

MASTER

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ZIRCALOY-4 TUBING FOR FUEL SHEATHING

RESEARCH METALLURGY

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ZIRCALOY-4 TUBING FOR FUEL SHEATHING

1. SCOPE

This specification covers Zircaloy-4 tubing, both seamless and welded, for reactor fuel rod sheathing where high integrity, and satisfactory corrosion resistance at elevated temperatures are required.

2. DEFINITION OF TERMS

2.1 Lot

In this specification, a lot shall consist of all material of the same size, shape, condition, and finish on an order produced from the same ingot and annealed in the same vacuum annealing charge. The lot size shall not exceed 1000 pounds or 1000 feet, whichever is less.

3. BASIS OF PURCHASE

Orders for tube under this specification shall define information with respect to the following:

- 3.1 Condition (temper)
- 3.2 Dimensions and permissible variations
- 3.3 Seamless or Welded Tubing
- 3.4 Special Tests
- 3.5 Special Requirements

4. MATERIALS AND MANUFACTURE

- 4.1 The ingot from which the tubing is produced shall be made by double vacuum arc melting.

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- 4.2 In the case of seamless tubing the hollow billet for extrusion shall be produced by the boring or drilling of a solid billet, unless prior agreement has been reached with the Purchaser to use hot piercing. The extruded shell shall be conditioned by the removal of a uniform layer of metal from the ID and OD surfaces. The depth of layer removed shall be sufficient to eliminate all visible defects.
- 4.3 Welded tube shall be made from flat rolled products by an automatic or semi-automatic welding process with no addition of filler metal. The welded tube will be normally reduced by conventional cold-reducing methods to the desired dimensions, and the degree of cold reduction shall be such as to produce a recrystallized structure throughout the wall of the tube, including the weld zone.
- 4.4 All annealing subsequent to the initial hot working operation shall be performed at an equilibrium absolute pressure not to exceed one micron of mercury unless prior agreement has been reached with the Purchaser to use air annealing.

5. CHEMICAL COMPOSITION

The composition of the tubing shall conform to the requirements set out in 5.1 and 5.2.

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5.1 Alloying Elements

Tin	1.20 - 1.70 weight per cent
Iron	0.12 - 0.18 weight per cent
Chromium	0.05 - 0.15 weight per cent
Oxygen	1000 - 1400 ppm
Zirconium	Balance (including impurities)

5.2 Impurities

Aluminum	75 ppm maximum
Boron	0.5 ppm maximum
Cadmium	0.5 ppm maximum
Carbon	500 ppm maximum
Chlorine	15 ppm maximum
Cobalt	20 ppm maximum
Copper	50 ppm maximum
Hafnium	200 ppm maximum
Hydrogen	30 ppm maximum
Lead	130 ppm maximum
Magnesium	20 ppm maximum
Manganese	50 ppm maximum
Molybdenum	50 ppm maximum
Nickel	40 ppm maximum
Nitrogen	100 ppm maximum
Silicon	120 ppm maximum
Titanium	50 ppm maximum

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5.2 Impurities (Cont'd)

Tungsten	100	ppm maximum
Uranium	3.5	ppm maximum
Vanadium	50	ppm maximum

Any other impurities measured shall be reported.

5.3 Chemical Analysis

5.3.1 Whilst ingot analysis may be accepted as defining the chemical composition of the tubing as specified in 5.1 and 5.2 with the exceptions set out in 5.3.2, the Purchaser reserves the right to reject tubing in the event of a check analyses showing departure from this specification.

5.3.2 Check analyses on the tubing for Copper, Hydrogen, Nitrogen, and Nickel shall be made on at least one sample from each tubing lot. The content of these elements shall not exceed the values specified in 5.1 and 5.2.

6. MECHANICAL PROPERTIES

6.1 Unless otherwise specified on the purchase order the tubing shall conform to the following requirements as to room temperature tensile properties in the longitudinal direction.

Ultimate Tensile strength	75,000 psi minimum
Yield strength	65,000 psi minimum
Elongation in 2 inches	10% minimum

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6.2 One sample for tensile test shall be taken from each lot of finished tube. The tensile, yield and elongation properties shall be determined on a full cross-section of the tube where possible. The test shall be performed in accordance with ASTM E8-54T.

7. SURFACE

The tubes shall be supplied with the inside and outside surfaces in the bright pickled and rinsed condition such that there is no surface contamination which is detrimental to their corrosion properties. The surface finish of tubing supplied shall be 63 RMS or less.

8. HYDROSTATIC TEST

Prior to all other tests each length of tubing shall be hydrostatically tested at room temperature for 30 seconds at a pressure which will induce a fibre stress equal to 3/4 of the minimum specified yield strength. Evidence of cracking, leaking, or permanent set shall cause rejection of the tubing being tested. The fibre stress shall be calculated from the following formula:

$$P = \frac{2St}{D}$$

where S = allowable fibre stress psi

P = hydrostatic test pressure psi

t = minimum allowable wall thickness, inches

D = inside diameter, inches

9. BURST TEST

One sample for burst test at room temperature shall be taken from each lot of finished tube. Bursting pressure and rate of

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9. BURST TEST (Cont'd)

pressurizing together with the test samples shall be forwarded for information purposes and will not be cause for rejection. Any abnormal result shall be reported immediately to the Purchaser.

10. CORROSION TEST

At least one sample, having a length not less than 1 1/2 inches, from each lot of tubing shall be etched to remove 0.001 inch of surface and tested in 750°F steam for 3 days at a minimum pressure of 100 psi. After test both outside and inside surfaces of specimen shall show a uniform black, lustrous oxide finish and have a weight gain of no more than 22 milligrams per square decimeter of surface.

If the corrosion tested samples fails to meet the above requirements, two additional specimens may be selected from other tubes in the lot and tested for 14 days in 1500 psi steam at 750°F. After test both inside and outside of specimens shall show a uniform black, lustrous oxide finish and have a weight gain of no more than 38 milligrams per square decimeter of surface. If either of these specimens fails to meet the above requirements the lot shall be rejected.

11. NON-DESTRUCTIVE TESTING

Each length of finished tubing shall be tested for both longitudinal and transverse defects by one or more of the following methods; ultrasonic, eddy-current, fluorescent penetrant. The method, procedure and standard for rejection shall be agreed between the Purchaser and the Contractor.

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12. METALLOGRAPHIC EXAMINATION

Two transverse and two longitudinal samples from each lot of tubing are to be microscopically examined after suitable chemical or electrolytic polishing. These samples are to be examined for stringers, surface cracks, and grain size. Any abnormal result, such as cracks exceeding 0.001 inch in depth, should be immediately reported to the Purchaser. The average grain size shall not exceed 35 microns and no grain shall be larger than 50 microns.

13. IDENTIFICATION

Ingot number and lot number shall be maintained through all stages of fabrication and delivery.

14. INSPECTION

14.1 Unless otherwise agreed between Purchaser and Contractor the tests called for in this specification shall be made at the Contractor's works and at his expense.

14.2 The Contractor shall afford the inspector representing the Purchaser all reasonable facilities to satisfy him that the tubes are being furnished in accordance with this specification.

15. SHIPPING

15.1 The Contractor shall make adequate provisions to protect the material supplied to this specification to ensure that on arrival at the destination specified in the pertinent tendering or purchasing documents and after storage as stated therein it will not have suffered corrosion or damage of any sort.

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15. SHIPPING (Cont'd)

The material shall be wrapped or packaged sufficiently to prevent damage by weather, dirt or other foreign matter.

It is desired that the packaging and shipping practices adhere as closely as possible to the Contractor's standard, but they shall nevertheless comply with the requirements stated herein.

- 15.2 Each package or container shall be marked with the purchase order number, lot number, quantity, size and name of the manufacturer.

16. CERTIFICATION

The Contractor shall perform all tests and certify that the tubing supplied meets all the requirements of this specification and relevant purchase order. This certification shall include test results, analyses, fabrication history including source of ingot. All reports shall be signed by a responsible technical representative of the Contractor.

END