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Zirconium alloy tubes

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Foreword

This translation has been made based on the original Japanese Industrial Standard 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 Japan Society of Newer Metals (JSNM)/ Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14. Consequently **JIS H 4751:1998** is replaced with this Standard.

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Zirconium alloy tubes

1 Scope

This Japanese Industrial Standard specifies seamless zirconium alloy tubes (hereafter referred to as “tubes”) used for nuclear fuel cladding.

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 H 0321 *General rules for inspection of non-ferrous metal materials*

JIS H 1653 *Methods for determination of nitrogen in zirconium and zirconium alloys*

JIS H 1664 *Methods for determination of hydrogen in zirconium and zirconium alloys*

JIS H 1665 *Methods for determination of oxygen in zirconium and zirconium alloys*

JIS Z 2241 *Metallic materials—Tensile testing—Method of test at room temperature*

3 Classification and symbols

The tubes shall be classified by the chemical compositions, and their classification and symbols shall be as given in Table 1.

Table 1 Classification and symbols

Classification	Symbols
Sn-Fe-Cr-Ni zirconium alloy tube	ZrTN 802 D
Sn-Fe-Cr zirconium alloy tube	ZrTN 804 D

4 Quality

4.1 Appearance

Tubes shall be examined as given in 7.1, and be well-finished and free from detrimental defects such as stains, cracks, flaws and others.

4.2 Chemical composition

Tubes shall be examined as given in 7.2, and the chemical compositions shall be as given in Table 2. The permissible values of impurities shall be as given in Table 3. The permissible variation given in Table 2 and Table 3 refers to a deviation from the specified or permissible values, in the analyses of tubes, by the purchaser with an aim to confirm the chemical composition.

Table 2 Chemical composition

Unit: %

Division	Elements	Specified value		Permissible variation
		ZrTN 802 D	ZrTN 804 D	
Chemical composition	Sn	1.20 to 1.70	1.20 to 1.70	0.050
	Fe	0.07 to 0.20	0.18 to 0.24	0.020
	Cr	0.05 to 0.15	0.07 to 0.13	0.010
	Ni ^{a)}	0.03 to 0.08	—	0.010
	Fe+Cr+Ni	0.18 to 0.38	—	0.020
	Fe+Cr	—	0.28 to 0.37	0.020
	O ^{b)}	—	—	0.020
	Zr	Remainder	Remainder	—
Notes ^{a)} For tubes of grade ZrTN 802 D, Ni is treated as a chemical component. For tubes of grade ZrTN 804 D, it is treated as an impurity.				
^{b)} Oxygen content is as agreed between the purchaser and the manufacturer.				

Table 3 Permissible values of impurities

Unit: %

Division	Elements	Permissible value		Permissible variation
		ZrTN 802 D	ZrTN 804 D	
Impurities	Al	0.007 5 max.	0.007 5 max.	0.002 0 or 20 % of the permissible value, whichever is smaller.
	B	0.000 05 max.	0.000 05 max.	
	Cd	0.000 05 max.	0.000 05 max.	
	Ca	0.003 0 max.	0.003 0 max.	
	C	0.027 max.	0.027 max.	
	Co	0.002 0 max.	0.002 0 max.	
	Cu	0.005 0 max.	0.005 0 max.	
	Hf	0.010 max.	0.010 max.	
	H	0.002 5 max.	0.002 5 max.	
	Mg	0.002 0 max.	0.002 0 max.	
	Mn	0.005 0 max.	0.005 0 max.	
	Mo	0.005 0 max.	0.005 0 max.	
	Ni ^{a)}	—	0.007 0 max.	
	Nb	0.010 0 max.	0.010 0 max.	
	N	0.008 0 max.	0.008 0 max.	
	Si	0.012 0 max.	0.012 0 max.	
	W	0.010 max.	0.010 max.	
	Ti	0.005 0 max.	0.005 0 max.	
	U	0.000 35 max.	0.000 35 max.	
Note ^{a)} For tubes of grade ZrTN 802 D, Ni is treated as a chemical component. For tubes of grade ZrTN 804 D, it is treated as an impurity.				

4.3 Mechanical properties

Tubes shall be subjected to the tensile test as given in 7.3, and the mechanical properties (tensile strength, proof stress and elongation) shall be as given in Table 4.

Table 4 Mechanical properties

Symbols	Temper ^{a)}	Tensile test		
		Tensile strength N/mm ²	Resistance N/mm ²	Elongation %
ZrTN 802 D	O	413 min.	241 min.	20 min.
	SR	As agreed between the purchaser and the manufacturer.		
ZrTN 804 D	O	413 min.	241 min.	20 min.
	SR	As agreed between the purchaser and the manufacturer.		

NOTE : 1 N/mm² = 1 MPa

Note ^{a)} O and SR represent recrystallization-annealed materials and stress relief-annealed materials, respectively.

4.4 Grain size

Tubes of temper O shall be subjected to the grain size test as given in 7.4, and the grain size shall be no bigger than that of No. 7 specified in Annex A.

4.5 Corrosion resistance

Tubes shall be subjected to the corrosion test as given in 7.5, and the increase in the mass of corrosion shall be not more than 38 mg/dm² in a duration of 336⁺⁸₀ h. When the increase in the mass of corrosion is not more than 22 mg/dm² in a duration of 72⁺⁸₀ h, the test shall be terminated. After the corrosion test, the surface of the test piece shall be free from noticeable adherence of white or brown oxides.

4.6 Hydride orientation

Tubes shall be subjected to the hydride orientation test as given in 7.6. Hydride orientation factor (see Annex C), F_n , shall not exceed 0.45.

4.7 External and internal defects

Tubes shall be subjected to the ultrasonic test as given in 7.7. There shall be no signal equivalent to or greater than the signal from the artificial defects of the reference sample.

5 Dimensions and dimensional tolerances

Tubes shall be tested as given in 7.8, and the dimensional tolerances shall be as agreed between the purchaser and the manufacturer.

6 Production process

Tubes shall be produced by heat treatment and straightening after cold drawing of a seamless crude tube, which has been made from an ingot melted in a vacuum consumable-electrode arc furnace.

7 Tests

7.1 Appearance test

Tubes shall be subjected to the appearance test over the entire length. The frequency of test shall be as agreed between the purchaser and the manufacturer.

7.2 Chemical analysis

The chemical analysis shall be as follows.

- a) **Test piece** The test piece shall be as follows.
- 1) For analyses of oxygen, hydrogen and nitrogen, take two sample tubes arbitrarily from a group of tubes produced from a same ingot by using the same processing conditions and the same final heat treatment batch. From each tube, take one test piece.
 - 2) For analyses of other elements than oxygen, hydrogen and nitrogen, take test pieces, each from the top, middle and bottom of the same ingot or from the corresponding positions of an intermediate product.
 - 3) The number of test pieces for 1) and 2) may be as agreed between the purchaser and the manufacturer.
- b) **Analytical methods** The analytical methods of chemical composition and impurities of tubes shall be as given in Table 5.

The analytical method not specified in individual **JIS** as given in Table 5, if used, shall be as agreed between the purchaser and the manufacturer.

Table 5 Analytical methods of chemical composition and impurities

Division	Elements	Analytical methods
Chemical composition	Sn	As agreed between the purchaser and the manufacturer.
	Fe	As agreed between the purchaser and the manufacturer.
	Cr	As agreed between the purchaser and the manufacturer.
	Ni ^{a)}	As agreed between the purchaser and the manufacturer.
	Fe+Cr+Ni	—
	Fe+Cr	—
	O	JIS H 1665
Impurities	Al	As agreed between the purchaser and the manufacturer.
	B	As agreed between the purchaser and the manufacturer.
	Cd	As agreed between the purchaser and the manufacturer.
	Ca	As agreed between the purchaser and the manufacturer.
	C	As agreed between the purchaser and the manufacturer.
	Co	As agreed between the purchaser and the manufacturer.
	Cu	As agreed between the purchaser and the manufacturer.
	Hf	As agreed between the purchaser and the manufacturer.
	H	JIS H 1664
	Mg	As agreed between the purchaser and the manufacturer.
	Mn	As agreed between the purchaser and the manufacturer.
	Mo	As agreed between the purchaser and the manufacturer.
	Ni ^{b)}	As agreed between the purchaser and the manufacturer.
	Nb	As agreed between the purchaser and the manufacturer.
	N	JIS H 1653
	Si	As agreed between the purchaser and the manufacturer.
	W	As agreed between the purchaser and the manufacturer.
	Ti	As agreed between the purchaser and the manufacturer.
	U	As agreed between the purchaser and the manufacturer.
Notes ^{a)} For tubes of grade ZrTN 802 D, Ni is treated as a chemical component.		
^{b)} For tubes of grade ZrTN 804 D, Ni is treated as an impurity.		

7.3 Tensile test

The tensile test shall be as follows.

- a) **Test piece** Take two sample tubes arbitrarily from a group of tubes produced from a same ingot by using the same processing conditions and the same final heat treatment batch. From each tube, take one test piece.

The number of test pieces may be changed upon agreement between the purchaser and the manufacturer.

- b) **Test method** The test method shall be as follows.

- 1) The tensile test shall be as specified in **JIS Z 2241**. Test piece No. 11 specified in **JIS Z 2241** shall be used for the test.