Designation: E1751/E1751M – 20

Standard Guide for Temperature Electromotive Force (emf) Tables for Non-Letter Designated Thermocouple Combinations[1]

This standard is issued under the fixed designation E1751/E1751M; 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 guide consists of reference tables that give temperature-electromotive force (emf) relationships for special purpose limited-use, thermocouple combinations that do not have a letter designation.

1.2 Extension wire or compensating extension wires are not covered by this guide. ASTM MNL12[2] or thermocouple alloy suppliers should be consulted.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E344 Terminology Relating to Thermometry and Hydrometry

E696 Specification for Tungsten-Rhenium Alloy Thermocouple Wire

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this guide see Terminology E344.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *matched pairs, n*—a set of positive and negative thermoelements chosen so that a thermocouple fabricated from these thermoelements will match a specified temperature-electromotive force relationship to within a specified tolerance, at the time of initial use.

4. Source of Data

4.1 The data in these tables are based on the SI Volt and the International Temperature Scale of 1990.

4.2 All temperature-electromotive force data in Tables 1-20 have been developed from National Institute of Standards and Technology (NIST), Nuclear Regulatory Committee (NRC), and wire manufacturers' data.

4.3 Tables 1-16 give emf values in millivolts to three decimal places (1 μV) at 1 °C or 1 °F intervals. Tables 17-20 give emf values in microvolts to one decimal place (0.1 μV) at 1 °C or 1 °F intervals. If greater precision is required, refer to the equation and coefficients listed for each thermocouple alloy.

5. Significance and Use

5.1 The thermocouple combinations have been developed for specific applications by the wire manufacturer(s). If additional information is required, consult ASTM MNL12 or the wire manufacturer(s).

6. Thermocouple Types

6.1 Letter symbols have not been assigned. Identification is made by alloy composition with the thermoelectrically positive material listed first.

6.1.1 Tungsten versus tungsten-26 % rhenium.

6.1.2 Tungsten-3 % rhenium versus tungsten-25 % rhenium.

NOTE 1—Tungsten-3 % rhenium versus tungsten-25% rhenium is commonly referred to as type "D" amongst suppliers, although not officially designated.

[1] This guide is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.11 on Thermocouples - Calibration.

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[2] *Manual on the Use of Thermocouples in Temperature Measurement, ASTM MNL12,* ASTM International, 1993.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

6.1.3 Palladium-55 % platinum 31 % gold 14 % versus gold 65 % palladium 35 %.[4]

6.1.4 KP versus gold-0.07 % iron.

NOTE 2—Alloy compositions are expressed in percentages by mass, except for the gold-0.07 % iron alloy, which is given in atomic percent.

6.1.5 Platinum-5 % molybdenum versus platinum-0.1 % molybdenum.

6.1.6 Platinum-40 % rhodium versus platinum-20 % rhodium.

6.1.7 Nickel-18 % molybdenum versus nickel-0.8 % cobalt.

NOTE 3—Nickel-18 % molybdenum versus nickel 0.8 % cobalt is supplied by Carpenter Technology as 20 alloy and 19 alloy.

NOTE 4—Nickel-18 % molybdenum versus nickel 0.8 % cobalt is commonly referred to as type "M" amongst suppliers although not officially designated.

6.1.8 Iridium-40 % rhodium versus iridium.

6.1.9 Gold versus platinum.

6.1.10 Platinum versus palladium.

7. Tolerances on Initial Values of emf versus Temperature

7.1 Tolerances on initial values of emf versus temperature have not been established for the thermocouples in this guide except for the tungsten-3 % rhenium versus tungsten-25 % rhenium, and that data can be found in Specification E696. When required, tolerances on initial values of emf versus temperature should be established by agreement between the purchaser and the producer. Thermocouple combinations are typically supplied as matched pairs.

8. Table Information

8.1 The following is a list of emf versus temperature tables included in this guide.

Table No.	Thermocouple Type	Temperature Range
Table 1	Tungsten versus Tungsten-26 % Rhenium	0 to 2315 °C
Table 2	Tungsten versus Tungsten-26 % Rhenium	32 to 4200 °F
Table 3	Tungsten-3 % Rhenium versus Tungsten-25 % Rhenium	0 to 2315 °C
Table 4	Tungsten-3 % Rhenium versus Tungsten-25 % Rhenium	32 to 4200 °F
Table 5	Palladium-55 % Platinum 31% Gold 14% versus Gold 65% Palladium 35%	0 to 1395 °C
Table 6	Palladium-55 % Platinum 31% Gold 14% versus Gold 65% Palladium 35%	32 to 2543 °F
Table 7	KP versus Gold-0.07 % Iron	–273 to 7 °C
Table 8	KP versus Gold-0.07 % Iron	–459 to 44 °F
Table 9	Platinum-5 % Molybdenum versus Platinum-0.1 % Molybdenum	0 to 1600 °C
Table 10	Platinum-5 % Molybdenum versus Platinum-0.1 % Molybdenum	32 to 2912 °F
Table 11	Platinum-40 % Rhodium versus Platinum-20 % Rhodium	0 to 1888 °C
Table 12	Platinum-40 % Rhodium versus Platinum-20 % Rhodium	3 to 3430 °F
Table 13	Nickel-18 % Molybdenum versus Nickel-0.8 % Cobalt	–50 to 1410 °C
Table 14	Nickel-18 % Molybdenum versus Nickel-0.8 % Cobalt	–58 to 2570 °F
Table 15	Iridium 40 % Rhodium versus Iridium	0 to 2110 °C
Table 16	Iridium 40 % Rhodium versus Iridium	32 to 3830 °F
Table 17	Gold versus Platinum	0 to 1000 °C
Table 18	Gold versus Platinum	32 to 1832 °F
Table 19	Platinum versus Palladium	0 to 1500 °C
Table 20	Platinum versus Palladium	32 to 2732 °F
Table 21	Polynomial Coefficients for the Computation of Temperatures in °C or °F as Function of Thermocouple emf	

8.2 Tables 1-20 were derived from equations of the form:

$$E = c_0 + c_1 T + c_2 T^2 + \ldots c_n T^n \quad (1)$$

where:

E = the emf in millivolts (except for Tables 17-20 where E is in microvolts), and

T = the temperature in °C or °F. The coefficients used to calculate each table are given at the end of the table.

8.3 Table 21 gives coefficients of inverse equations that may be used to compute approximate values of temperature (T) in either °C or °F for each thermocouple combination. The inverse equations are of the form:

$$T = b_0 + b_1 E + b_2 E^2 + \ldots b_n E^n \quad (2)$$

Except for the gold-versus-platinum thermocouple in the ranges 209 to 1000 °C (408.2 to 1832 °F), where the inverse equation is of the form:

$$T = b_0 + \sum_{i=1}^{11} b_i \left(\frac{E - 9645}{7620} \right)^I \quad (3)$$

For these equations, the thermocouple emf (E) is in units of millivolts, except for gold-versus-platinum and platinum-versus-palladium, for which the emf is in units of microvolts.

8.3.1 Table 21 also gives the temperature range, emf range, and error range of each inverse equation.

9. Keywords

9.1 cobalt; coefficients; gold; iridium; iron; molybdenum; nickel; palladium; platinel; platinum; polynomial; rhenium; rhodium; thermocouple; tungsten

[4] Known as Platinel II, Trademark of Engelhard Corp., Specialty Metals Division.

TABLE 1

Tungsten versus Tungsten-26 % Rhenium Thermocouples
Thermoelectric Voltage as a Function of Temperature (°C), Reference Junctions at 0 °C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
	Thermoelectric Voltage in Millivolts											
0	0.000	0.001	0.003	0.004	0.005	0.007	0.008	0.010	0.012	0.013	0.015	**0**
10	0.015	0.017	0.018	0.020	0.022	0.024	0.026	0.028	0.030	0.032	0.034	**10**
20	0.034	0.036	0.038	0.041	0.043	0.045	0.048	0.050	0.053	0.055	0.058	**20**
30	0.058	0.060	0.063	0.065	0.068	0.071	0.074	0.076	0.079	0.082	0.085	**30**
40	0.085	0.088	0.091	0.094	0.097	0.100	0.104	0.107	0.110	0.113	0.117	**40**
50	0.117	0.120	0.123	0.127	0.130	0.134	0.138	0.141	0.145	0.148	0.152	**50**
60	0.152	0.156	0.160	0.164	0.168	0.172	0.175	0.179	0.184	0.188	0.192	**60**
70	0.192	0.196	0.200	0.204	0.209	0.213	0.217	0.222	0.226	0.231	0.235	**70**
80	0.235	0.240	0.244	0.249	0.254	0.258	0.263	0.268	0.273	0.277	0.282	**80**
90	0.282	0.287	0.292	0.297	0.302	0.307	0.312	0.318	0.323	0.328	0.333	**90**
100	0.333	0.339	0.344	0.349	0.355	0.360	0.366	0.371	0.377	0.382	0.388	**100**
110	0.388	0.394	0.399	0.405	0.411	0.417	0.422	0.428	0.434	0.440	0.446	**110**
120	0.446	0.452	0.458	0.464	0.471	0.477	0.483	0.489	0.495	0.502	0.508	**120**
130	0.508	0.514	0.521	0.527	0.534	0.540	0.547	0.553	0.560	0.567	0.573	**130**
140	0.573	0.580	0.587	0.594	0.601	0.607	0.614	0.621	0.628	0.635	0.642	**140**
150	0.642	0.649	0.656	0.664	0.671	0.678	0.685	0.693	0.700	0.707	0.715	**150**
160	0.715	0.722	0.729	0.737	0.744	0.752	0.760	0.767	0.775	0.782	0.790	**160**
170	0.790	0.798	0.806	0.813	0.821	0.829	0.837	0.845	0.853	0.861	0.869	**170**
180	0.869	0.877	0.885	0.893	0.902	0.910	0.918	0.926	0.935	0.943	0.951	**180**
190	0.951	0.960	0.968	0.976	0.985	0.993	1.002	1.011	1.019	1.028	1.037	**190**
200	1.037	1.045	1.054	1.063	1.072	1.080	1.089	1.098	1.107	1.116	1.125	**200**
210	1.125	1.134	1.143	1.152	1.161	1.170	1.180	1.189	1.198	1.207	1.217	**210**
220	1.217	1.226	1.235	1.245	1.254	1.264	1.273	1.283	1.292	1.302	1.311	**220**
230	1.311	1.321	1.331	1.340	1.350	1.360	1.369	1.379	1.389	1.399	1.409	**230**
240	1.409	1.419	1.429	1.439	1.449	1.459	1.469	1.479	1.489	1.499	1.509	**240**
250	1.509	1.520	1.530	1.540	1.550	1.561	1.571	1.582	1.592	1.602	1.613	**250**
260	1.613	1.623	1.634	1.644	1.655	1.666	1.676	1.687	1.698	1.708	1.719	**260**
270	1.719	1.730	1.741	1.752	1.762	1.773	1.784	1.795	1.806	1.817	1.828	**270**
280	1.828	1.839	1.850	1.862	1.873	1.884	1.895	1.906	1.918	1.929	1.940	**280**
290	1.940	1.951	1.963	1.974	1.986	1.997	2.009	2.020	2.032	2.043	2.055	**290**
300	2.055	2.066	2.078	2.090	2.101	2.113	2.125	2.136	2.148	2.160	2.172	**300**
310	2.172	2.184	2.196	2.208	2.219	2.231	2.243	2.255	2.267	2.280	2.292	**310**
320	2.292	2.304	2.316	2.328	2.340	2.353	2.365	2.377	2.389	2.402	2.414	**320**
330	2.414	2.426	2.439	2.451	2.464	2.476	2.489	2.501	2.514	2.526	2.539	**330**
340	2.539	2.552	2.564	2.577	2.590	2.602	2.615	2.628	2.641	2.653	2.666	**340**
350	2.666	2.679	2.692	2.705	2.718	2.731	2.744	2.757	2.770	2.783	2.796	**350**
360	2.796	2.809	2.822	2.836	2.849	2.862	2.875	2.888	2.902	2.915	2.928	**360**
370	2.928	2.942	2.955	2.968	2.982	2.995	3.009	3.022	3.036	3.049	3.063	**370**
380	3.063	3.076	3.090	3.104	3.117	3.131	3.145	3.158	3.172	3.186	3.200	**380**
390	3.200	3.214	3.227	3.241	3.255	3.269	3.283	3.297	3.311	3.325	3.339	**390**
400	3.339	3.353	3.367	3.381	3.395	3.409	3.423	3.438	3.452	3.466	3.480	**400**
410	3.480	3.494	3.509	3.523	3.537	3.552	3.566	3.580	3.595	3.609	3.624	**410**
420	3.624	3.638	3.653	3.667	3.682	3.696	3.711	3.725	3.740	3.755	3.769	**420**
430	3.769	3.784	3.799	3.813	3.828	3.843	3.858	3.872	3.887	3.902	3.917	**430**
440	3.917	3.932	3.947	3.962	3.977	3.992	4.007	4.022	4.037	4.052	4.067	**440**
450	4.067	4.082	4.097	4.112	4.127	4.142	4.158	4.173	4.188	4.203	4.219	**450**
460	4.219	4.234	4.249	4.264	4.280	4.295	4.311	4.326	4.341	4.357	4.372	**460**
470	4.372	4.388	4.403	4.419	4.434	4.450	4.465	4.481	4.497	4.512	4.528	**470**
480	4.528	4.544	4.559	4.575	4.591	4.606	4.622	4.638	4.654	4.670	4.685	**480**
490	4.685	4.701	4.717	4.733	4.749	4.765	4.781	4.797	4.813	4.829	4.845	**490**
500	4.845	4.861	4.877	4.893	4.909	4.925	4.941	4.957	4.974	4.990	5.006	**500**
510	5.006	5.022	5.038	5.055	5.071	5.087	5.104	5.120	5.136	5.153	5.169	**510**
520	5.169	5.185	5.202	5.218	5.235	5.251	5.267	5.284	5.300	5.317	5.334	**520**
530	5.334	5.350	5.367	5.383	5.400	5.416	5.433	5.450	5.466	5.483	5.500	**530**
540	5.500	5.517	5.533	5.550	5.567	5.584	5.600	5.617	5.634	5.651	5.668	**540**
550	5.668	5.685	5.702	5.718	5.735	5.752	5.769	5.786	5.803	5.820	5.837	**550**
560	5.837	5.854	5.871	5.888	5.906	5.923	5.940	5.957	5.974	5.991	6.008	**560**
570	6.008	6.026	6.043	6.060	6.077	6.095	6.112	6.129	6.146	6.164	6.181	**570**
580	6.181	6.198	6.216	6.233	6.250	6.268	6.285	6.303	6.320	6.338	6.355	**580**
590	6.355	6.373	6.390	6.408	6.425	6.443	6.460	6.478	6.495	6.513	6.531	**590**