For sulfur levels ≤ 0.001 percent, inclusion shape control may be waived by agreement.

B-4 ACCEPTACNE CRITERIA

B-4.1 Chemical Composition

B-4.1.1 For steel with $t \leq 25.0$ mm, the chemical composition for standard grades shall be as given in Table 8 and the chemical composition for intermediate grades shall be as agreed, but consistent with those given for the standard grades in Table 8. The steel designation shall be as given in Table 8 and consists of an alpha or alphanumeric designation that identifies the grade, followed by a suffix that consists of a letter (N, Q or M) that identifies the delivery condition and a second letter (S) that identifies the service condition.

B-4.1.2 For steel with $t > 25.0$ mm, the chemical composition shall be as agreed, with the requirements given in Table 8 being amended as appropriate.

Table 8 Chemical Composition for Steel with t ≤ 25.0 mm

(*Clause*s B-4.1.1 *and* B-4.1.2)

Sl No.	Steel Grade	Weight Percent Based Upon Ladle and Product Analyses Percent, *Max*									Carbon Equivalent[a] Percent, *Max*	
		C[b]	Si	Mn[b]	P	S	V	Nb	Ti	Other[c, d]	CE_{IIW}	CE_{Pcm}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Normalized rolled or normalized												
i)	ISL245NS	0.14	0.40	1.35	0.020	0.003	[f]	[f]	0.04	[g]	0.36	0.19[h]
ii)	ISL290NS	0.14	0.40	1.35	0.020	0.003	0.05	0.05	0.04	—	0.36	0.19[h]
iii)	ISL320NS	0.14	0.40	1.40	0.020	0.003	0.07	0.05	0.04	[g]	0.38	0.20[h]
iv)	ISL360NS	0.16	0.45	1.65	0.020	0.003	0.10	0.05	0.04	[g]	0.43	0.22[h]
Quenched and tempered												
v)	ISL245QS	0.14	0.40	1.35	0.020	0.003[e]	0.04	0.04	0.04	—	0.34	0.19
vi)	ISL290QS	0.14	0.40	1.35	0.020	0.003[e]	0.04	0.04	0.04	—	0.34	0.19
vii)	ISL320QS	0.15	0.45	1.40	0.020	0.003[e]	0.05	0.05	0.04	—	0.36	0.20
viii)	ISL360QS	0.16	0.45	1.65	0.020	0.003[e]	0.07	0.05	0.04	[g]	0.39	0.20
ix)	ISL390QS	0.16	0.45	1.65	0.020	0.003[e]	0.07	0.05	0.04	[g]	0.40	0.21
x)	ISL415QS	0.16	0.45	1.65	0.020	0.003[e]	0.08	0.05	0.04	[g, h, i, j]	0.41	0.22
xi)	ISL450QS	0.16	0.45	1.65	0.020	0.003[e]	0.09	0.05	0.06	[g, h, i, j]	0.42	0.22
xii)	ISL485QS	0.16	0.45	1.65	0.020	0.003[e]	0.09	0.05	0.06	[g, h, i, j]	0.42	0.22
Thermo-mechanical controlled processing (TMCP)												
xiii)	ISL245MS	0.10	0.40	1.25	0.020	0.002[e]	0.04	0.04	0.04	—	—	0.19
xiv)	ISL290MS	0.10	0.40	1.25	0.020	0.002[e]	0.04	0.04	0.04	—	—	0.19
xv)	ISL320MS	0.10	0.40	1.35	0.020	0.002[e]	0.05	0.05	0.04	—	—	0.20
xvi)	ISL360MS	0.10	0.45	1.45	0.020	0.002[e]	0.05	0.06	0.04	—	—	0.20
xvii)	ISL390MS	0.10	0.45	1.45	0.020	0.002[e]	0.06	0.08	0.04	[g]	—	0.21
xviii)	ISL415MS	0.10	0.45	1.45	0.020	0.002[e]	0.08	0.08	0.06	[g, h, i, j]	—	0.21
xix)	ISL450MS	0.10	0.45	1.60	0.020	0.002[e]	0.10	0.08	0.06	[g, h, i, j]	—	0.22
xx)	ISL485MS	0.10	0.45	1.60	0.020	0.002[e]	0.10	0.08	0.06	[g, h, i, j]	—	0.22

[a] Based on product analysis, the CE_{IIW} limits shall apply if C > 0.12 percent and the CE_{Pcm} limits shall apply if C ≤ 0.12 percent.

[b] For each reduction of 0.01 percent below the specified maximum for carbon, an increase of 0.05 percent above the specified maximum for manganese is permissible, up to a maximum increase of 0.20 percent.

[c] Al total ≤ 0.060 percent; N ≤ 0.012 percent; Al/N ≥ 2 : 1 (not applicable to titanium-killed or titanium-treated steel); Cu ≤ 0.35 percent (if agreed, Cu ≤ 0.10 percent); Ni ≤ 0.30 percent; Cr ≤ 0.30 percent; Mo ≤ 0.15 percent; B ≤ 0.000 5 percent.

[d] For steel where calcium is intentionally added, the calcium content shall be 0.006 percent maximum. Unless otherwise agreed, Ca/S ≥ 1.5 if S > 0. 0 015 percent.

[e] If agreed at the time of order the maximum limit for sulphur content may be increased to ≤ 0.006 percent; for such higher S levels, lower Ca/S ratios may be agreed.

[f] Unless otherwise agreed, the sum of niobium and vanadium contents shall be ≤ 0.06 percent.

[g] The sum of the niobium, vanadium and titanium contents shall be ≤ 0.15 percent.

[h] If agreed, the molybdenum content shall be ≤ 0.35 percent.

[i] If agreed, the chromium content shall be ≤ 0.45 percent.

[j] If agreed, Cr content shall be ≤ 0.45 percent and Ni content shall be ≤ 0.50 percent.

B-4.2 Tensile Properties

B-4.2.1 The tensile properties shall be as given in Table 9.

Table 9 Requirements of Tensile Tests

(*Clause* B-4.2.1)

Sl No.	Steel Grade	Yield Strength[a] $R_{t0.5}$ MPa		Tensile Strength[a] R_m MPa		Ratio[a,] $R_{t0.5}/R_m$	Elongation (GL = 50 mm) Percent
		Min	*Max*	*Min*	*Max*	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i) ii) iii)	ISL245NS ISL245QS ISL245MS	245	450[d]	415	655	0.93	[b]
iv) v) vi)	ISL290NS ISL290QS ISL290MS	290	495	415	655	0.93	[b]
vii) viii) ix)	ISL320NS ISL320QS ISL320MS	320	525	435	655	0.93	[b]
x) xi) xii)	ISL360NS ISL360QS ISL360MS	360	530	460	760	0.93	[b]
xiii) xiv)	ISL390QS ISL390MS	390	545	490	760	0.93	[b]
xvi) xvii)	ISL415QS ISL415MS	415	565	520	760	0.93	[b]
xviii) xix)	ISL450QS ISL450MS	450	600	535	760	0.93	[b]
xx)	ISL485MS	485	635	570	760	0.93	[b]

[a] For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength shall be as given in the table for the next higher grade, and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in the Table for the next higher grade. For intermediate grades, the tensile strength shall be ≤ 760 MPa.

[b] The specified minimum elongation shall be as determined using the following equation:

$$A = C \left[\frac{B^{0.2}}{U^{0.9}} \right]$$

where

A = the minimum elongation in 50 mm or 2 in, expressed in percent, rounded to the nearest percent;

C = 1940 for calculations using SI units and 625 000 for calculation using USC units; and

B = the applicable tensile test piece cross-sectional area, expressed in square millimeters (square inches), as follows:

a) For circular cross-section test pieces, 130 mm^2 (0.20 in^2) for 12.5 mm (0.500 in) and 8.9 mm (0.350 in) diameter test pieces; and 65 mm^2 (0.10 in^2) for 6.4 mm (0.250 in) diameter test pieces;

b) For full-section test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest;

c) 10 mm^2 (0.01 in^2);

d) For strip test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest; and

e) 10 mm^2 (0.01 in^2).

U = the specified minimum tensile strength, expressed in mega pascal (pounds per square inch).

[c] $R_{t0.5}$ = yield strength (0.5 percent total extension), expressed in megapascals (pounds per square inch).

NOTE — More stringent mechanical properties can be mutually agreed between the steel producer and pipe manufacturer.

B-4.3 HIC Test

The test for evaluation of resistance to hydrogen-induced cracking shall meet the following acceptance criteria, with each ratio being the maximum permissible average for three sections per test specimen when tested in solution a (*see* Table B.3 of ISO 15156-2).

a) Crack sensitivity ratio (CSR) ≤ 2 percent;

b) Crack length ratio (CLR) ≤ 15 percent; and

c) Crack thickness ratio (CTR) ≤ 5 percent.

If HIC tests are conducted in any alternative media/solution (*see* **H.7.3.1.3** of IS/ISO3183) to simulate specific service conditions, alternative acceptance criteria may be agreed at the time of order.

B-4.4 Hardness Test

The maximum acceptable hardness of the steel shall be 248 HV10, *Max*.

B-4.5 SSC Test

SSC tests shall be carried out and reported in accordance with **H.4.5** of IS/ISO 3183.

B-4.6 Test Methods

B-4.6.1 *HIC Test*

HIC tests shall be carried out and reported in accordance with **H.7.3.1** of IS/ISO 3183.

B-4.6.2 *SSC Test*

SSC tests shall be carried out and reported in accordance to **H.7.3.2** of IS/ISO 3183.

B-4.7 Grain Size

Test shall be carried out in accordance with IS 4748 for requirements as agreed to between the manufacturer and the purchaser.

B-4.8 Test Frequency

Test frequency is given in Table 10:

Table 10 Test Frequency

(*Clause* B-4.8)

Sl No.	Characteristic	Sample Orientation	Test Frequency
(1)	(2)	(3)	(4)
i)	Chemical analysis (ladle & product)	—	One sample per heat
ii)	Tensile test	Transverse to rolling direction	One sample per heat
iii)	Bend test	Transverse to rolling direction	One sample per heat
iv)	Charpy impact test	Transverse to rolling direction	One set of three specimens per heat
v)	DWT test	Transverse to rolling direction	One set of two specimens per heat
vi)	Hardness test	Transverse to rolling direction	One sample per heat
vii)	Ferritic grain size measurement	Transverse to rolling direction	One sample per heat
viii)	HIC test	Transverse to rolling direction	One set of three specimens per heat for first 3 heats, thereafter for every 10 heats
ix)	SSC test	—	Mutually agreed

ANNEX C

(*Foreword and clause* 6.2)

STEEL FOR OFFSHORE SERVICE

C-1 INTRODUCTION

This annex specifies additional provisions that apply for PSL 2 steel that is ordered for offshore service.

C-2 ADDITIONAL INFORMATION TO BE SUPPLIED BY THE PURCHASER

The purchase order shall indicate which of the following provisions apply for the specific order item:

a) Steel casting method for HR strip (including cut to length plates from strip) or plate used;
b) Ultrasonic inspection of plate for laminar imperfections; and
c) Chemical composition for intermediate grades.

C-3 MANUFACTURING

C-3.1 Steel Manufacturing

C.3.1.1 The steel shall be made to a clean steel practice using either the basic oxygen steel making process or the electric furnace process and shall be fully killed and fine grained.

C-3.1.2 Vacuum degassing or alternative processes to reduce the gas content of the steel shall be used.

C-3.1.3 The molten steel shall be treated for inclusion shape control. If agreed at the time of order, inclusion content may be determined by the manufacturer as per ISO 4967. For sulfur levels ≤ 0.001 percent, inclusion shape control may be waived by agreement.

C-4 ACCEPTACNE CRITERIA

C-4.1 Chemical Composition

C-4.1.1 For steel with $t \leq 25.0$ mm, the chemical composition for standard grades shall be as given in Table11 and the chemical composition for intermediate grades shall be as agreed, but consistent with those given for the standard grades in Table 11. The steel designation shall be as given in Table 11 and consists of an alpha or alphanumeric designation that identifies the grade, followed by a suffix that consists of a letter (N, Q or M) that identifies the delivery condition and a second letter (O) that identifies the offshore condition.

C-4.1.2 For steel with $t > 25.0$ mm, the chemical composition shall be as agreed, with the requirements given in Table 11 being amended as appropriate.

Table 11 Chemical Composition for Steel with t ≤ 25.0 mm

(*Clauses* C-4.1.1 *and* C-4.1.2)

Sl No.	Steel Name	Weight Percent Based Upon Ladle and Product Analyses Percent, *Max*									Carbon Equivalent[a] Percent, *Max*	
		C[b]	Si	Mn[b]	P	S	V	Nb	Ti	Other[c,d]	CE_{IIW}	CE_{Pcm}
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Normalized rolled or normalized											
i)	ISL245NO	0.14	0.40	1.35	0.020	0.010	[f]	[f]	0.04	[g]	0.36	0.19[h]
ii)	ISL290NO	0.14	0.40	1.35	0.020	0.010	0.05	0.05	0.04	—	0.36	0.19[h]
iii)	ISL320NO	0.14	0.40	1.40	0.020	0.010	0.07	0.05	0.04	[g]	0.38	0.20[h]
iv)	ISL360NO	0.16	0.45	1.65	0.020	0.010	0.10	0.05	0.04	[g]	0.43	0.22[h]
	Quenched and tempered											
v)	ISL245QO	0.14	0.40	1.35	0.020	0.010	0.04	0.04	0.04	—	0.34	0.19
vi)	ISL290QO	0.14	0.40	1.35	0.020	0.010	0.04	0.04	0.04	—	0.34	0.19
vii)	ISL320QO	0.15	0.45	1.40	0.020	0.010	0.05	0.05	0.04	—	0.36	0.20
viii)	ISL360QO	0.16	0.45	1.65	0.020	0.010	0.07	0.05	0.04	[g]	0.39	0.20
ix)	ISL390QO	0.16	0.45	1.65	0.020	0.010	0.07	0.05	0.04	[g]	0.40	0.21
x)	ISL415QO	0.16	0.45	1.65	0.020	0.010	0.08	0.05	0.04	[g, h, i, j]	0.41	0.22
xi)	ISL450QO	0.16	0.45	1.65	0.020	0.010	0.09	0.05	0.06	[g, h, i, j]	0.42	0.22
xii)	ISL485QO	0.17	0.45	1.75	0.020	0.010	0.10	0.05	0.06	[g, h, i, j]	0.42	0.22
xiii)	ISL555QO	0.17	0.45	1.85	0.020	0.010	0.10	0.05	0.06	[g, h, i, j]	As agreed	
xiv)	ISL625QO	0.14	0.45	1.85	0.020	0.010	0.10	0.05	0.06	[g, h, i, j]	As agreed	
xv)	ISL690QO	0.14	0.45	1.85	0.020	0.010	0.10	0.05	0.06	[g, h, i, j]	As agreed	
	Thermo mechanical controlled processing (TMCP)											
xvi)	ISL245MO	0.12	0.40	1.25	0.020	0.010	0.04	0.04	0.04	—	—	0.19
xvii)	ISL290MO	0.12	0.40	1.25	0.020	0.010	0.04	0.04	0.04	—	—	0.19
xviii)	ISL320MO	0.12	0.40	1.35	0.020	0.010	0.05	0.05	0.04	—	—	0.20
xix)	ISL360MO	0.12	0.45	1.45	0.020	0.010	0.05	0.06	0.04	—	—	0.20
xx)	ISL390MO	0.12	0.45	1.45	0.020	0.010	0.06	0.08	0.04	[g]	—	0.21
xxi)	ISL415MO	0.12	0.45	1.45	0.020	0.010	0.08	0.08	0.06	[g, h, i, j]	—	0.21
xxii)	ISL450MO	0.12	0.45	1.60	0.020	0.010	0.10	0.10	0.06	[g, h, i, j]	—	0.22
xxiii)	ISL485MO	0.12	0.45	1.75	0.020	0.010	0.10	0.10	0.06	[g, h, i, j]	—	0.22
xxiv)	ISL555MO	0.12	0.45	1.85	0.020	0.010	0.10	0.10	0.06	[g, h, i, j]	—	0.24

[a] Based on product analysis, the *CEIIW* limits shall apply if C > 0.12 percent and the CE*P*cm limits shall apply if C ≤ 0.12 percent.

[b] For each reduction of 0.01 percent below the specified maximum for carbon, an increase of 0.05 percent above the specified maximum for manganese is permissible, up to a maximum increase of 0.20 percent.

[c] Al total ≤ 0.060 percent; N ≤ 0.012 percent; Al/N ≥ 2: 1 (not applicable to titanium-killed or titanium-treated steel); Cu ≤ 0.35 percent (if agreed, Cu ≤ 0.10 percent); Ni ≤ 0.30 percent; Cr ≤ 0.30 percent; Mo ≤ 0.15 percent; B ≤ 0.000 5 percent.

[d] For steel where calcium is intentionally added, the calcium content shall be 0.006 percent maximum. Unless otherwise agreed, Ca/S ≥ 1.5 if S > 0.0 015 percent.

[f] Unless otherwise agreed, the sum of niobium and vanadium contents shall be ≤ 0.06 percent.

[g] The sum of the niobium, vanadium and titanium contents shall be ≤ 0.15 percent.

[h] If agreed, the molybdenum content shall be ≤ 0.35 percent.

[i] If agreed, the chromium content shall be ≤ 0.45 percent.

[j] If agreed, Cr content shall be ≤ 0.45 percent and Ni content shall be ≤ 0.50 percent.

C-4.2 Tensile Properties

C-4.2.1 The tensile properties shall be as given in Table 12.

Table 12 Requirements of Tensile Tests

(*Clause* 4.2.1)

Sl No.	Steel grade	Yield Strength[a] $R_{t0.5}$ MPa		Tensile Strength[a] R_m Mpa		Ratio[a,] $R_{t0.5}/R_m$	Elongation (GL = 50 mm) Percent
		Min	*Max*	*Min*	*Max*	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i) ii) iii)	ISL245NO ISL245QO ISL245MO	245	450[d]	415	655	0.93	[b]
iv) v) vi)	ISL290NO ISL290QO ISL290MO	290	495	415	655	0.93	[b]
vii) viii) ix)	ISL320NO ISL320QO ISL320MO	320	525	435	655	0.93	[b]
x) xi) xii)	ISL360NO ISL360QO ISL360MO	360	530	460	760	0.93	[b]
xiii) xiv)	ISL390QO ISL390MO	390	545	490	760	0.93	[b]
xv) xvi)	ISL415QO ISL415MO	415	565	520	760	0.93	[b]
xvii) xviii)	ISL450QO ISL450MO	450	600	535	760	0.93	[b]
xix) xx)	ISL485QO ISL485MO	485	635	570	760	0.93	[b]
xxi) xxii)	ISL555QO ISL555MO	555	675	625	825	0.93	[b]
xxiii)	ISL625QO	625	745	695	895	0.97[e]	[b]
xxv)	ISL690QO	690[d]	810[d]	760	960	0.97[f]	[b]

[a] For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength shall be as given in the table for the next higher grade, and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in the table for the next higher grade. For intermediate grades, the tensile strength shall be ≤ 760 MPa.

[b] The specified minimum elongation shall be as determined using the following equation:

$$A = C \left[\frac{B^{0.2}}{U^{0.9}} \right]$$

Table 12 (*Concluded*)

Sl No.	Steel grade	Yield Strength[a] $R_{t0.5}$ MPa		Tensile Strength[a] R_m Mpa		Ratio[a,] $R_{t0.5}/R_m$	Elongation (GL = 50 mm) Percent
		Min	*Max*	*Min*	*Max*	*Max*	*Min*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

where

A = the minimum elongation in 50 mm or 2 in, expressed in percent, rounded to the nearest percent;

C = 1940 for calculations using SI units and 625 000 for calculations using USC units; and

B = the applicable tensile test piece cross-sectional area, expressed in square millimeters (square inches), as follows:

a) For circular cross-section test pieces, 130 mm^2 (0.20 in^2) for 12.5 mm (0.500 in) and 8.9mm (0.350 in) diameter test pieces; and 65 mm^2 (0.10 in^2) for 6.4 mm (0.250 in) diameter test pieces;

b) For full-section test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified outside diameter and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2); and

c) For strip test pieces, the lesser of a) 485 mm^2 (0.75 in^2) and b) the cross-sectional area of the test piece, derived using the specified width of the test piece and the specified wall thickness of the pipe, rounded to the nearest 10 mm^2 (0.01 in^2).

U = the specified minimum tensile strength, expressed in mega pascal (pounds per square inch).

[c] $R_{t0.5}$ = yield strength (0.5 percent total extension), expressed in mega pascals (pounds per square inch).

[d] For grades ISL690QO, $R_{p0.2}$ applies.

where

$R_{p0.2}$ = yield strength (0.2 percent non-proportional extension), expressed in megapascals (pounds per square inch);

[e] Lower $R_{t0.5}/R_m$ ratio values may be specified by agreement for ISL625QO; and

[f] For grade ISL690QO, $R_{p0.2}/R_m$ applies; lower $R_{p0.2}/R_m$ ratio values may be specified by agreement.

NOTE — More stringent mechanical properties can be mutually agreed between the steel producer and pipe manufacturer.

C-4.3 Hardness Test

The maximum acceptable hardness of the steel shall be:

a) 270 HV10, *Max* for < = ISL 450; and

b) 300 HV10, *Max* for > ISL 450 & < = ISL 555.

C-4.4 Grain Size

Test shall be carried out in accordance with IS 4748 for requirements as agreed to between the manufacturer and the purchaser.

C-4.5 Test Frequency

Test frequency is given in Table 13.

Table 13 Test Frequency

(*Clause* C-4.5)

Sl No.	Characteristic	Sample Orientation	Test Frequency
(1)	(2)	(3)	(4)
i)	Chemical analysis (ladle & product)	—	One sample per heat
ii)	Tensile test	Transverse to rolling direction	One sample per heat
iii)	Bend test	Transverse to rolling direction	One sample per heat
iv)	Charpy impact test	Transverse to rolling direction	One set of three specimens per heat
v)	DWT test	Transverse to rolling direction	One set of two specimens per heat
vi)	Hardness test	Transverse to rolling direction	One sample per heat
vii)	Ferritic grain size measurement	Transverse to rolling direction	One sample per heat

ANNEX D

(*Foreword*)

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