Use of W-Re alloys for Manufacturing of High Temperature Thermocouples W-Re5% / W-Re20%

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Development and application of thermoelectric converters on the base of W-Re alloys

Time	Development and application	Firms	Remarks
1956-1957	Development of manufacturing technology for W-Re wires	Moscow electro bulbs plant (MELZ)	Ø 0.1-0.5 mm
1958-1959	Investigation of thermoelectric properties of W-Re alloys and their content optimization for the thermocouple W-Re 5/20	Central Laboratory Of Automation (CLA)	
1960-1970	Production of test consignments of W-Re thermocouples for temperature control in industry and science	CLA , LUCH, «TEMOPRIBOR»	
1965-1975	Data accumulation on reproducibility of characteristics of W-Re 5/20 thermocouple	MELZ, CLA , LUCH,	
1974	Approval of specifications for W-Re alloys TU SU0.021.142	MELZ	
1976	Development of Standard Specimens of Thermoelectric Materials (SOTM-1 and 2)	Ural's Institute of Metrology	Up to 2500°C
1977	Reference table including to GOST 3044-77	«TEMOPRIBOR»	A -1, 2, 3

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1978-1988	Production of serial TCs for metallurgy	Electrothermometry ,	
1977-1980	TCs for nuclear propulsion engines (zonal, console, antenna types)	SIA "LUCH"	
1994-2001	Correction of reference tables according to ITS-90 in GOST 6616-94 and GOSTR 8.585-2001	VNIIM, St-Petersburg	
2002	Restore of MELZ's manufacturing technology	«Rheniy», Ltd.	
2002-2005	Small-scale production of W-Re thermometers with gas-filled protective sheaths	SIA LUCH, OTC, Ltd.	
2008-2010	Researches to approve W-Re 5/20 reference table for the new draft of IEC 60584-1 и 2.	Russian and foreign labs	TEMPME KO- 2010
2010-2011	Investigation of experimental batch of wires hardened by nano-particles of Yttrium oxide	VNII NM, SIA LUCH	d ~ 50 nm

Reference instrument for W/Re 5/20 thermocouples and existing standards

- SOTM – standard Specimen Of Thermoelectric Material, i.e. standard thermoelements of W-Re5% and W-Re20% wires, calibrated in the freezing points of pure metals.
- The interstate standard GOST 6616-94. Thermoelectric converters. General specifications. Minsk, 2000.
- Russian State Standard GOSTR 8.585-2001. Thermocouples. Reference tables. 2002, Gosstandard of Russia, Moscow.

Calibration curves

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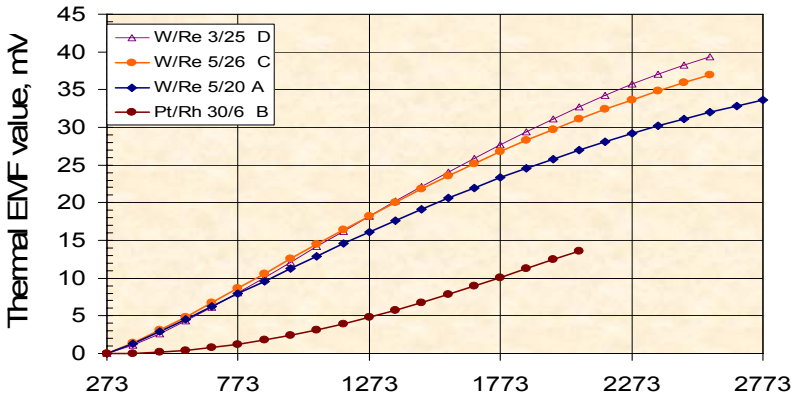

Temperature, K

admissible EMF deviation limits for :
W/Re 5/20 ±0,7%; W/Re 5/26 (3/25) ±1%

Sensitivity of W/Re thermocouples

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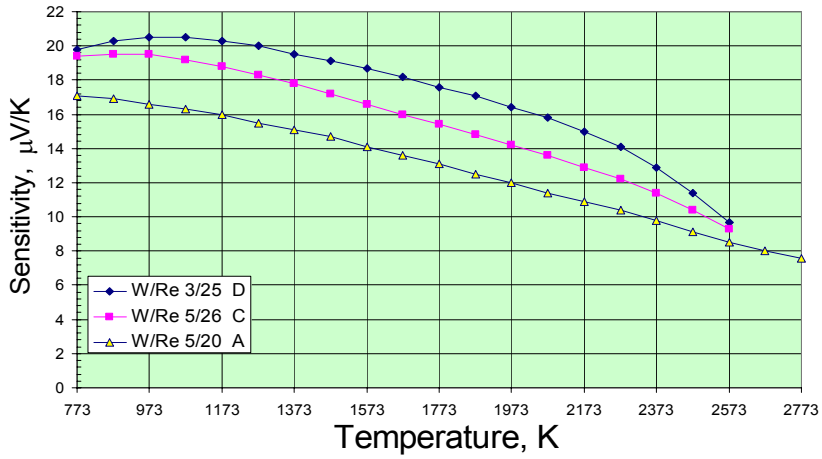

Note: Sensitivity of W/Re 5/20 thermocouple decreases evenly by 1 µV/K per each 200K in the range (1173 - 2373) K

W/Re 5/20 thermocouple datasheet

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1. Measuring range (0 – 2773) K.

2. EMF tolerances in the range (1273-2773) K according to Standard GOSTR 8.585-2001:
   ±0,5% for the 2-nd class and
   ±0,7% for the 3-rd class thermocouples.

3. Inhomogeneity of WRe alloys may result in ±100 μV EMF difference (~7.7 K) within one pair of W/Re5/20 coils of wires at the temperature 1773 K.

4. EMF drift while annealing for 2 h at 1773 K should be within the limits:

   ±50 μV for the 2-nd class and
   ±70 μV for the 3-rd class thermocouples

Specimen sealed in a sapphire tube

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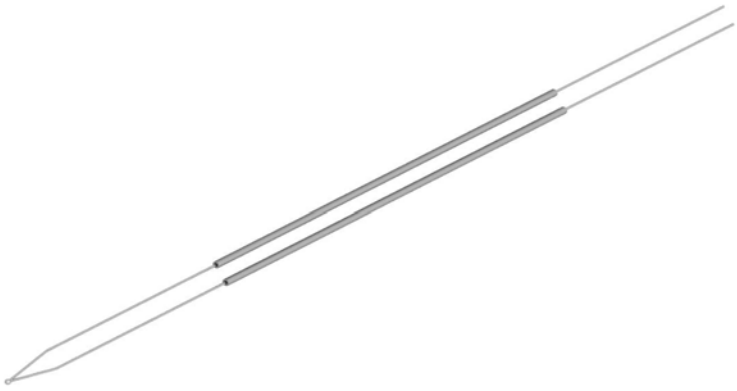
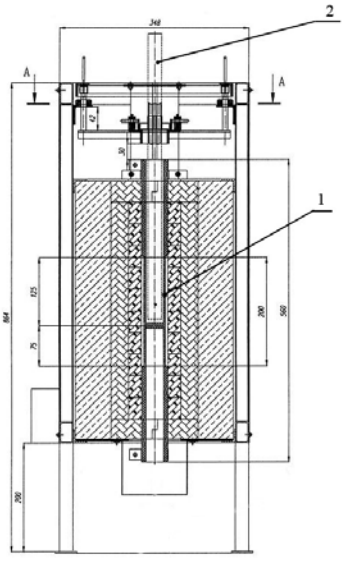
Specimen for calibration in vacuum or hydrogen



OTC's calibration procedure

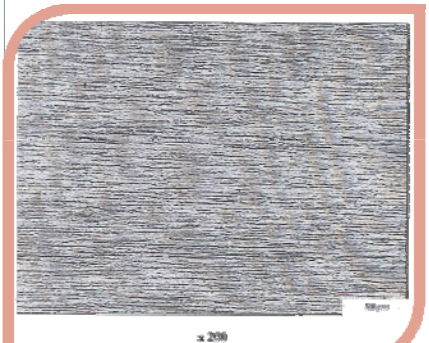


- Calibration in air against standard type B thermocouple in the range (873 – 1923) K.
- Tubular vertical furnace with annular LaCrO3 heater.
- Alumina one-end closed tube was inserted into the heater forming working zone for calibration.

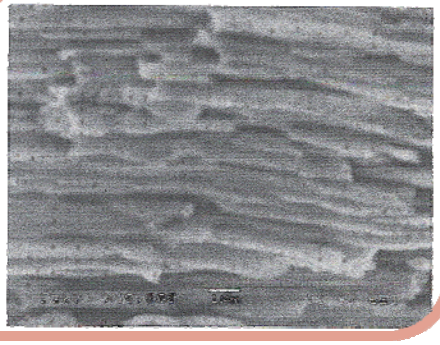
ROSTEST calibration procedure

- Thermoelement wires W5%Re and W20%Re were calibrated against corresponding SOTM wires (wire-by-wire) in vacuum;
- Calibration range (873-2273) K;

Microstructure of W-Re5% thermoelement with 0,1% Y_2O_3

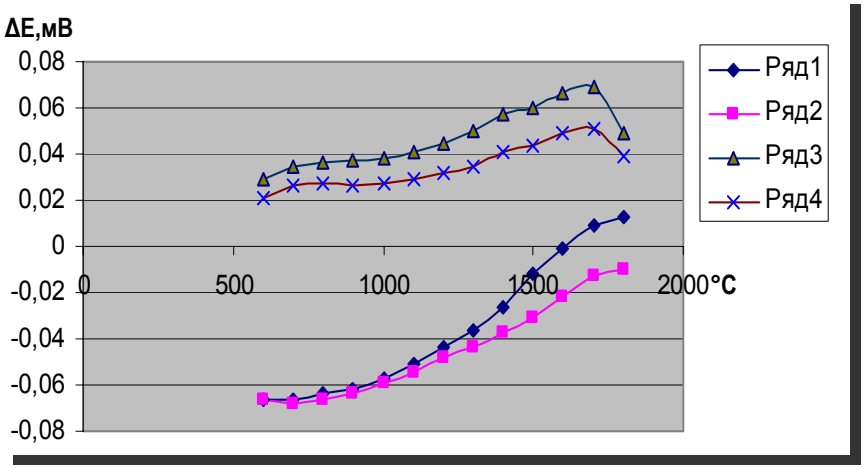


Microstructure of experimental W-Re5% wire containing 0,1% of nano-particles of Yttrium oxide.



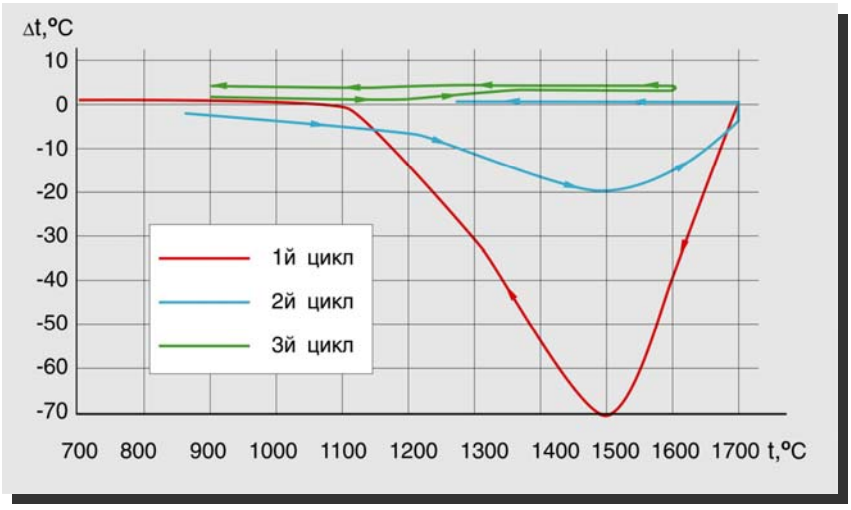
Fracture surface of W-Re5 % wire containing 0,1% of nano-particles of Yttrium oxide.

Thermal EMF changing of nano-strengthened W-Re5 wire against SOTM-1 wire under heating from initial state (as delivered)

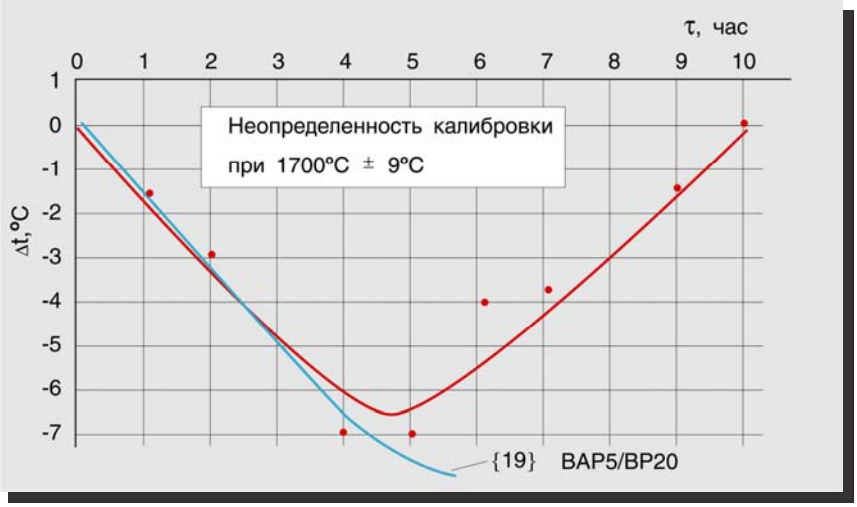


Raw 1 – heating of initial wire, Raw 2 - cooling,
Raw 3 – the wire heating after 0.5 h annealing at 1650°C, Raw 4 –cooling

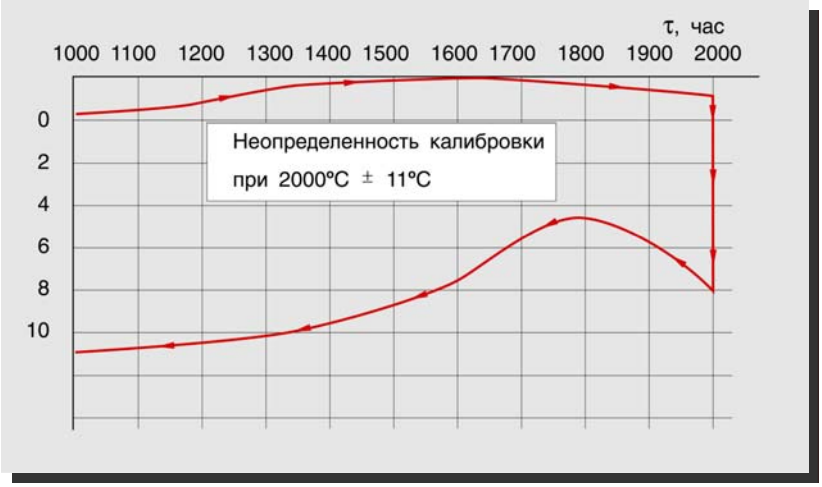
Thermal EMF changing for paired wires W-Re5% (+0,1% Y_2O_3) against W-Re20% (coil 311, A1 calibration) during three consequent cycles "heating-cooling"



Thermal EMF changing for paired wires W-Re5% (+0,1% Y_2O_3) against W-Re20% (coil 311, A1 calibration) compare to initial value in the first cycle at 1700 °C (uncertainty ±9 degrees)



Thermal EMF deviation for W-Re5%(+0,1%Y_2O_3) and SOTM2 wires from the reference table for type A1 thermocouple during "heating-cooling" cycle with 1h annealing at 2000 °C

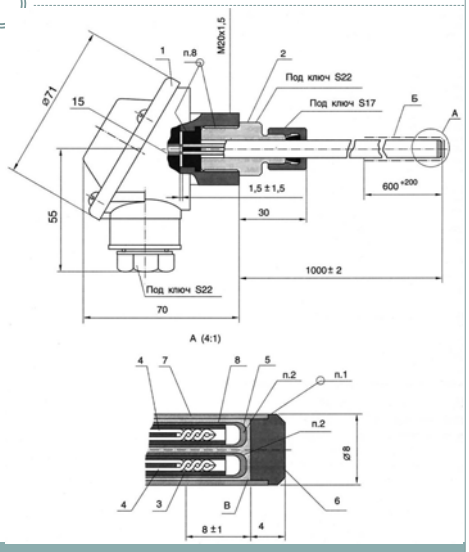


Conclusion

Preliminary results of the research of physical, mechanical and thermoelectric properties of the W-Re5% wire, which was disperse strengthened by nano-particles of Yttrium oxide of ~50 nm medium size, gives the hope to improve metrological characteristics as SOTM-1 wires and thermoelectric thermometers of W-Re 5/20 type.

W/Re 5/20 thermometer designs

High temperature thermometer with W/Re thermocouples protected by sealed Mo-tubes



W/Re 5/20 thermometer designs

Gas-tight WRe 5/20 thermometers with sapphire protective tube

W/Re 5/20 thermometer designs

Thermal probe with W/Re 5/20 thermocouple for short-time temperature measurements in molten metals

Thank you very much for your attention