Low alloy steel plates for low temperature pressure vessels

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Foreword

In this standard, Sections 5.2.1, 6.4.3, 6.5.2, and 8.3 are recommended requirements, whereas others are mandatory requirements.

This standard is the amendment of GB 3531—1996 “Low alloy steel plates for low temperature pressure vessels”.

Since the date of enforcement, GB 3531-1996 “Low alloy steel plates for low temperature pressure vessels” is repealed.

Comparing with GB 3531—1996, the amendments are as follows:

— The specification of thickness of steel plates is enlarged, and the maximum thickness increased from 100mm to 120mm;
— The negative deviation of thickness of steel plate is changed from -0.25mm to -0.30mm;
— The mass fraction of Sulphur content of each designated grade is lowered from 0.015% to 0.012%;
— The requirement of refining process outsides the furnace is added;
— The impact energy at low-temperature is raised from ≥27J to ≥34J. And the temperature of impact testing of 16MnDR with thickness >36mm~60mm is lowered from -30°C to -40°C.

This Standard was proposed by the China Iron and Steel Association.

This Standard is under the jurisdiction of Chinese National Steel Standardization Technical Committee.

The main Drafting Organizations: Chongqing Iron & Steel Co. Ltd., China Metallurgical Information & Standardization Research Institute, Jinan Iron & Steel Co. Ltd.

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This standard supersedes the standards of previous editions:
Low alloy steel plates for low temperature pressure vessels

1 Scope

This standard specifies dimensions, shapes, weights and tolerances, technical requirements, test methods, inspection rules, package, marks and product quality certificates of low alloy steel plates for low temperature pressure vessels.

This standard applies to low alloy steel plates with a thickness of 6mm to 120mm for the construction of pressure containing components for −20°C～−70°C low temperature pressure vessels (hereinafter referred to as the plate).

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, all subsequent amendments (not including the contents of the corrigenda) or revised edition shall not apply to this standard. However, it is encouraged to study whether these latest version be applied to this Standard. For undated references, the latest edition of the referenced documents applies.

| GB/T 222 | Permissible variations of chemical composition for steel product analysis |
| GB/T 223.3 | Methods for chemical analysis of iron, steel and alloy: The diantipyryl methane phosphomolybdate gravimetric method for the determination of phosphorus content |
| GB/T 223.9 | Iron, steel, and alloy Determination of aluminum contents: Chrome azurol S photometric method |
| GB/T 223.11 | Iron, steel, and alloy: Determination of chromium contents——Visual titration or potentiometric titration method |
| GB/T 223.12 | Methods for chemical analysis of iron, steel and alloy: The sodium carbonate separation-diphenyl carbazide photometric method for the determination of chromium content |
| GB/T 223.14 | Methods for chemical analysis of iron, steel and alloy: The N-benzoyl-N-phenylhydroxylamine extraction photometric method for the determination of vanadium content |
| GB/T 223.17 | Methods for chemical analysis of iron, steel and alloy: The diantipyryl methane photometric method for the determination of titanium content |
| GB/T 223.19 | Methods for chemical analysis of iron steel and alloy: The neocuproine-chloroform extraction photometric method for the determination of copper content; |
| GB/T 223.23 | Methods for chemical analysis of iron, steel and alloy: The dimethylglyoxime spectrophotometric method for the determination of nickel content; |
GB/T 223.26 Methods for chemical analysis of iron, steel and alloy: The thiocyanate direct photometric method for the determination of molybdenum content.

GB/T 223.40 Iron steel and alloy: Determination of niobium content by the sulphochlorophenol-S spectrophotometric method;

GB/T 223.49 Methods for chemical analysis of iron, steel and alloy: Extraction separation-chlorophosphonazo mA spectrophotometric method for the determination of the total rare earth content

GB/T 223.53 Methods for chemical analysis of iron, steel and alloy: The flame atomic absorption spectrophotometric method for the determination of copper content

GB/T 223.54 Methods for chemical analysis of iron, steel and alloy: The flame atomic absorption spectrophotometric method for the determination of nickel content

GB/T 223.60 Methods for chemical analysis of iron, steel and alloy: The perchloric acid dehydration gravimetric method for the determination of silicon content;

GB/T 223.62 Methods for chemical analysis of iron, steel and alloy: The butyl acetate extraction photometric method for the determination of phosphorus content

GB/T 223.63 Methods for chemical analysis of iron, steel and alloy: The sodium (potassium) periodate photometric method for the determination of manganese content

GB/T 223.68 Methods for chemical analysis of iron, steel and alloy: The potassium iodate titration method after combustion in the pipe furnace for the determination of sulphur content;

GB/T 223.69 Methods for chemical analysis of iron, steel and alloy: The gas-volumetric method after combustion in the pipe furnace for the determination of carbon content.

GB/T 223.76 Methods for chemical analysis of iron, steel and alloy: The flame atomic absorption spectrophotometric method for the determination of vanadium content

GB/T 228 Metallic materials: Tensile testing at room temperature


GB/T 232 Metallic materials: Bend test (ISO 7438:2005, MOD)

GB/T 247 General rule of acceptance, package, mark, and certification for steel plates (sheets) and strips


GB/T 2970 Thicker steel plates—Method for ultrasonic inspection


GB/T 4336 Standard test method for spark discharge atomic emission spectrometric analysis of carbon and low-Alloy steel (routine method)
3 Ordering information

a) The standard number
b) Name of the product
c) Designated grade and Code
d) Delivery condition
e) Dimensions
f) Weight(Mass)
g) Additional technical requirements

4 Expressive method of grade and designation

The suffix in the "D" and "R" of the grades listed in this standard refer to the first letter of word “low” (Di) and the “vessel” (Rong) in Hanyu Pinyin of the low temperature pressure vessels.

5 Dimensions, shapes, weights and their tolerances, permissible variations

5.1 The dimensions, shape, and tolerances of steel plates should conform to the provisions specified in GB/T 709-2006.
5.2 The thickness tolerances should conform to the requirements stipulated in Category B of permissible variations of GB/T709-2006.

According to the request of the purchaser, upon the agreement between the purchaser and the manufacturer, the delivery can also be accomplished with the requirement of Category C of permissible variations stipulated in GB/T709-2006.
5.3 The delivery weights of steel plates are the theoretical weights, whereas the thickness for theoretical weight is calculated by the mean value of permissible maximum and minimum thickness. The densities of steel plates are 7.85g/cm³

6 Technical requirements

6.1 Designated grades and Chemical Composition
GB 3531—2009

Designated grades and Chemical Composition (heat analysis) for steels shall be consistent with requirements specified in Table 1.

### Table 1 Chemical Composition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chemical Composition (Mass %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>16MnDR</td>
<td>≤0.20</td>
</tr>
<tr>
<td>15MnNiDR</td>
<td>≤0.18</td>
</tr>
<tr>
<td>09MnNiDR</td>
<td>≤0.12</td>
</tr>
</tbody>
</table>

6.1.1 To improve the performance of the steel plates, vanadium, titanium, niobium, rare earth and other elements may be added to the steel, \( \omega (V+Ti+Nb) \leq 0.12\% \), and the mass percentage of these elements shall be filled in the material quality certificate.

6.1.2 As residual elements, the mass percentage of chromium or copper shall not be greater than 0.25% respectively, the mass percentage of nickel shall not be greater than 0.40%, and the mass percentage of molybdenum shall not be greater than 0.08%. If the manufacturer can guarantee the quality, the analysis can be omitted.

6.1.3 The mass percentage of full aluminum Al₁ can be substituted by the mass percentage of acid soluble aluminum, at the same time the mass percentage of the acid soluble aluminum shall not be less than 0.015%.

6.1.4 The permissible tolerance of chemical composition of the end product of steel plates shall conform to the stipulations in GB/T 222.

6.2 Steel-making process

Steels are smelted by oxygen converter furnace or electric furnace, and followed by the refining process outside the furnace.

6.3 Delivery condition

Steel plates shall be delivered at the normalized condition or at the tempered and normalized condition.

6.4 Mechanical properties and process properties

The tensile test, Charpy (V notch) low temperature impact test, and bend test of steel plates shall be consistent with the stipulations in Table 2.

### Table 2 Mechanical properties, process properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Nominal thickness of steel plates (mm)</th>
<th>Tensile Test</th>
<th>Impact Test</th>
<th>180°Bend Test³ Bending Diameter (b≥35mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tensile Strength ( R_m ) (N/mm²)</td>
<td>Yield Strength ( R_p ) (N/mm²)</td>
<td>Elongation A (％)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not less than</td>
<td>Not less than</td>
<td>Not less than</td>
</tr>
<tr>
<td>Steel Grade</td>
<td>Thickness (mm)</td>
<td>Yield Strength (MPa)</td>
<td>Impact Energy (J)</td>
<td>Temperature (°C)</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------</td>
<td>----------------------</td>
<td>------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>16MnDR</td>
<td>6-16</td>
<td>490-620</td>
<td>315</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>&gt;16-36</td>
<td>470-600</td>
<td>295</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;36-60</td>
<td>460-590</td>
<td>285</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;60-100</td>
<td>450-580</td>
<td>275</td>
<td>-30</td>
</tr>
<tr>
<td></td>
<td>&gt;100-120</td>
<td>440-570</td>
<td>265</td>
<td></td>
</tr>
<tr>
<td>15MnNiDR</td>
<td>6-16</td>
<td>490-620</td>
<td>325</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>&gt;16-36</td>
<td>480-610</td>
<td>315</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;36-60</td>
<td>470-600</td>
<td>305</td>
<td></td>
</tr>
<tr>
<td>09MnNiDR</td>
<td>6-16</td>
<td>440-570</td>
<td>300</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>&gt;16-36</td>
<td>430-560</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;36-60</td>
<td>430-560</td>
<td>270</td>
<td>-70</td>
</tr>
<tr>
<td></td>
<td>&gt;60-120</td>
<td>420-550</td>
<td>260</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**

a. When the yield strength is not available, use $R_{p0.2}$.
b. The width of bending test specimen for arbitration $b=35mm$.

6.4.1 The value of Charpy (V-notch) impact energy at low-temperature, can be calculated by the mean of values from 3 specimens, and one of the value among the specimens may be lower than the value stipulated in Table 2, but shall not be less than 70% of the stipulated value.

6.4.2 For the steel plates with the thickness less than 12mm, the auxiliary specimens shall be used in the Charpy (V-notch) low temperature impact test. The dimension of the auxiliary specimens for the steel plates with thickness in the range of 6mm-8mm is 5mm×10mm×55mm, and the test result shall not be less than 50% of the value stipulated in Table 2. For the steel plates with thickness between 8mm and 12mm, the dimension of the auxiliary specimens is 7.5mm×10mm×55mm, and the test result shall not be less than 75% of the value stipulated in Table 2.

6.4.3 Upon the agreement between the manufacturer and the purchaser at the time of order, the steel plates may be supplied by the values of low temperature impact energy that greater than those in Table 2, and the actual values shall be indicated in the contract (purchase order).

6.5 Ultrasonic Testing

6.5.1 The manufacturer of steel plates with the thickness greater than 20mm shall carry out the ultrasonic test plate by plate.

6.5.2 For the steel plate with the thickness not greater than 20mm, upon the agreement between the manufacturer and the purchaser, the ultrasonic testing can also be carried out plate by plate.
6. 5. 3 The standard of ultrasonic testing is carried out according to GB/T 2970 or JB/T 4730.3, and the testing standard and each classification are indicated in the contract.

6. 6 surface quality

6. 6. 1 The surface of the steel plates shall be free from any harmful defects, such as cracks, blisters, scabs, overlaps, and foreign inclusions. The plate shall be free from the lamination.

Removal of the above defects is permitted. The removal depth from real size shall not exceed half tolerance of the specified thickness, and the minimum thickness at the removal place shall be guaranteed. The places for defect removal should be smooth and without any edge or corner.

6. 6. 2 Other existing imperfections are permitted and the imperfection depth from real size shall not exceed half tolerance of the thickness, and the thickness at the imperfection place shall not less than the minimum permissible thickness of the steel plate.

7 Test methods

The inspection items, sampling quantity, sampling method and testing methods shall be in accordance with specifications given in Table 3.

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Inspection item</th>
<th>Quantity of sampling</th>
<th>Method of sampling</th>
<th>Direction of sampling</th>
<th>Testing method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chemical composition</td>
<td>1 per heat</td>
<td>GB/T 20066</td>
<td>—</td>
<td>GB/T 223, GB/T 4336, GB/T 20123, GB/T 20125</td>
</tr>
<tr>
<td>2</td>
<td>Tensile test</td>
<td>1 per lot</td>
<td>GB/T 2975</td>
<td>transverse</td>
<td>GB/T 228</td>
</tr>
<tr>
<td>3</td>
<td>Bending test</td>
<td>1 per lot</td>
<td>GB/T 2975</td>
<td>transverse</td>
<td>GB/T 232</td>
</tr>
<tr>
<td>4</td>
<td>Impact test at low temperature</td>
<td>3 per lot</td>
<td>GB/T 2975</td>
<td>transverse</td>
<td>GB/T 229</td>
</tr>
<tr>
<td>5</td>
<td>Ultrasonic testing</td>
<td>plate by plate</td>
<td>—</td>
<td>—</td>
<td>GB/T 2970 or GB/T 4730</td>
</tr>
<tr>
<td>6</td>
<td>Dimension and shape</td>
<td>plate by plate</td>
<td>—</td>
<td>—</td>
<td>Feasible measure accord with precision requirement</td>
</tr>
<tr>
<td>7</td>
<td>Surface</td>
<td>plate by plate</td>
<td>—</td>
<td>—</td>
<td>Visual testing</td>
</tr>
</tbody>
</table>

8 Inspection rules

8. 1 The examinations and inspections of the quality of steel plates shall be carried by the local authority of the quality supervision department over the supplier.

8. 2 Steel plates shall be inspected by per lot, in which is composed of plates from the same designated grade, the same heat number, the same thickness, and the same heat treatment process. The weight of each lot shall be not greater than 30t. A lot is composed of one plate while the weight of single steel plate is greater than 30t.

8. 3 According to the purchaser’s request, upon the agreement between the manufacturer and the purchaser, the mechanical testing may be carried out by each heat treatment plate for steel plates that the thickness are greater than 16mm.

8. 4 The sampling location of steel plates shall conform to the specifications in Table 20. For the steel plates that thickness are greater than 40mm, the axis of the impact test specimen shall located at the one
quarter of the thickness.

8.5 While results of the Charpy (V notch) low temperature impact tests are not satisfied with the requirements of Sect. 6.4, 3 samples shall be taken from the same steel plate (or the same billet) for retest. The mean value of the impact test results from the 2 sets of specimens that are altogether 6 pieces of specimens shall not be lower than the specified value, and 2 of the values are acceptable to be lower than the specified value. However, only one of the results is permitted to be lower than 70% of the specified value.

8.6 The items for retest and acceptance criterion shall conform to the requirements specified in GB/T 17505.

9 Package, marks and quality certificates

The packaging, marking and quality certificates of steel plates shall conform to the specifications in GB/T 247.

10 Method of rounding off

Method of rounding off shall be in accordance with the specifications in GB/T 8170.