PRELIMINARY SPECIFICATIONS

Thermocouples, Tungsten/Tungsten-26% Rhenium, for Use in Nuclear Reactors

This is a preliminary draft of specifications (subject to modification) covering the requirements of the Westinghouse Astronuclear Laboratory (hereinafter designated as WANL) for metal-sheathed tungsten/tungsten-26% rhenium thermocouples for use in a nuclear radiation environment.

1. Physical Construction

- 1.1 The thermocouple shall be of the two-wire, ceramic-insulated, metal-sheathed type, with physical dimensions and tolerances as shown in Figure 1. The appropriate lengths L_1 and L_2 are to be specified for each application.

2. Materials

REFERENCE

2.1 Thermocouple Wire

- 2.1.1 The thermocouple wires shall be of tungsten and tungsten-26% rhenium, with a temperature-EMF curve conforming to the attached Table I within $\pm 1\%$.
- 2.1.2 The thermocouple wire shall be continuous for the entire length of the thermocouple.
- 2.1.3 No welds are to be performed upon the thermocouple wire.
- 2.1.4 The fabrication of the thermocouple shall be performed in such a manner that no cold-working of the thermocouple wires occurs.

2.2 Sheath Materials

- 2.2.1 The 347 stainless steel sheath shall conform to Specification MIL-T-18063, Class 1, Type A, except that the requirements for macroscopic examination, ultrasonic test, and hydrostatic test do not apply.
- 2.2.2 The molybdenum tubing shall not contain impurities in excess of 0.1%.
- 2.2.3 The stainless steel tubing shall not contain defects greater than $3/32"$ in the axial direction or greater than $.0015"$ in the radial direction.

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- 2.2.4 The molybdenum tubing shall not contain defects greater than 1/32" in the axial direction or greater than .0005" in the radial direction.

2.3 Insulation

- 2.3.1 The magnesium oxide insulation shall meet or exceed the requirements of Oakridge National Laboratory Specification ORPM 7-1.
- 2.3.2 The beryllium oxide shall be at least 99.8% pure, and shall not contain more than 30 PPM of boron average analysis.
- 2.3.3 The magnesium oxide shall be capable of being crushed to a firmly compacted form that can withstand belt abrading without crumbling.

2.4 Sheath Transition

- 2.4.1 Transition from molybdenum sheath to stainless steel sheath shall be accomplished by interference fit and a flux free braze. The maximum temperature of the W wires during this operation shall not exceed 1850°F and the remelt temperature of the braze shall be not less than 2000°F.

2.5 Thermocouple Junction

- 2.5.1 The thermocouple junction shall be formed mechanically, as shown in Figure 1.

3. Thermocouple Assembly

3.1 Thermocouple Wire Continuity

- 3.1.1 The electrical resistance of the thermocouple before and after reduction of the stainless steel and before and after junctioning shall coincide within $\pm 2\%$.
- 3.1.2 There shall be electrical continuity of the thermocouple wires and of each thermocouple wire-sheath combination when the thermocouple is in the following conditions:
 - a.) At room temperature.
 - b.) After immersion of a length of the thermocouple including the measuring junction and the brazed transition in liquid hydrogen or liquid helium for at least 5 minutes.

3.2 Insulation Resistance

- 3.2.1 The resistances between the two wires and between each wire and the sheath shall be greater than 10 megohms (for lengths of 10 to 25 feet) when tested at ambient temperature with an impressed voltage of at least 500 volts DC.
- 3.2.2 The resistances between each wire and the sheath shall not differ by more than 10%.

3.3 Sheath Integrity

- 3.3.1 There shall be no evidence of leaks through the thermocouple sheath when the following samples are subjected to an internal helium pressure test:
 - a.) The full length thermocouple in its final condition, after subjection to the temperature extremes specified under testing procedures.
 - b.) A 16 inch length, taken from the end opposite the measuring junction of the thermocouple in its final condition and coiled with a resulting inside radius between 0.50 and 0.75 inches. One end of this length shall have a welded closure.

3.4 Metallurgical Structure

- 3.4.1 The stainless steel sheath material in a section of the thermocouple bent 90° to a radius between 0.50 and 0.75 inches shall not contain evidence, when examined at 250X, of any cracks, harmful inclusions, porosity, or grain boundary attack.
- 3.4.2 The average grain size of the stainless steel sheath material shall be no larger than Size 5. (See "Classification of Austenitic Grain Sizes in Steel", contained in Supplement A of Federal Test Method Standard No. 151 - "Metal Test Methods".)

3.5 Integrity of Measuring Junction and Transition Joint

- 3.5.1 A length of the thermocouple extending a minimum of 4 inches from the welded closure and a length extending 2 inches on each side of the transition joint when tested by radiography shall not show indications of the following:
 - a.) Cracks.

- b.) Any notches, crevices, voids, inclusions or local reductions in dimensions in the thermocouple wires or sheath.
- c.) Any notches, crevices, or local reductions in dimensions in the welded end closure.
- d.) Voids or inclusions greater than .005 inch in largest dimensions in the welded or brazed areas.

3.6 Surface Condition

- 3.6.1 The surface finish of the final thermocouple shall not be greater than 32 microinches average. In addition, the oxide coating shall be such that the surface does not appear darker than a light straw color.
- 3.6.2 There shall be no cracks or defects with sharp contour (such as gauges), and no defects with smooth contours (such as dents, die or tool marks) greater than 0.001 inch in depth on the surface of the finished thermocouple, as evidenced by examination at 5X.
- 3.6.3 There shall be no cracks, holes, seams or other defects as evidenced by a fluorescent test on the surface of the following samples:
 - a.) The full length thermocouple in its final condition.
 - b.) A 16 inch length, taken from the end opposite the measuring junction of the thermocouple in its final condition and coiled with a resulting inside radius between 0.50 and 0.75 inches.

3.7 Cleanliness

- 3.7.1 The surface of the finished thermocouple shall be free of residues containing nuclear poisons (such as boron compounds), residues that could become the source of corrosion or chemistry changes in the primary coolant (such as chlorine compounds, strong acids or bases), and foreign material (such as dust and lubricants).

3.8 Identification

- 3.8.1 Each thermocouple shall be individually identified by two corrosion resistant steel tags approximately 3/8 by 3/4 inch affixed to the thermocouple with corrosion resistant steel wire. Plastic electrical tape shall be used to restrict movement of the tags and to prevent damage to adjacent thermocouples during shipment. The tags shall be located approximately 6 inches from each end

The tags shall bear the thermocouple identification number on one face and the buyer's purchase number on the other face. The manufacturer's identification system shall be so constituted that the raw material (sheath, insulation and thermocouple wires) and test records can be identified with any particular thermocouple.

4. Calibration

4.1 No calibrations are to be performed upon the thermocouples.

5. Quality Assurance Provisions

5.1 The supplier is responsible for the performance of all inspection requirements prior to submission for WANL inspection and acceptance. The supplier may use his own facilities or any commercial laboratory acceptable to WANL. Inspection records of the examinations and tests shall be kept complete and available to WANL.

5.2 Sampling - A sample 2" long from the end of the thermocouple opposite the measuring junction shall be used to determine compliance with 3.4. This sample shall have received processing identical to the remainder of the stainless steel sheath.

A sample 16" long from the end opposite the measuring junction of each thermocouple shall be used to determine compliance with 3.3.1 (b) and 3.6.3 (b).

5.3 Test Procedures

5.3.1 Sheath Materials - To determine conformance with 2.2.3, all sheath material shall be inspected by eddy current techniques with equipment capable of resolving the largest acceptable defects specified for that material.

5.3.2 Insulation Composition - To determine conformance with 2.3.1 and 2.3.2, chemical analyses shall be performed on representative samples of the insulation materials used. The method, sampling plan, and laboratory for making these analyses shall be approved by WANL.

5.3.3 Insulation Crushability - To determine conformance with 2.3.3, the open end of one thermocouple section representative of the type and size ordered shall be belt abraded, tapped on a hard surface and visually examined for loss of insulation material.

5.3.4 It is requested that the manufacturer supply a description of the technique by which 2.4 may be accomplished. The final specification by WANL will specify the best technique for the purpose.

5.3.5 Thermocouple Wire Resistance and Continuity

- 1.) To determine conformance with 2.1.4 and 3.1, the resistance of the thermocouple wires (joined mechanically) shall be measured (a) before reduction of the stainless steel sheath material, (b) after reduction of the sheath material and compaction of the MgO around the wires, (c) after formation of the measuring junction. All of these measurements are to be made at room temperature. In addition, (c) is to be repeated after immersion of a length of the thermocouple including the measuring junction and the brazed transition in liquid helium or liquid hydrogen for five minutes or more. After formation of the measuring junction, the resistance between each wire and the sheath shall be measured at ambient and at cryogenic temperatures (with the cryogenic measurement as specified above).
- 2.) The accuracy of the resistance measurements shall be $\pm 2\%$. If the resistance measurements at ambient temperature (corrected to the same temperature, if necessary) do not agree within $\pm 2\%$, the thermocouple shall be rejected. If the measurements on the wires and wire-sheath combinations at ambient and cryogenic temperatures do not agree within $\pm 10\%$, the thermocouple shall be rejected.

5.3.6 Insulation Resistance - To determine conformance with 3.2, the resistance between the two wires and between each wire and the sheath shall be measured on the thermocouple prior to forming the end closure or measuring junction. The resistances between the two wires and between each wire and the sheath shall also be measured on the 16-inch sample in its coiled condition. A minimum impressed voltage of 500 v.d.c. shall be used. To assure that this resistance is maintained in the final thermocouple, silicone varnish shall be used to seal open ends of thermocouples until the thermocouple is sealed for shipment.

5.3.7 Sheath Integrity - To determine conformance with 3.3, the open end of the full length thermocouple and the open end of the coiled sample shall be subjected to 100 ± 20 pounds per square inch (p.s.i.) of helium. The time at pressure shall be sufficient to

assure that for the full length thermocouple, an internal pressure of 100 ± 20 p.s.i. is obtained at the sealed end; and for the coiled sample, that helium has traversed the sample length. Time at pressure shall be redetermined for any change in process variable affecting packing density of the insulation. The procedure and sensitivity of the helium test shall be in accordance with Standard MIL-STD-271. The sensitivity shall be determined at the start and finish of each test. If the sensitivity at the finish of the test is lower than the allowable minimum, all tests shall be repeated.

- 5.3.8 Calibration - No calibrations are to be performed upon the thermocouples. Calibration certificates from the wire supplier shall be furnished to show conformance with 2.1.1.
- 5.3.9 Metallurgical Structure - To determine conformance with 3.4, the 2 inch samples taken in accordance with 5.2 shall be bent 90 degrees to a radius equal to the sheath outside diameter and sectioned longitudinally through the bent section. A portion, including at least 1/2 inch on either side of the bend shall be polished, etched and examined at a magnification of 250X.
- 5.3.10 Measuring Junction Integrity - To determine conformance with 3.5, a length of the thermocouple extending a minimum of 4 inches from the welded closure and a length extending 2" on each side of the transition joint shall be radiographed in two directions 90 degrees apart and perpendicular to the thermocouple axis. The radiography shall be performed in accordance with Standard MIL-STD-271 at a sensitivity level of 2-1T, using a 0.002 inch thick penetrometer.
- 5.3.11 Dimensions - To determine conformance with 1.1 the 16 inch sample taken in accordance with shall be examined at one end and the sheath dimensions measured. The other end shall have the sheath and insulation removed for a length of about 1/2 inch and the diameter of the conducting wires shall be measured. (See also 3.2.2. This is to insure proper centering of the wires in the sheath.)
- 5.3.12 Surface Finish - To determine conformance with 3.6.1, visual comparison with commercially available surface finish standards shall be made.
- 5.3.13 Surface Defects - To determine conformance with 3.6.2, a visual examination shall be made at 5X. To determine conformance with

3.6.3, a dye penetrant test shall be performed in accordance with Standard MIL-STD-271. Type IV fluorescent penetrant shall be used.

5.3.14 Cleanliness - The requirements of Specification MIL-C-19874 shall be met during the fabrication and packaging of the thermocouples.

6. Certification and Test Reports

6.1 The manufacturer shall provide WANL with written certification at the time of delivery that the thermocouples have been inspected in accordance with the methods outlined herein and are in conformance with all the requirements of this specification. In addition, the following certified test and inspection reports shall be submitted to WANL:

- a.) Resistances measured as specified in 5.3.5 and 5.3.6.
- b.) Calibration data from the wire supplier.
- c.) Certification from the molybdenum supplier showing compliance with 2.2.2.
- d.) Radiographs of the measuring junctions, both views.

7. Preparation for Delivery

- 7.1 Sealing - The open end of each thermocouple shall be sealed by welding to prevent moisture from entering.
- 7.2 Coiling - All thermocouples shall be shipped in straight lengths. No coiling of the thermocouples is permitted.
- 7.3 Packing - Thermocouples shall be packed in boxes as specified for wire products in straight cut lengths.
- 7.4 Marking - Marking instructions will be outlined in the final version of this document.

8. Ordering Data - Procurement documents should specify the following:

- a.) Title, number, and date of this specification.
- b.) Number of thermocouples and lengths of molybdenum section and stainless steel section for each thermocouple.

TABLE I

WANL-TME-098

Temperature-Millivolt Equivalents for Tungsten/Tungsten-26% Rhenium Thermocouples—°F

(Reference Junction at 32°F)

Degrees F	0°	100°	200°	300°	400°	500°	600°	700°	800°	900°	1000°	Degrees F
0°	—	.103	.320	.673	1.064	1.573	2.212	2.927	3.716	4.565	5.470	0°
20°	—	.136	.384	.750	1.148	1.692	2.350	3.079	3.881	4.741	5.660	20°
40°	.012	.173	.452	.828	1.246	1.816	2.492	3.235	4.049	4.919	5.851	40°
60°	.042	.215	.522	.906	1.349	1.944	2.635	3.393	4.219	5.100	6.043	60°
80°	.072	.264	.597	.985	1.458	2.076	2.779	3.553	4.391	5.283	6.236	80°
100°	.103	.320	.673	1.064	1.573	2.212	2.927	3.716	4.565	5.470	6.430	100°
Degrees F	1100°	1200°	1300°	1400°	1500°	1600°	1700°	1800°	1900°	2000°		Degrees F
0°	6.430	7.436	8.481	9.576	10.702	11.837	12.984	14.149	15.339	16.549		0°
20°	6.626	7.641	8.696	9.800	10.928	12.065	13.215	14.385	15.580	16.791		20°
40°	6.826	7.848	8.913	10.025	11.155	12.294	13.447	14.622	15.822	17.033		40°
60°	7.028	8.057	9.132	10.250	11.382	12.523	13.680	14.860	16.064	17.274		60°
80°	7.232	8.268	9.353	10.476	11.609	12.753	13.914	15.099	16.307	17.515		80°
100°	7.436	8.481	9.576	10.702	11.837	12.984	14.149	15.339	16.549	17.755		100°
Degrees F	2100°	2200°	2300°	2400°	2500°	2600°	2700°	2800°	2900°	3000°		Degrees F
0°	17.755	18.940	20.113	21.280	22.424	23.529	24.587	25.616	26.636	27.646		0°
20°	17.994	19.175	20.347	21.512	22.649	23.744	24.794	25.821	26.839	27.847		20°
40°	18.232	19.410	20.581	21.742	22.872	23.957	25.000	26.026	27.041	28.048		40°
60°	18.469	19.645	20.814	21.970	23.093	24.169	25.206	26.230	27.243	28.249		60°
80°	18.705	19.879	21.047	22.198	23.312	24.379	25.411	26.433	27.445	28.449		80°
100°	18.940	20.113	21.280	22.424	23.529	24.587	25.616	26.636	27.646	28.649		100°
Degrees F	3100°	3200°	3300°	3400°	3500°	3600°	3700°	3800°	3900°	4000°	4100°	Degrees F
0°	28.649	29.640	30.627	31.606	32.575	33.531	34.477	35.412	36.338	37.209	37.926	0°
20°	28.848	29.838	30.824	31.801	32.767	33.721	34.665	35.598	36.520	37.369	38.040	20°
40°	29.047	30.036	31.020	31.995	32.959	33.911	34.852	35.784	36.699	37.523	38.151	40°
60°	29.245	30.233	31.216	32.189	33.150	34.100	35.039	35.969	36.874	37.669	38.260	60°
80°	29.443	30.430	31.411	32.382	33.341	34.289	35.226	36.154	37.044	37.804	38.368	80°
100°	29.640	30.627	31.606	32.575	33.531	34.477	35.412	36.338	37.209	37.926	38.474	100°

Temperature-Millivolt Equivalents for Tungsten/Tungsten-26% Rhenium Thermocouples—°C

(Reference Junction at 0°C)

Degrees C	0°	100°	200°	300°	400°	500°	600°	700°	800°	900°	1000°	1100°	Degrees C
0°	—	0.356	1.033	2.030	3.330	4.848	6.548	8.395	10.386	12.431	14.527	16.695	0°
10°	0.027	0.417	1.105	2.148	3.472	5.009	6.726	8.588	10.589	12.638	14.741	16.912	10°
20°	0.054	0.480	1.182	2.267	3.617	5.172	6.906	8.782	10.792	12.845	14.956	17.129	20°
30°	0.081	0.544	1.274	2.392	3.765	5.337	7.088	8.978	10.996	13.053	15.171	17.346	30°
40°	0.109	0.611	1.369	2.520	3.914	5.506	7.272	9.176	11.200	13.261	15.387	17.563	40°
50°	0.140	0.680	1.469	2.649	4.066	5.678	7.456	9.375	11.404	13.470	15.604	17.779	50°
60°	0.173	0.750	1.573	2.779	4.219	5.851	7.641	9.576	11.609	13.680	15.822	17.994	60°
70°	0.211	0.820	1.680	2.912	4.374	6.024	7.827	9.778	11.814	13.891	16.040	18.208	70°
80°	0.254	0.891	1.790	3.048	4.531	6.198	8.015	9.980	12.019	14.102	16.259	18.422	80°
90°	0.302	0.962	1.904	3.188	4.689	6.372	8.204	10.183	12.225	14.314	16.477	18.635	90°
100°	0.356	1.033	2.030	3.330	4.848	6.548	8.395	10.386	12.431	14.527	16.695	18.847	100°
Degrees C	1200°	1300°	1400°	1500°	1600°	1700°	1800°	1900°	2000°	2100°	2200°	2300°	Degrees C
0°	18.847	20.954	23.005	24.918	26.758	28.569	30.352	31.112	33.835	35.524	37.145	38.325	0°
10°	19.058	21.164	23.203	25.104	26.940	28.749	30.529	32.286	34.006	35.691	37.291	38.422	10°
20°	19.269	21.373	23.399	25.289	27.122	28.928	30.706	32.459	34.176	35.858	37.432	38.516	20°
30°	19.480	21.581	23.593	25.474	27.304	29.106	30.883	32.632	34.345	36.025	37.567		30°
40°	19.691	21.787	23.786	25.658	27.485	29.284	31.059	32.805	34.514	36.191	37.696		40°
50°	19.902	21.993	23.978	25.842	27.666	29.462	31.235	32.978	34.683	36.356	37.816		50°
60°	20.113	22.198	24.169	26.026	27.847	29.640	31.411	33.150	34.852	36.520	37.926		60°
70°	20.324	22.402	24.358	26.210	28.028	29.818	31.587	33.322	35.021	36.681	38.029		70°
80°	20.534	22.604	24.546	26.393	28.209	29.996	31.762	33.493	35.189	36.840	38.129		80°
90°	20.744	22.805	24.732	26.576	28.389	30.174	31.937	33.664	35.357	36.995	38.227		90°
100°	20.954	23.005	24.918	26.758	28.569	30.352	31.112	33.835	35.524	37.145	38.325		100°