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Standard Temperature-Electromotive Force (EMF) Tables for Tungsten-Rhenium Thermocouples[1]

This standard is issued under the fixed designation E 988; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard consists of reference tables that give temperature-electromotive force (emf) relationships for 97 % Tungsten 3 % Rhenium versus 75 % Tungsten 25 % Rhenium and 95 % Tungsten 5 % Rhenium versus 74 % Tungsten 26 % Rhenium thermocouples. These are the refractory metal thermocouple types most commonly used in industry.

1.2 Also included is a list (Table 1) of initial calibration tolerances for the thermocouple types referred to in 1.1, and their respective compensating extension wires (Table 2).

1.3 These data are intended for industrial and laboratory use.

2. Referenced Documents

2.1 *ASTM Standards:*

E 380 Practice for Use of the International System of Units (SI) (the Modernized Metric System)[2]

3. Source of Data

3.1 The data in these tables are based upon the SI volt (see Practice E 380) and the International Temperature Scale of 1990.

3.2 All temperature-electromotive force data in Tables 3-6 have been developed from wire manufacturers' data.

3.3 These tables give emf values to three decimal places (1 μV) for each degree of temperature. Such tables are satisfactory for most industrial uses but may not be adequate for computer and similar applications. If greater precision is required, the reader should refer to the equations in Table 7 which permit further generation of the temperature-emf relationships. In addition, Tables 8 and 9 present polynomial approximations giving temperature as a function of the thermocouple EMF.

4. Identification of Thermocouple Types

4.1 Letter symbols have not been assigned. Identification is made by composition.

4.2 *W3Re/W25Re*—97 % Tungsten 3 % Rhenium (+) versus 75 % Tungsten 25 % Rhenium (−).

4.3 *W5Re/W26Re*—95 % Tungsten 5 % Rhenium (+) versus 74 % Tungsten 26 % Rhenium (−).

5. Initial Calibration Tolerances

5.1 Thermocouples and matched thermocouple wire are supplied to the initial calibration tolerances listed in Table 1.

6. List of Tables

6.1 Following is a list of tables included in this standard:

Table Number	Title
1	Initial Calibration Tolerances and Suggested Temperature Ranges for Thermocouples
2	Initial Calibration Tolerances and Suggested Temperature Ranges for Thermocouple Compensating Extension Wires
3	Temperature versus EMF for W3Re/W25Re from 0 to 2315°C
4	Temperature versus EMF for W3Re/W25Re from 32 to 4200°F
5	Temperature versus EMF for W5Re/W26Re from 0 to 2315°C
6	Temperature versus EMF for W5Re/W26Re from 32 to 4200°F
7	Equations Used to Derive Tables 3-6
8	Polynomial Coefficients for the Computation of Temperatures in °C as a Function of the Thermocouple EMF
9	Polynomial Coefficients for the Computation of Temperatures in °F as a Function of the Thermocouple EMF

7. Keywords

7.1 emf; rhenium; thermocouple; tungsten

[1] These tables are under the jurisdiction of ASTM Committee E20 on Temperature Measurement and are the direct responsibility of Subcommittee E20.04 on Thermocouples.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

TABLE 1 Initial Calibration Tolerances and Suggested Temperature Ranges for Thermocouples[A]

NOTE 1—Initial calibration tolerances in this table apply to new thermocouple wire, normally in the size range 0.125 to 0.5 mm in diameter (No. 36 to 24 Awg) and used at temperatures not exceeding the suggested upper temperatures of Table 1. If used at higher temperatures these initial calibration tolerances may not apply.

NOTE 2—Initial calibration tolerances apply to new wire as delivered to the user and do not allow for calibration drift during use. The magnitude of such changes depends on such factors as wire size, temperature, time of exposure, and environment.

NOTE 3—Where initial calibration tolerances are given in percent, the percentage applies to the temperature being measured when expressed in degrees Fahrenheit. To determine the tolerance in degrees Celsius multiply the tolerance in degrees Fahrenheit by 5/9.

NOTE 4—Tables 1 and 2 also describe suggested upper temperature limits for the thermocouples and extension wires. These limits apply to protected thermocouples, that is, thermocouples in inert or non-oxidizing atmospheres.

Thermocouple Type	Temperature Range	Initial Calibration Tolerances
W3%Re/W25%Re and W5%Re/W26%Re	0 to 426°C 32 to 800°F 426 to 2315°C 800 to 4200°F}	±4.4°C ±8°F ±1 % of actual temperature

[A] CAUTION—Users should be aware that certain characteristics of thermocouple materials including calibration may change in time with use; consequently, test results obtained at time of manufacture may not necessarily apply throughout an extended period of use.

TABLE 2 Initial Calibration Tolerances and Suggested Temperature Ranges for Thermocouple Compensating Extension Wires

Designation	Temperature Range	Initial Calibration Tolerances
For W3%Re/W25%Re 300P(+) 97.7Ni BAL Cr,Al,Si[A] 300N(−) 96Ni, 4W[A]	0 *to* 330°*C* 32 *to* 625°*F*}	±0.125 mV
203(+) 90Ni, 10Cr[B] 225(−) 98Ni, 2Cr[B]	0 *to* 260°*C* 32 *to* 500°*F*}	±0.110 mV
For W5%Re/W26%Re 405(+) 94.5Ni[B] 2 Mn 1 Si 1.5 AL 426(−) 80 Ni, 20 Cu[B]	0 *to* 871°*C* 32 *to* 1600°*F*}	±0.110 mV

[A] U.S. Patent 3,502,510 assigned to Engelhard Industries.
[B] Designation of Hoskins Mfg.

TABLE 3 Tungsten-3 % Rhenium versus Tungsten-25 % Rhenium Thermocouples—Thermoelectric Voltage as a Function of Temperature (°C)

EMF in Millivolts												Reference Junctions at 0°C
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
Thermoelectric Voltage in Millivolts												
0	0.000	0.010	0.019	0.029	0.039	0.048	0.058	0.068	0.078	0.088	0.098	**0**
10	0.098	0.108	0.118	0.128	0.138	0.148	0.159	0.169	0.179	0.189	0.200	**10**
20	0.200	0.210	0.221	0.231	0.242	0.252	0.263	0.273	0.284	0.295	0.305	**20**
30	0.305	0.316	0.327	0.338	0.349	0.360	0.371	0.382	0.393	0.404	0.415	**30**
40	0.415	0.426	0.437	0.448	0.460	0.471	0.482	0.494	0.505	0.517	0.528	**40**
50	0.528	0.540	0.551	0.563	0.574	0.586	0.598	0.609	0.621	0.633	0.645	**50**
60	0.645	0.657	0.668	0.680	0.692	0.704	0.716	0.728	0.741	0.753	0.765	**60**
70	0.765	0.777	0.789	0.802	0.814	0.826	0.839	0.851	0.863	0.876	0.888	**70**
80	0.888	0.901	0.914	0.926	0.939	0.951	0.964	0.977	0.990	1.002	1.015	**80**
90	1.015	1.028	1.041	1.054	1.067	1.080	1.093	1.106	1.119	1.132	1.145	**90**
100	1.145	1.158	1.172	1.185	1.198	1.212	1.225	1.238	1.252	1.265	1.278	**100**
110	1.278	1.292	1.305	1.319	1.333	1.346	1.360	1.374	1.387	1.401	1.415	**110**
120	1.415	1.428	1.442	1.456	1.470	1.484	1.498	1.512	1.526	1.540	1.554	**120**
130	1.554	1.568	1.582	1.596	1.610	1.624	1.639	1.653	1.667	1.681	1.696	**130**
140	1.696	1.710	1.725	1.739	1.753	1.768	1.782	1.797	1.811	1.826	1.841	**140**
150	1.841	1.855	1.870	1.884	1.899	1.914	1.929	1.943	1.958	1.973	1.988	**150**
160	1.988	2.003	2.018	2.033	2.048	2.063	2.078	2.093	2.108	2.123	2.138	**160**
170	2.138	2.153	2.168	2.183	2.199	2.214	2.229	2.244	2.260	2.275	2.290	**170**
180	2.290	2.306	2.321	2.337	2.352	2.368	2.383	2.399	2.414	2.430	2.445	**180**
190	2.445	2.461	2.477	2.492	2.508	2.524	2.539	2.555	2.571	2.587	2.603	**190**
200	2.603	2.618	2.634	2.650	2.666	2.682	2.698	2.714	2.730	2.746	2.762	**200**
210	2.762	2.778	2.794	2.810	2.826	2.843	2.859	2.875	2.891	2.907	2.924	**210**
220	2.924	2.940	2.956	2.973	2.989	3.005	3.022	3.038	3.055	3.071	3.088	**220**
230	3.088	3.104	3.121	3.137	3.154	3.170	3.187	3.203	3.220	3.237	3.253	**230**
240	3.253	3.270	3.287	3.303	3.320	3.337	3.354	3.371	3.387	3.404	3.421	**240**
250	3.421	3.438	3.455	3.472	3.489	3.506	3.523	3.540	3.557	3.574	3.591	**250**
260	3.591	3.608	3.625	3.642	3.659	3.676	3.693	3.711	3.728	3.745	3.762	**260**
270	3.762	3.780	3.797	3.814	3.831	3.849	3.866	3.883	3.901	3.918	3.936	**270**
280	3.936	3.953	3.970	3.988	4.005	4.023	4.040	4.058	4.075	4.093	4.111	**280**
290	4.111	4.128	4.146	4.163	4.181	4.199	4.216	4.234	4.252	4.269	4.287	**290**
300	4.287	4.305	4.323	4.340	4.358	4.376	4.394	4.412	4.430	4.447	4.465	**300**
310	4.465	4.483	4.501	4.519	4.537	4.555	4.573	4.591	4.609	4.627	4.645	**310**
320	4.645	4.663	4.681	4.699	4.717	4.735	4.753	4.772	4.790	4.808	4.826	**320**
330	4.826	4.844	4.862	4.881	4.899	4.917	4.935	4.954	4.972	4.990	5.009	**330**
340	5.009	5.027	5.045	5.064	5.082	5.100	5.119	5.137	5.156	5.174	5.192	**340**
350	5.192	5.211	5.229	5.248	5.266	5.285	5.303	5.322	5.340	5.359	5.378	**350**
360	5.378	5.396	5.415	5.433	5.452	5.471	5.489	5.508	5.527	5.545	5.564	**360**
370	5.564	5.583	5.601	5.620	5.639	5.658	5.676	5.695	5.714	5.733	5.752	**370**
380	5.752	5.770	5.789	5.808	5.827	5.846	5.865	5.884	5.902	5.921	5.940	**380**
390	5.940	5.959	5.978	5.997	6.016	6.035	6.054	6.073	6.092	6.111	6.130	**390**
400	6.130	6.149	6.168	6.187	6.206	6.225	6.245	6.264	6.283	6.302	6.321	**400**
410	6.321	6.340	6.359	6.378	6.398	6.417	6.436	6.455	6.474	6.494	6.513	**410**
420	6.513	6.532	6.551	6.571	6.590	6.609	6.628	6.648	6.667	6.686	6.706	**420**
430	6.706	6.725	6.744	6.764	6.783	6.802	6.822	6.841	6.861	6.880	6.899	**430**
440	6.899	6.919	6.938	6.958	6.977	6.997	7.016	7.035	7.055	7.074	7.094	**440**
450	7.094	7.113	7.133	7.152	7.172	7.191	7.211	7.231	7.250	7.270	7.289	**450**
460	7.289	7.309	7.328	7.348	7.368	7.387	7.407	7.427	7.446	7.466	7.485	**460**
470	7.485	7.505	7.525	7.544	7.564	7.584	7.604	7.623	7.643	7.663	7.682	**470**
480	7.682	7.702	7.722	7.742	7.761	7.781	7.801	7.821	7.840	7.860	7.880	**480**
490	7.880	7.900	7.920	7.939	7.959	7.979	7.999	8.019	8.038	8.058	8.078	**490**
500	8.078	8.098	8.118	8.138	8.158	8.178	8.197	8.217	8.237	8.257	8.277	**500**