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**Determination of diffusible hydrogen
content in steel weld metal**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Welding Engineering Society (JWES)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS Z 3118** : 2007), which has been technically revised.

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Determination of diffusible hydrogen content in steel weld metal

Introduction

This Japanese Industrial Standard has been prepared based on **ISO 3690** : 2018, Edition 4, with some modifications of the technical contents.

The vertical lines on both sides and dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JD.

1 Scope

This Standard specifies the procedure for the determination of diffusible hydrogen, measured by the gas chromatography method or hot carrier gas extraction method, in steel weld metal arising from the welding of such steels using arc welding processes.

The welding processes covered in this Standard are shielded metal arc welding, submerged arc welding, gas-shielded metal arc welding (hereafter referred to as gas-shielded arc welding) and self-shielded arc welding.

NOTE 1 Diffusible hydrogen content is used as one of the factors in calculating the preheating temperature to prevent cold cracking of the weld or the properties of the welding material.

The calculation of the preheating temperature is carried out by converting the diffusible hydrogen content per mass of deposited metal calculated in **6.2** by the relational formula given in Annex JC.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows.

ISO 3690 : 2018 *Welding and allied processes — Determination of hydrogen content in arc weld metal* (MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS G 3106 *Rolled steels for welded structure*

JIS K 0114 *General rules for gas chromatography*

JIS Z 3001-7 *Welding and allied processes — Vocabulary — Part 7 : Arc welding*

JIS Z 3200 *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances and markings*

JIS Z 3253 *Shielding gases for fusion welding and thermal cutting*

NOTE Corresponding International Standard : ISO 14175 *Welding consumables — Gases and gas mixtures for fusion welding and allied processes*

JIS Z 8401 *Rounding of numbers*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in JIS Z 3001-7, and the following apply.

3.1

diffusible hydrogen

hydrogen moving freely in the crystal lattice of the weld

3.2

diffusible hydrogen content

amount of diffusible hydrogen evolved when a test piece for measuring hydrogen is maintained at ordinary temperature ($25\text{ °C} \pm 5\text{ °C}$)

3.3

gas chromatography method

method for the determination of diffusible hydrogen content by holding a test piece for measuring hydrogen at $45\text{ °C} \pm 3\text{ °C}$ for at least 72 h or at $150\text{ °C} \pm 3\text{ °C}$ for at least 6 h to extract and collect diffusible hydrogen in a container and then carrying out the measurement using a gas chromatograph

3.4

hot carrier gas extraction method

method for the determination of diffusible hydrogen content by heating a test piece for measuring hydrogen to 160 °C to 400 °C to extract and measure continuously the diffusible hydrogen evolved

3.5

test plate

parent material prepared by machining the specified, dehydrogenated steel plate, and used for a test

3.6

test piece for measuring hydrogen

test material obtained by welding a test plate and weld tabs and then removing mechanically the tabs of both ends in order to measure the diffusible hydrogen content

4 Principle

Diffusible hydrogen requires a long time for extraction at ordinary temperature but can be extracted in a short time by increasing the temperature of a test piece for measuring hydrogen. In the gas chromatography method, diffusible hydrogen is extracted and collected in a special container for measurement. In the hot carrier gas extraction method, the diffusible hydrogen evolved is continuously extracted and measured.

Diffusive hydrogen content is determined by comparing the peak area of hydrogen obtained by a thermal conductivity detector (TCD) with the peak area of calibration hydrogen obtained under the same measurement conditions.

5 Determination of diffusible hydrogen content

5.1 Overview of determination method

The overview of determination method of diffusible hydrogen content is given in Figure 1.

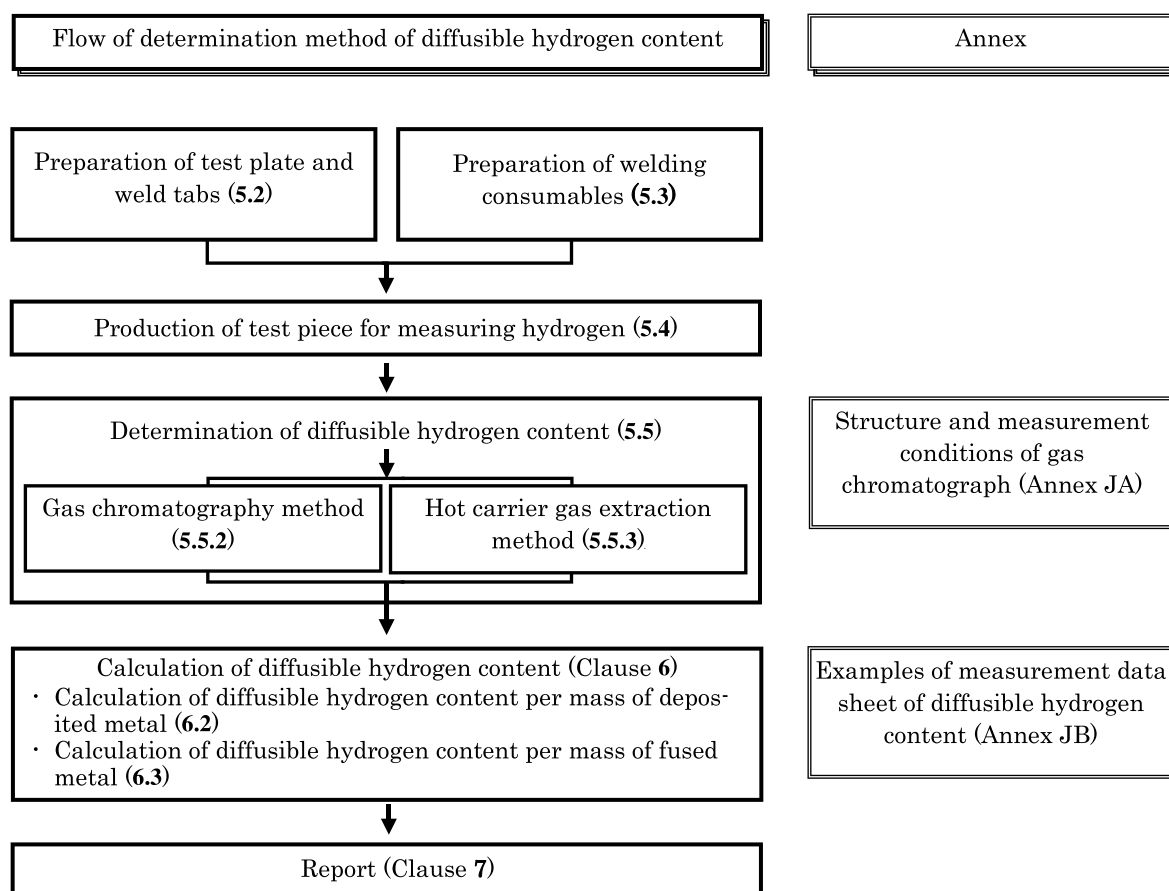


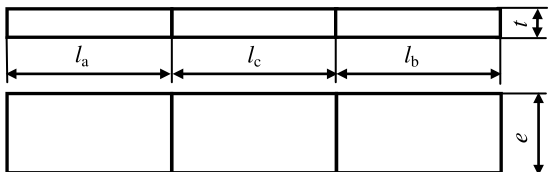
Figure 1 Overview of determination method of diffusible hydrogen content

5.2 Preparation of test plate and weld tabs

The test plate and weld tabs shall be prepared as follows.

- The test plate and weld tabs shall be prepared by using the steel plate of SM400A, SM 400B or SM400C specified in **JIS G 3106** or the low carbon steel plate with a carbon content of not more than 0.18 % by mass and a sulfur content of not more than 0.02 % by mass.
- The test plate and weld tabs shall be kept at 400 °C to 650 °C in atmospheric air for at least 1 h to remove hydrogen and cooled in atmospheric air.
- All surfaces of test plate and weld tabs shall be grounded and cleaned.
- The test plate shall be numbered by engraving or stamping.
- Dimensions and dimensional tolerances of test plate and weld tabs shall be as given in Table 1.
- The test plate shall be weighed to the nearest 0.01 g.

Table 1 Dimensions of test plate and weld tabs

								Unit: mm
Welding process	Type of test plate	Dimensions of test material			Dimensions of weld tab			Dimensional tolerance
		Thickness t	Width e	Length l_c	Thickness t	Width e	Length l_a, l_b	
Shielded metal arc welding Gas-shielded arc welding Self-shielded arc welding	No. 1	10	15	30	10	15	45 min.	±0.25
Submerged arc welding		10	30	15	10	30	45 min.	
Shielded metal arc welding Gas-shielded arc welding Self-shielded arc welding	No. 2	12	25	40	12	25	45 min.	
Submerged arc welding	No. 3	12	25	80	12	25	45 min.	
Arrangement of test plate and weld tabs								
		Weld tab			Test plate		Weld tab	

5.3 Preparation of welding consumables

5.3.1 General

The rod and wire diameters of welding consumables shall have dimensions within tolerances specified in 4.1 of **JIS Z 3200**.

5.3.2 Covered electrode

The covered electrode (hereafter referred to as electrode) shall be prepared as follows.

- a) The diameter of electrode shall be 4.0 mm.
- b) ~~The electrode shall be dried under the conditions recommended by the manufacturer.~~

~~When the electrode does not need to be re-dried after the seal is broken, the conditions shall be subjected to the agreement between the interested parties.~~

- c) During any drying treatment, the electrodes shall not touch each other or the side of the oven.
- d) The electrode to be tested shall be placed in the oven so as to be identified.
- e) ~~The electrode shall be used as soon as removed from the oven.~~
- f) The electrode with cracked or broken coatings shall not be used.
- g) Different electrodes shall be used for each test plate.

5.3.3 Submerged arc welding consumables

The submerged arc welding consumables shall be prepared as follows.

- a) The diameter of welding wire shall be 4.0 mm.
- b) The flux shall be dried under the conditions recommended by the manufacturer.

~~When the flux does not need to be re-dried after the seal is broken, the conditions shall be subjected to the agreement between the interested parties.~~

- c) ~~Flux thickness during drying treatment shall be 15 mm or less.~~
- d) ~~The flux removed from the oven shall be used immediately.~~ Used flux shall not be recycled.

5.3.4 Gas-shielded arc welding consumables

The tubular cored electrode, solid wire and shielding gas used for gas-shielded arc welding shall be prepared as follows.

- a) The diameter of welding wire shall be 1.2 mm.
- b) The type of shielding gas to be used shall be as specified in **JIS Z 3253**.

5.3.5 Self-shielded arc welding consumables

The tubular cored electrode used for self-shielded arc welding shall be prepared as follows.

- a) ~~The diameter of tubular cored electrode shall be 2.4 mm or 3.2 mm.~~

5.4 Production of test piece for measuring hydrogen

5.4.1 Welding conditions

5.4.1.1 Shielded metal arc welding

The welding conditions of shielded metal arc welding shall be as follows.

- a) The welding current shall be either alternating current or direct current. For direct current, the polarity recommended by the welding consumables manufacturer shall be used.
- b) The welding conditions shall be as given in Table 2. The welding speed shall be adjusted so that the bead length is about 10 mm per 12 mm to 13 mm of an electrode.
- c) When the weld bead does not fit on Test plate No. 1, the test plate may be oriented so that it is 30 mm wide and 15 mm long.

5.4.1.2 Submerged arc welding

The welding conditions of submerged arc welding shall be as follows.

- a) The welding current shall be either alternating current or direct current. For direct current, the polarity recommended by the welding consumables manufacturer shall be used.
- b) The welding conditions shall be as given in Table 2.
- c) The height for spreading flux shall be 30 mm and shall be adjusted using an appropriate jig.

5.4.1.3 Gas-shielded arc welding

The welding conditions of gas-shielded arc welding using a tubular cored electrode and solid wire shall be as follows.

- a) The welding current shall be either alternating current or direct current. For direct current, the polarity recommended by the welding consumables manufacturer shall be used.
- b) The welding conditions shall be as given in Table 2.
- c) The flow rate of shielding gas shall be 25 L/min.
- d) When Test plate No. 1 is used, the welding speed shall be doubled.

5.4.1.4 Self-shielded arc welding

The welding conditions of self-shielded arc welding shall be as follows.

- a) The welding current shall be either alternating current or direct current. For direct current, the polarity recommended by the welding consumables manufacturer shall be used.
- b) The welding conditions shall be as given in Table 2.

Table 2 Welding conditions

Welding process (welding consumables)	Diameter of welding consumables mm	Welding current A	Arc voltage V	Welding speed mm/min	Distance between base metal and chip mm
Shielded metal arc welding	4.0	$[\alpha^a - 15]$ or $0.9\alpha^a$	—	—	—
Submerged arc welding	4.0	500 ± 50	32 ± 2	500 ± 20	30 ± 1
Gas-shielded arc welding (tubular cored electrode)	1.2	270 ± 15	—	350 ± 20	25 ± 1
Gas-shielded arc welding (solid wire)	1.2	290 ± 15	—	350 ± 20	20 ± 1
Self-shielded arc welding (tubular cored electrode)	2.4	300 ± 15	—	350 ± 20	40 ± 1
	3.2	380 ± 15	—	350 ± 20	40 ± 1
NOTE This table shows welding conditions under which the deposition rate specified in the corresponding International Standard is obtained.					
Note ^{a)} α is the maximum value within the current range recommended by the manufacturer.					

5.4.2 Production procedure of test piece for measuring hydrogen

The procedure for production of test piece for measuring hydrogen shall be as follows.

- a) Bead on plate welding is performed on the weld tab, test plate and weld tab arranged in this order in the longitudinal direction. Figure 2 a) shows an example of a test plate and weld tabs fixed with a copper fixture using e.g. a toggle clamp.

Copper foil may be inserted between the copper fixture and the test plate and weld tabs.

NOTE Example of copper foil dimensions : 1 mm × 15 mm minimum × 300 mm

- b) The surface temperature of the copper fixture shall be between ambient and 25 °C above ambient at the start of each test weld to prevent condensation of water on the surface of the fixture. For purposes of classifying welding consumables, during welding of the test piece, the ambient absolute humidity shall be at least 3 g of water vapour per 1 000 g of dry air. [This corresponds to 4.7 hPa of partial water vapour pressure, 20 °C and 20 % (mass fraction) relative humidity.]
- c) The welding shall be performed under the welding conditions specified in 5.4.1. The bead length on the run-off plate shall not exceed 25 mm as shown in Figure 2 b).
- d) In the first test of gas-shielded arc welding, air, moisture, etc. in a welding torch