

JIS

JAPANESE INDUSTRIAL STANDARD

**Testing method for
corrosivity of industrial water**

JIS K 0100—1990

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In the event of any doubt arising,
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Testing method for corrosivity of industrial water K 0100-1990

1. Scope

This Japanese Industrial Standard specifies the testing method to check the corrosivity of industrial water used in a plant.

Additionally, this testing method can be used to test the effect of corrosion inhibitors and the anticorrosivity of metallic material against industrial water.

- Remarks 1. In the case of a heating surface of a heat exchanger, this testing method cannot be applied because of its different corrosivity than that of test pieces.
2. In the case of the measurement of the flow rate under the testing condition mentioned in testing method, JIS K 0094 shall be applied.

JIS K 0101 shall be applied for tests such as temperature, electric conductivity, pH, dissolved oxygen, and so on.

3. The corrosivity test for the closed cooling water system of an internal combustion engine shall be carried out in accordance with JIS K 2234.
4. The applicable standards in this Standard are as follows.

JIS G 3101-Rolled Steel for General Structure

JIS G 3141-Cold Rolled Carbon Steel Sheets and Strip

JIS K 0094-Sampling Methods for Industrial Water and Industrial Waste Water

JIS K 0101-Testing Methods for Industrial Water

JIS K 2234-Engine Antifreeze Coolants

JIS R 6251-Abrasive Cloths

JIS R 6252-Abrasive Papers

JIS R 6253-Waterproof Abrasive Papers

2. Summary

This testing method shall be carried out by either weight loss method or polarization-resistance method. In the case of weight loss method, an average corrosion rate (rate of corrosion) during testing period can be obtained from the weight loss by corrosion. In case of the polarization-resistance method, corrosion rate (rate of corrosion) can be obtained at the point of measurement from the electrochemical polarization resistance.

When the corrosivity of industrial water is tested, a standard metal sample is used, and when the anticorrosivity of metal material is tested, the metal piece referred to is used.

When the corrosivity of industrial water is compared, the test conditions as water temperature, flow rate and so on, should be the same as much as possible, but the results show only the values of targeted piping or equipment under such conditions, therefore satisfactory attention is needed when judging the meaning of the results.

Additionally, the rotation method is appended in the Informative Reference which can be used for comparing the corrosivity of industrial water and the additional effect of corrosive inhibitor.

3. Weight Loss Method

Attach a plate-type test piece on a test-piece holder, fix it in piping or equipment under insulated condition, observe corroded condition of the test piece owing to industrial water after a definite testing period, measure the corrosion loss of the test piece, and calculate the average corrosion rate (rate of corrosion) during the testing period.

3.1 Test-piece Holder The test-piece holder is the tool to fix test pieces in equipment under insulated condition, and Attached Fig. 1 and Attached Fig. 2 exemplifies the holder in straight pipe and bent pipe equipment. Attached Fig. 3 exemplifies the construction of a test-piece holder which is used in a tank or the like.

In case of using a test-piece holder for straight or bent pipe, fix one end of a supporting plate to a flange, attach a steady rest at the other end, put the test piece through a holding rod set in the insulating pipe ⁽¹⁾ via an insulating spacer ⁽¹⁾, and then fix test pieces on the supporting plate by the holding plate, and supporting bolts and nuts.

In case of using a test-piece holder in a tank or the like, set a supporting rod in insulating pipe ⁽¹⁾, put alternately test pieces and insulating spacers ⁽¹⁾, and fix end plates at both ends with double nuts. And reinforce and protect them with four protecting rods.

The holder of test pieces shall be the same kind of anticorrosive metal ⁽²⁾ at every set.

Notes ⁽¹⁾ Synthetic resin or the like must be used.

⁽²⁾ In case of fresh water, austenite stainless steel, and in case of sea water, titanium or the like should be used.

3.2 Test Piece

(1) Shape and Dimension Shape and dimensions are exemplified in Attached Fig. 4.

(2) Material Low carbon steel first grade (SPCC) specified in JIS G 3141 should be used as a standard metal sample. If necessary, other metal materials can be used instead.

- (3) Surface Finish and Measurement After removing dirt from the surface of a test piece, imprint a mark, and finish the whole surface by wet or dry polishing with up to No. 400 abrasive paper or cloth (JIS R 6251, JIS R 6252 or JIS R 6253) ⁽³⁾ ⁽⁴⁾. Measure the dimensions of a test piece to the nearest 0.1 mm and calculate all surface area ⁽⁵⁾. Then wash completely with water, degrease with methanol then with acetone, and weigh to the nearest 0.1 mg after drying. When measuring, observe its appearance ⁽⁶⁾. It is recommended to prepare a test piece immediately before the test.

- Notes ⁽³⁾ In case of aluminium or an aluminium alloy, instead of this polishing, dip it in nitric acid (4 + 1) at room temperature for about 10 min, or dip it for about 30 s in a solution which has been prepared by dissolving 20 g potassium dichromate and 28 ml phosphoric acid in 1 liter of water and heated at 70 to 80°C.
- ⁽⁴⁾ When numbers or symbols are stamped on a test piece, it should be carried out at as for a peripheral part as possible.
- ⁽⁵⁾ The whole surface area of a test piece, which is supposed to have no holding hole, should be calculated up to three significant figures, and this should be regarded as the surface area for corrosion-rate calculation.
- ⁽⁶⁾ The test piece, after degreasing, should be carefully handled so as not to generate rust or leave finger prints.

For storing, it must be kept in a desiccator.

3.3 Testing Method

- (1) Attaching of Test Piece Fix a test piece on a test piece holder as shown in Attached Fig. 1, Fig. 2 and Fig. 3, and in case of test in pipe, make the attachment in the straight length at upper stream at least ten times the inner diameter of the pipe and down stream at least five times the inner diameter of the pipe ⁽⁶⁾.

And in the test using a tank or the like, fix the test piece to be vertical ⁽⁶⁾.

- (2) Testing Condition Record all items relating to corrosion such as flow rate, water temperature, electric conductivity, pH, dissolved oxygen, consuming quantity of acid, chloride ions, total hardness, number of general bacteria, and other necessary items.

During testing period, the fluctuation of the atmospheric conditions is preferably as little as possible.

- (3) Testing Period Testing period shall be 30 days. Testing period, however, can be shortened because of circumference, material or other reasons.

- (4) Post-treatment of a Test Piece After detaching the test piece from the test-piece holder ⁽⁷⁾, remove material produced by corrosion, dip it in methanol and then in acetone, dry it, and weigh its mass to the nearest 0.1 mg. In order to remove the produced material by corrosion, use a non-metallic brush (for instance a nylon brush), gauze, or other materials in running water. When the material strongly sticks, apply either of the following methods. In this case, preferably carry out a blank test ⁽⁸⁾ simultaneously, and correct the weight loss of a test piece due to removal.

Notes ⁽⁷⁾ Handle a test piece carefully to avoid leaving finger prints.

⁽⁸⁾ Blank test shall be carried out by the similar post-treatment using another test piece, whose size and type are the same as the test piece referred to, and correct the mass of the test piece after measuring weight loss due to post-treatment.

- (a) Electrolysis Method Electrolyze the test piece by either of the following: after making electrolyte the solution of sulfuric acid (5 %) containing a suitable amount of corrosion inhibitor for acid washing such as 0.05 % thiourea, electrolyze it at about 70°C temperature for about 3 min under 20 A/dm² cathode current density with the test piece as a cathode and platinum plate as an anode; or after making electrolyte the solution containing 75 g/l sodium hydroxide, 75 g/l sodium carbonate and 24 g/l sodium sulfate, electrolyze it at approximately 60°C for approximately 3 min with the test piece as a cathode and platinum plate as an anode under 6 A/dm² cathode current density for steel or 2.5 A/dm² for nonferrous metal.

The former method is unsuitable for magnesium and zinc, and the latter for aluminium and lead.

- (b) Acid-washing Method According to the material of a test piece, immerse it in the following solution, and remove produced material by corrosion using a non-metallic brush (for instance a nylon brush), gauze or others.

- 1 Low Carbon Steel Immerse in about 15 % hydrochloric acid containing corrosion inhibitor for acid washing at room temperature for about 15 s.
- 2 Stainless Steel Immerse in about 30 % nitric acid at room temperature for about 5 min.
- 3 Copper or Copper Alloy Immerse in about 10 % sulfuric acid at room temperature for about 5 min.
- 4 Aluminium or Aluminium Alloy Immerse either in nitric acid (4 + 1) at room temperature for about 10 min, or in a solution prepared by dissolving 20 g potassium dichromate and 28 ml phosphoric acid in 1 liter of water at 70 to 80°C temperature for about 30 s.

3.4 Expression of Results

- (1) Observation of Appearance Observe the color, shape and surface condition of the material produced by corrosion on the test piece, and then check the distribution of corrosion spots on the surface of the test piece after removing it using the method in 3.3 (4) so as to judge whether the corrosion spreads all over the surface or is localized.
- (2) Corrosion Rate or Erosion Rate Corrosion rate and erosion rate shall be calculated in accordance with the following formulas.

Corrosion rate is expressed with mdd, that is mg value of weight loss by corrosion per one day per 1 dm² of surface area.

$$W = \frac{M_1 - M_2}{S \times T}$$

where, W : corrosion rate (mdd)

M_1 : mass of test piece before test (mg)

M_2 : mass of test piece after test (mg)

S : surface area of test piece (dm²)

T : days for test

Erosion rate is expressed with mm/y, that is mm value of eroded depth per year, and converted from the corrosion rate using the following formula.

$$P = W \times \frac{365 \times 10^{-4}}{d}$$

where, P : erosion rate (mm/y)

W : corrosion rate (mdd)

d : density of test piece (g/cm³)

Remarks: If pitting takes place on a test piece such as a stainless steel piece, the pitting corrosion (PT) is preferably expressed by the following three ways.

Number of Pitting Holes After counting the number of all pitting holes on a test piece, express the number of pitting holes per unit area (1 cm²). In this case, disregarding the shape of a pitting, count every pitting as a unit.

Symbol N : number/cm²

Depth of Pitting Express the value of the deepest among all pitting holes found on a test piece. When measuring, use such instruments as a depth micrometer, dial gauge, or a microscope with focused graduation.

Symbol D : mm

Erosion Rate Use the value of erosion rate obtained at 3.4 (2).

Symbol P : mm/y

Example of Expression PT-2.0 N , 0.5 D , 0.05 P

3.5 Report On a test report, mention testing method and items specified in 3.2 (1), (2), 3.3 (1) to (3), and 3.4 (1), (2).

Furthermore, mention the items probably giving the influence on corrosion as much as possible.

4. Polarization-resistance Method

Polarization-resistance is obtained by applying very little electric current on a sample electrode and measuring the response due to it (change of electric potential or current). Use either the three-electrode way ⁽⁹⁾ in which three electrodes as a sample electrode, a reference electrode, and counter electrode are used, or two-electrode way in which a counter electrode doubles as a reference electrode. Use direct current or low frequency alternating current, and carry out the test under the condition as constant current or constant voltage ⁽¹⁰⁾. Because almost all industrial water, except sea water, has low electric conductivity, measure the resistance in solution, subtract the solution resistance from polarization resistance, and correct the value of polarization resistance.

Fix the test piece to be used as an electrode on a test-piece holder, and then attach it to an apparatus.

Notes ⁽⁹⁾ The three-electrode way gives better measuring accuracy because of the small error due to solution resistance.

⁽¹⁰⁾ Applying alternating current may use a complicated apparatus, but has good continuous monitoring properties. Direct and constant current method uses a simple apparatus and gives easy measurement, therefore it is convenient for laboratory operation.

4.1 Test Piece

- (1) Shape and Dimensions A rod type shall be standard, but the other types may be acceptable. The surface area serviceable for testing shall not be smaller than 5 cm², and they are exemplified in Attached Fig. 5.

- (2) Material Standard metal sample shall be low carbon SS 41 steel bar specified in JIS G 3101. If necessary, the other metal materials can be used.
- (3) Surface Finishing and Measurement Conform to 3.2 (3).
Provided that no symbol be attached.

4.2 Test-piece Holder A test-piece holder ⁽¹¹⁾ shall have two or three metal rods, whose ends have a screw to fasten a test piece and which are buried in insulating material such as synthetic resin ⁽¹²⁾, and shall be attached to an apparatus. A test piece is fastened to the metal rod using packing and can be connected outside the measuring apparatus.

When testing in straight pipe of an apparatus, the example of a test-piece holder is shown in Attached Fig. 6.

In case of a test in a tank, a similarly constructed apparatus shall be used.

Notes ⁽¹¹⁾ When metal is used for a test-piece holder proper, the material should conform to Note ⁽²⁾.

⁽¹²⁾ High insulating resin, such as epoxy resin, shall be used.

4.3 Attaching of Test Piece Prepare several needed test pieces, which are the same material, the same shape, and the same dimensions, for each three-electrode way and two-electrode way, and attach them to a test-piece holder.

In case of testing in pipe, the attaching location of a test-piece holder in an apparatus shall be the same as that in 3.3 (1). Provided that a test piece should be put vertically and two test pieces should be perpendicular to flow direction. In case of three-electrode way, set the test piece to be used for a counter electrode at the down stream side.

In case of testing in a tank or the like, fasten a test piece to a test-piece holder to make it as vertical as possible.

4.4 Measuring Apparatus The measuring apparatus for polarization resistance shall be either the combination of a power source [constant current device ⁽¹³⁾ or constant voltage device ⁽¹⁴⁾], an ammeter ⁽¹⁵⁾, and high input-resistance voltmeter ⁽¹⁶⁾, or the apparatus with equivalent performance. Attached Fig. 7 gives Measuring Block diagram for three-electrode way and two-electrode way. The measuring apparatus ⁽¹⁷⁾ of solution resistance to be used for correction of solution resistance error shall be, in case of an impedance method as shown in Attached Fig. 8, either combination of a high-frequency oscillator and an ammeter • voltmeter for alternating current, or an impedance bridge.

Notes ⁽¹³⁾ This shall be a device stably supplying various constant currents, and have one or more waveform outputs out of direct current, square-wave alternating current, or sine-wave alternating current (0.1 Hz or less frequency in any case).

- (14) This shall be a constant voltage device capable of electrolyzing at constant voltage with the three wave forms shown in (13).
- (15) When measuring current with either plus polarity or minus polarity, it is recommended to have a measuring range of approximately 0.1 μ A to 10 mA.
- (16) The voltmeter has 1 M Ω or more input resistance, and is capable of measuring the peak • peak value of direct current or low-frequency alternating current with an ammeter (which measures the discrepancy between the maximum at plus half period and the minimum at minus half period). Scales are preferably readable up to 0.1 mV.

The scales in an ammeter and a voltmeter is passable if they indicate the rate of corrosion.

- (17) In the case of industrial water except sea water, the apparatus for solution-resistance measuring is necessary. Some apparatus has an automatically correcting device for solution resistance.

4.5 Testing Condition

- (1) Testing Condition Testing condition to be recorded shall follow 3.3 (2).
- (2) Testing Period Testing period shall be set depending on the purpose of a test.

4.6 Testing Method Polarization resistance shall be measured in accordance with any of 1. (a) to (c).

(1) Measurement of Apparent Polarization Resistance

- (a) Alternating and Constant Current Method As shown in Attached Fig. 7, use an alternating and constant current apparatus as a power source, let flow constantly a very small amount of low-frequency alternating current between a sample electrode and counter electrode, and follow the change of indicated values on the ammeter and voltmeter. Every change of polarity of current, read the peak • peak value (18) of voltage shown during the previous one cycle. After confirming that the voltage (peak • peak value) is kept nearly constant after 1.5 cycles or more (preferably 4 cycles or more), switch off the current.

Calculate the apparent polarization-resistance value by dividing the final voltage peak • peak value by current peak • peak value. Provided that in case of two-electrode way, calculate it using a half of the voltage peak • peak value.