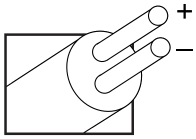
MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
32 to 3092°F
0 to 1700°C
Extension Grade
32 to 212°F
0 to 100°C

LIMITS OF ERROR
(whichever is greater)
Standard: 0.5°C over 800°C
Special: NOT ESTABLISHED

COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Do Not Insert in Metal Tubes; Beware of Contamination; High Temperature; Common Use in Glass Industry

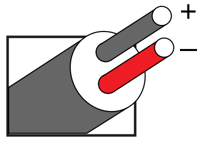
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

NONE ESTABLISHED

Platinum-30% Rhodium vs. Platinum-6% Rhodium



Extension Grade

Revised Thermocouple Reference Tables

TYPE B

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

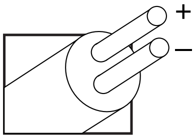
°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	0
10	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003	10
20	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	20
30	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	30
40	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	40
50	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006	50
60	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011	60
70	0.011	0.012	0.012	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017	70
80	0.017	0.018	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.024	0.025	80
90	0.025	0.026	0.026	0.027	0.028	0.029	0.030	0.031	0.031	0.032	0.033	90
100	0.033	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.041	0.042	0.043	100
110	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.051	0.052	0.053	110
120	0.053	0.055	0.056	0.057	0.058	0.059	0.060	0.062	0.063	0.064	0.065	120
130	0.065	0.066	0.068	0.069	0.070	0.072	0.073	0.074	0.075	0.077	0.078	130
140	0.078	0.079	0.081	0.082	0.084	0.085	0.086	0.088	0.089	0.091	0.092	140
150	0.092	0.094	0.095	0.096	0.098	0.099	0.101	0.102	0.104	0.106	0.107	150
160	0.107	0.109	0.110	0.112	0.113	0.115	0.117	0.118	0.120	0.122	0.123	160
170	0.123	0.125	0.127	0.128	0.130	0.132	0.134	0.135	0.137	0.139	0.141	170
180	0.141	0.142	0.144	0.146	0.148	0.150	0.151	0.153	0.155	0.157	0.159	180
190	0.159	0.161	0.163	0.165	0.166	0.168	0.170	0.172	0.174	0.176	0.178	190
200	0.178	0.180	0.182	0.184	0.186	0.188	0.190	0.192	0.195	0.197	0.199	200
210	0.199	0.201	0.203	0.205	0.207	0.209	0.212	0.214	0.216	0.218	0.220	210
220	0.220	0.222	0.225	0.227	0.229	0.231	0.234	0.236	0.238	0.241	0.243	220
230	0.243	0.245	0.248	0.250	0.252	0.255	0.257	0.259	0.262	0.264	0.267	230
240	0.267	0.269	0.271	0.274	0.276	0.279	0.281	0.284	0.286	0.289	0.291	240
250	0.291	0.294	0.296	0.299	0.301	0.304	0.307	0.309	0.312	0.314	0.317	250
260	0.317	0.320	0.322	0.325	0.328	0.330	0.333	0.336	0.338	0.341	0.344	260
270	0.344	0.347	0.349	0.352	0.355	0.358	0.360	0.363	0.366	0.369	0.372	270
280	0.372	0.375	0.377	0.380	0.383	0.386	0.389	0.392	0.395	0.398	0.401	280
290	0.401	0.404	0.407	0.410	0.413	0.416	0.419	0.422	0.425	0.428	0.431	290
300	0.431	0.434	0.437	0.440	0.443	0.446	0.449	0.452	0.455	0.458	0.462	300
310	0.462	0.465	0.468	0.471	0.474	0.478	0.481	0.484	0.487	0.490	0.494	310
320	0.494	0.497	0.500	0.503	0.507	0.510	0.513	0.517	0.520	0.523	0.527	320
330	0.527	0.530	0.533	0.537	0.540	0.544	0.547	0.550	0.554	0.557	0.561	330
340	0.561	0.564	0.568	0.571	0.575	0.578	0.582	0.585	0.589	0.592	0.596	340
350	0.596	0.599	0.603	0.607	0.610	0.614	0.617	0.621	0.625	0.628	0.632	350
360	0.632	0.636	0.639	0.643	0.647	0.650	0.654	0.658	0.662	0.665	0.669	360
370	0.669	0.673	0.677	0.680	0.684	0.688	0.692	0.696	0.700	0.703	0.707	370
380	0.707	0.711	0.715	0.719	0.723	0.727	0.731	0.735	0.738	0.742	0.746	380
390	0.746	0.750	0.754	0.758	0.762	0.766	0.770	0.774	0.778	0.782	0.787	390
400	0.787	0.791	0.795	0.799	0.803	0.807	0.811	0.815	0.819	0.824	0.828	400
410	0.828	0.832	0.836	0.840	0.844	0.849	0.853	0.857	0.861	0.866	0.870	410
420	0.870	0.874	0.878	0.883	0.887	0.891	0.896	0.900	0.904	0.909	0.913	420
430	0.913	0.917	0.922	0.926	0.930	0.935	0.939	0.944	0.948	0.953	0.957	430
440	0.957	0.961	0.966	0.970	0.975	0.979	0.984	0.988	0.993	0.997	1.002	440
450	1.002	1.007	1.011	1.016	1.020	1.025	1.030	1.034	1.039	1.043	1.048	450
460	1.048	1.053	1.057	1.062	1.067	1.071	1.076	1.081	1.086	1.090	1.095	460
470	1.095	1.100	1.105	1.109	1.114	1.119	1.124	1.129	1.133	1.138	1.143	470
480	1.143	1.148	1.153	1.158	1.163	1.167	1.172	1.177	1.182	1.187	1.192	480
490	1.192	1.197	1.202	1.207	1.212	1.217	1.222	1.227	1.232	1.237	1.242	490
500	1.242	1.247	1.252	1.257	1.262	1.267	1.272	1.277	1.282	1.288	1.293	500
510	1.293	1.298	1.303	1.308	1.313	1.318	1.324	1.329	1.334	1.339	1.344	510
520	1.344	1.350	1.355	1.360	1.365	1.371	1.376	1.381	1.387	1.392	1.397	520
530	1.397	1.402	1.408	1.413	1.418	1.424	1.429	1.435	1.440	1.445	1.451	530
540	1.451	1.456	1.462	1.467	1.472	1.478	1.483	1.489	1.494	1.500	1.505	540
550	1.505	1.511	1.516	1.522	1.527	1.533	1.539	1.544	1.550	1.555	1.561	550
560	1.561	1.566	1.572	1.578	1.583	1.589	1.595	1.600	1.606	1.612	1.617	560
570	1.617	1.623	1.629	1.634	1.640	1.646	1.652	1.657	1.663	1.669	1.675	570
580	1.675	1.680	1.686	1.692	1.698	1.704	1.709	1.715	1.721	1.727	1.733	580
590	1.733	1.739	1.745	1.750	1.756	1.762	1.768	1.774	1.780	1.786	1.792	590
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
600	1.792	1.798	1.804	1.810	1.816	1.822	1.828	1.834	1.840	1.846	1.852	600
610	1.852	1.858	1.864	1.870	1.876	1.882	1.888	1.894	1.901	1.907	1.913	610
620	1.913	1.919	1.925	1.931	1.937	1.944	1.950	1.956	1.962	1.968	1.975	620
630	1.975	1.981	1.987	1.993	1.999	2.006	2.012	2.018	2.025	2.031	2.037	630
640	2.037	2.043	2.050	2.056	2.062	2.069	2.075	2.082	2.088	2.094	2.101	640
650	2.101	2.107	2.113	2.120	2.126	2.133	2.139	2.146	2.152	2.158	2.165	650
660	2.165	2.171	2.178	2.184	2.191	2.197	2.204	2.210	2.217	2.224	2.230	660
670	2.230	2.237	2.243	2.250	2.256	2.263	2.270	2.276	2.283	2.289	2.296	670
680	2.296	2.303	2.309	2.316	2.323	2.329	2.336	2.343	2.350	2.356	2.363	680
690	2.363	2.370	2.376	2.383	2.390	2.397	2.403	2.410	2.417	2.424	2.431	690
700	2.431	2.437	2.444	2.451	2.458	2.465	2.472	2.479	2.485	2.492	2.499	700
710	2.499	2.506	2.513	2.520	2.527	2.534	2.541	2.548	2.555	2.562	2.569	710
720	2.569	2.576	2.583	2.590	2.597	2.604	2.611	2.618	2.625	2.632	2.639	720
730	2.639	2.646	2.653	2.660	2.667	2.674	2.681	2.688	2.696	2.703	2.710	730
740	2.710	2.717	2.724	2.731	2.738	2.746	2.753	2.760	2.767	2.775	2.782	740
750	2.782	2.789	2.796	2.803	2.811	2.818	2.825	2.833	2.840	2.847	2.854	750
760	2.854	2.862	2.869	2.876	2.884	2.891	2.898	2.906	2.913	2.921	2.928	760
770	2.928	2.935	2.943	2.950	2.958	2.965	2.973	2.980	2.987	2.995	3.002	770
780	3.002	3.010	3.017	3.025	3.032	3.040	3.047	3.055	3.062	3.070	3.078	780
790	3.078	3.085	3.093	3.100	3.108	3.116	3.123	3.131	3.138	3.146	3.154	790
800	3.154	3.161	3.169	3.177	3.184	3.192	3.200	3.207	3.215	3.223	3.230	800
810	3.230	3.238	3.246	3.254	3.261	3.269	3.277	3.285	3.292	3.300	3.308	810
820	3.308	3.316	3.324	3.331	3.339	3.347	3.355	3.363	3.371	3.379	3.386	820
830	3.386	3.394	3.402	3.410	3.418	3.426	3.434	3.442	3.450	3.458	3.466	830
840	3.466	3.474	3.482	3.490	3.498	3.506	3.514	3.522	3.530	3.538	3.546	840
850	3.546	3.554	3.562	3.570	3.578	3.586	3.594	3.602	3.610	3.618	3.626	850
860	3.626	3.634	3.643	3.651	3.659	3.667	3.675	3.683	3.692	3.700	3.708	860
870	3.708	3.716	3.724	3.732	3.741	3.749	3.757	3.765	3.774	3.782	3.790	870
880	3.790	3.798	3.807	3.815	3.823	3.832	3.840	3.848	3.857	3.865	3.873	880
890	3.873	3.882	3.890	3.898	3.907	3.915	3.923	3.932	3.940	3.949	3.957	890
900	3.957	3.965	3.974	3.982	3.991	3.999	4.008	4.016	4.024	4.033	4.041	900
910	4.041	4.050	4.058	4.067	4.075	4.084	4.093	4.101	4.110	4.118	4.127	910
920	4.127	4.135	4.144	4.152	4.161	4.170	4.178	4.187	4.195	4.204	4.213	920
930	4.213	4.221	4.230	4.239	4.247	4.256	4.265	4.273	4.282	4.291	4.299	930
940	4.299	4.308	4.317	4.326	4.334	4.343	4.352	4.360	4.369	4.378	4.387	940
950	4.387	4.396	4.404	4.413	4.422	4.431	4.440	4.448	4.457	4.466	4.475	950
960	4.475	4.484	4.493	4.501	4.510	4.519	4.528	4.537	4.546	4.555	4.564	960
970	4.564	4.573	4.582	4.591	4.599	4.608	4.617	4.626	4.635	4.644	4.653	970
980	4.653	4.662	4.671	4.680	4.689	4.698	4.707	4.716	4.725	4.734	4.743	980
990	4.743	4.753	4.762	4.771	4.780	4.789	4.798	4.807	4.816	4.825	4.834	990
1000	4.834	4.843	4.853	4.862	4.871	4.880	4.889	4.898	4.908	4.917	4.926	1000
1010	4.926	4.935	4.944	4.954	4.963	4.972	4.981	4.990	5.000	5.009	5.018	1010
1020	5.018	5.027	5.037	5.046	5.055	5.065	5.074	5.083	5.092	5.102	5.111	1020
1030	5.111	5.120	5.130	5.139	5.148	5.158	5.167	5.176	5.186	5.195	5.205	1030
1040	5.205	5.214	5.223	5.233	5.242	5.252	5.261	5.270	5.280	5.289	5.299	1040
1050	5.299	5.308	5.318	5.327	5.337	5.346	5.356	5.365	5.375	5.384	5.394	1050
1060	5.394	5.403	5.413	5.422	5.432	5.441	5.451	5.460	5.470	5.480	5.489	1060
1070	5.489	5.499	5.508	5.518	5.528	5.537	5.547	5.556	5.566	5.576	5.585	1070
1080	5.585	5.595	5.605	5.614	5.624	5.634	5.643	5.653	5.663	5.672	5.682	1080
1090	5.682	5.692	5.702	5.711	5.721	5.731	5.740	5.750	5.760	5.770	5.780	1090
1100	5.780	5.789	5.799	5.809	5.819	5.828	5.838	5.848	5.858	5.868	5.878	1100
1110	5.878	5.887	5.897	5.907	5.917	5.927	5.937	5.947	5.956	5.966	5.976	1110
1120	5.976	5.986	5.996	6.006	6.016	6.026	6.036	6.046	6.055	6.065	6.075	1120
1130	6.075	6.085	6.095	6.105	6.115	6.125	6.135	6.145	6.155	6.165	6.175	1130
1140	6.175	6.185	6.195	6.205	6.215	6.225	6.235	6.245	6.256	6.266	6.276	1140
1150	6.276	6.286	6.296	6.306	6.316	6.326	6.336	6.346	6.356	6.367	6.377	1150
1160	6.377	6.387	6.397	6.407	6.417	6.427	6.438	6.448	6.458	6.468	6.478	1160
1170	6.478	6.488	6.499	6.509	6.519	6.529	6.539	6.550	6.560	6.570	6.580	1170
1180	6.580	6.591	6.601	6.611	6.621	6.632	6.642	6.652	6.663	6.673	6.683	1180
1190	6.683	6.693	6.704	6.714	6.724	6.735	6.745	6.755	6.766	6.776	6.786	1190
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

TYPE B

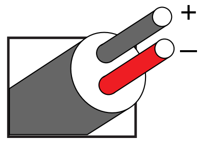
Reference Tables
N.I.S.T.
Monograph 175
Revised to
ITS-90



Thermocouple Grade

NONE ESTABLISHED

Platinum-30% Rhodium vs. Platinum-6% Rhodium



Extension Grade

MAXIMUM TEMPERATURE RANGE

Thermocouple Grade
32 to 3092°F
0 to 1700°C

Extension Grade
32 to 212°F
0 to 100°C

LIMITS OF ERROR
(whichever is greater)
Standard: 0.5°C over 800°C
Special: NOT ESTABLISHED

COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Do Not Insert in Metal Tubes; Beware of Contamination; High Temperature; Common Use in Glass Industry

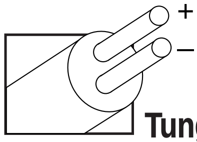
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1200	6.786	6.797	6.807	6.818	6.828	6.838	6.849	6.859	6.869	6.880	6.890	1200
1210	6.890	6.901	6.911	6.922	6.932	6.942	6.953	6.963	6.974	6.984	6.995	1210
1220	6.995	7.005	7.016	7.026	7.037	7.047	7.058	7.068	7.079	7.089	7.100	1220
1230	7.100	7.110	7.121	7.131	7.142	7.152	7.163	7.173	7.184	7.194	7.205	1230
1240	7.205	7.216	7.226	7.237	7.247	7.258	7.269	7.279	7.290	7.300	7.311	1240
1250	7.311	7.322	7.332	7.343	7.353	7.364	7.375	7.385	7.396	7.407	7.417	1250
1260	7.417	7.428	7.439	7.449	7.460	7.471	7.482	7.492	7.503	7.514	7.524	1260
1270	7.524	7.535	7.546	7.557	7.567	7.578	7.589	7.600	7.610	7.621	7.632	1270
1280	7.632	7.643	7.653	7.664	7.675	7.686	7.697	7.707	7.718	7.729	7.740	1280
1290	7.740	7.751	7.761	7.772	7.783	7.794	7.805	7.816	7.827	7.837	7.848	1290
1300	7.848	7.859	7.870	7.881	7.892	7.903	7.914	7.924	7.935	7.946	7.957	1300
1310	7.957	7.968	7.979	7.990	8.001	8.012	8.023	8.034	8.045	8.056	8.066	1310
1320	8.066	8.077	8.088	8.099	8.110	8.121	8.132	8.143	8.154	8.165	8.176	1320
1330	8.176	8.187	8.198	8.209	8.220	8.231	8.242	8.253	8.264	8.275	8.286	1330
1340	8.286	8.298	8.309	8.320	8.331	8.342	8.353	8.364	8.375	8.386	8.397	1340
1350	8.397	8.408	8.419	8.430	8.441	8.453	8.464	8.475	8.486	8.497	8.508	1350
1360	8.508	8.519	8.530	8.542	8.553	8.564	8.575	8.586	8.597	8.608	8.620	1360
1370	8.620	8.631	8.642	8.653	8.664	8.675	8.687	8.698	8.709	8.720	8.731	1370
1380	8.731	8.743	8.754	8.765	8.776	8.787	8.799	8.810	8.821	8.832	8.844	1380
1390	8.844	8.855	8.866	8.877	8.889	8.900	8.911	8.922	8.934	8.945	8.956	1390
1400	8.956	8.967	8.979	8.990	9.001	9.013	9.024	9.035	9.047	9.058	9.069	1400
1410	9.069	9.080	9.092	9.103	9.114	9.126	9.137	9.148	9.160	9.171	9.182	1410
1420	9.182	9.194	9.205	9.216	9.228	9.239	9.251	9.262	9.273	9.285	9.296	1420
1430	9.296	9.307	9.319	9.330	9.342	9.353	9.364	9.376	9.387	9.398	9.410	1430
1440	9.410	9.421	9.433	9.444	9.456	9.467	9.478	9.490	9.501	9.513	9.524	1440
1450	9.524	9.536	9.547	9.558	9.570	9.581	9.593	9.604	9.616	9.627	9.639	1450
1460	9.639	9.650	9.662	9.673	9.684	9.696	9.707	9.719	9.730	9.742	9.753	1460
1470	9.753	9.765	9.776	9.788	9.799	9.811	9.822	9.834	9.845	9.857	9.868	1470
1480	9.868	9.880	9.891	9.903	9.914	9.926	9.937	9.949	9.961	9.972	9.984	1480
1490	9.984	9.995	10.007	10.018	10.030	10.041	10.053	10.064	10.076	10.088	10.099	1490
1500	10.099	10.111	10.122	10.134	10.145	10.157	10.168	10.180	10.192	10.203	10.215	1500
1510	10.215	10.226	10.238	10.249	10.261	10.273	10.284	10.296	10.307	10.319	10.331	1510
1520	10.331	10.342	10.354	10.365	10.377	10.389	10.400	10.412	10.423	10.435	10.447	1520
1530	10.447	10.458	10.470	10.482	10.493	10.505	10.516	10.528	10.540	10.551	10.563	1530
1540	10.563	10.575	10.586	10.598	10.609	10.621	10.633	10.644	10.656	10.668	10.679	1540
°C	0	1	2	3	4	5	6	7	8	9	10	°C

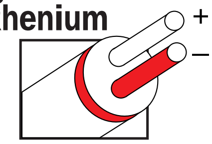
°C	0	1	2	3	4	5	6	7	8	9	10	°C
1550	10.679	10.691	10.703	10.714	10.726	10.738	10.749	10.761	10.773	10.784	10.796	1550
1560	10.796	10.808	10.819	10.831	10.843	10.854	10.866	10.877	10.889	10.901	10.913	1560
1570	10.913	10.924	10.936	10.948	10.959	10.971	10.983	10.994	11.006	11.018	11.029	1570
1580	11.029	11.041	11.053	11.064	11.076	11.088	11.099	11.111	11.123	11.134	11.146	1580
1590	11.146	11.158	11.169	11.181	11.193	11.205	11.216	11.228	11.240	11.251	11.263	1590
1600	11.263	11.275	11.286	11.298	11.310	11.321	11.333	11.345	11.357	11.368	11.380	1600
1610	11.380	11.392	11.403	11.415	11.427	11.438	11.450	11.462	11.474	11.485	11.497	1610
1620	11.497	11.509	11.520	11.532	11.544	11.555	11.567	11.579	11.591	11.602	11.614	1620
1630	11.614	11.626	11.637	11.649	11.661	11.673	11.684	11.696	11.708	11.719	11.731	1630
1640	11.731	11.743	11.754	11.766	11.778	11.790	11.801	11.813	11.825	11.836	11.848	1640
1650	11.848	11.860	11.871	11.883	11.895	11.907	11.918	11.930	11.942	11.953	11.965	1650
1660	11.965	11.977	11.988	12.000	12.012	12.024	12.035	12.047	12.059	12.070	12.082	1660
1670	12.082	12.094	12.105	12.117	12.129	12.141	12.152	12.164	12.176	12.187	12.199	1670
1680	12.199	12.211	12.222	12.234	12.246	12.257	12.269	12.281	12.292	12.304	12.316	1680
1690	12.316	12.327	12.339	12.351	12.363	12.374	12.386	12.398	12.409	12.421	12.433	1690
1700	12.433	12.444	12.456	12.468	12.479	12.491	12.503	12.514	12.526	12.538	12.549	1700
1710	12.549	12.561	12.572	12.584	12.596	12.607	12.619	12.631	12.642	12.654	12.666	1710
1720	12.666	12.677	12.689	12.701	12.712	12.724	12.736	12.747	12.759	12.770	12.782	1720
1730	12.782	12.794	12.805	12.817	12.829	12.840	12.852	12.863	12.875	12.887	12.898	1730
1740	12.898	12.910	12.921	12.933	12.945	12.956	12.968	12.980	12.991	13.003	13.014	1740
1750	13.014	13.026	13.037	13.049	13.061	13.072	13.084	13.095	13.107	13.119	13.130	1750
1760	13.130	13.142	13.153	13.165	13.176	13.188	13.200	13.211	13.223	13.234	13.246	1760
1770	13.246	13.257	13.269	13.280	13.292	13.304	13.315	13.327	13.338	13.350	13.361	1770
1780	13.361	13.373	13.384	13.396	13.407	13.419	13.430	13.442	13.453	13.465	13.476	1780
1790	13.476	13.488	13.499	13.511	13.522	13.534	13.545	13.557	13.568	13.580	13.591	1790
1800	13.591	13.603	13.614	13.626	13.637	13.649	13.660	13.672	13.683	13.694	13.706	1800
1810	13.706	13.717	13.729	13.740	13.752	13.763	13.775	13.786	13.797	13.809	13.820	1810
°C	0	1	2	3	4	5	6	7	8	9	10	°C

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
-32 to 4208°F
-0 to 2320°C
Extension Grade
32 to 1600°F
0 to 870°C
LIMITS OF ERROR
(whichever is greater)
Standard: 4.5°C to 425°C
1.0% to 2320°C
Special: Not Established
COMMENTS, BARE WIRE ENVIRONMENT:
Vacuum, Inert; Hydrogen; Beware of Embrittlement; Not Practical Below 750°F; Not for Oxidizing Atmosphere
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade
NONE ESTABLISHED

Tungsten-5% Rhenium vs. Tungsten-26% Rhenium



Extension Grade

Revised Thermocouple Reference Tables

TYPE C

Reference Tables
N.I.S.T. Monograph 175
Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

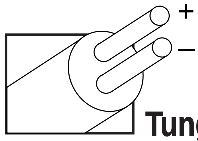
°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.013	0.026	0.040	0.053	0.067	0.080	0.094	0.107	0.121	0.135	0
10	0.135	0.148	0.162	0.176	0.189	0.203	0.217	0.231	0.244	0.258	0.272	10
20	0.272	0.286	0.300	0.314	0.328	0.342	0.356	0.370	0.384	0.398	0.412	20
30	0.412	0.426	0.440	0.454	0.469	0.483	0.497	0.511	0.525	0.540	0.554	0
40	0.554	0.568	0.583	0.597	0.612	0.626	0.640	0.655	0.669	0.684	0.698	40
50	0.698	0.713	0.727	0.742	0.757	0.771	0.786	0.801	0.815	0.830	0.845	50
60	0.845	0.860	0.874	0.889	0.904	0.919	0.934	0.948	0.963	0.978	0.993	60
70	0.993	1.008	1.023	1.038	1.053	1.068	1.083	1.098	1.114	1.129	1.144	70
80	1.144	1.159	1.174	1.189	1.205	1.220	1.235	1.250	1.266	1.281	1.296	80
90	1.296	1.312	1.327	1.342	1.358	1.373	1.389	1.404	1.420	1.435	1.451	90
100	1.451	1.466	1.482	1.497	1.513	1.529	1.544	1.560	1.576	1.591	1.607	100
110	1.607	1.623	1.639	1.654	1.670	1.686	1.702	1.718	1.733	1.749	1.765	110
120	1.765	1.781	1.797	1.813	1.829	1.845	1.861	1.877	1.893	1.909	1.925	120
130	1.925	1.941	1.957	1.973	1.989	2.006	2.022	2.038	2.054	2.070	2.087	130
140	2.087	2.103	2.119	2.135	2.152	2.168	2.184	2.201	2.217	2.233	2.250	140
150	2.250	2.266	2.283	2.299	2.316	2.332	2.349	2.365	2.382	2.398	2.415	150
160	2.415	2.431	2.448	2.464	2.481	2.498	2.514	2.531	2.548	2.564	2.581	160
170	2.581	2.598	2.614	2.631	2.648	2.665	2.682	2.698	2.715	2.732	2.749	170
180	2.749	2.766	2.783	2.800	2.816	2.833	2.850	2.867	2.884	2.901	2.918	180
190	2.918	2.935	2.952	2.969	2.986	3.003	3.020	3.038	3.055	3.072	3.089	190
200	3.089	3.106	3.123	3.140	3.158	3.175	3.192	3.209	3.227	3.244	3.26	200
210	3.261	3.278	3.296	3.313	3.330	3.348	3.365	3.382	3.400	3.417	3.434	210
220	3.434	3.452	3.469	3.487	3.504	3.522	3.539	3.557	3.574	3.592	3.609	220
230	3.609	3.627	3.644	3.662	3.679	3.697	3.714	3.732	3.750	3.767	3.785	230
240	3.785	3.803	3.820	3.838	3.856	3.873	3.891	3.909	3.927	3.944	3.962	240
250	3.962	3.980	3.998	4.015	4.033	4.051	4.069	4.087	4.104	4.122	4.140	250
260	4.140	4.158	4.176	4.194	4.212	4.230	4.248	4.266	4.284	4.301	4.319	260
270	4.319	4.337	4.355	4.373	4.391	4.410	4.428	4.446	4.464	4.482	4.500	270
280	4.500	4.518	4.536	4.554	4.572	4.590	4.608	4.627	4.645	4.663	4.681	280
290	4.681	4.699	4.717	4.736	4.754	4.772	4.790	4.809	4.827	4.845	4.863	290
300	4.863	4.882	4.900	4.918	4.937	4.955	4.973	4.992	5.010	5.028	5.047	300
310	5.047	5.065	5.083	5.102	5.120	5.139	5.157	5.175	5.194	5.212	5.231	310
320	5.231	5.249	5.268	5.286	5.305	5.323	5.342	5.360	5.379	5.397	5.416	320
330	5.416	5.434	5.453	5.471	5.490	5.508	5.527	5.546	5.564	5.583	5.601	330
340	5.601	5.620	5.639	5.657	5.676	5.695	5.713	5.732	5.751	5.769	5.788	340
350	5.788	5.807	5.825	5.844	5.863	5.882	5.900	5.919	5.938	5.956	5.975	350
360	5.975	5.994	6.013	6.032	6.050	6.069	6.088	6.107	6.126	6.144	6.163	360
370	6.163	6.182	6.201	6.220	6.239	6.257	6.276	6.295	6.314	6.333	6.352	370
380	6.352	6.371	6.390	6.409	6.427	6.446	6.465	6.484	6.503	6.522	6.541	380
390	6.541	6.560	6.579	6.598	6.617	6.636	6.655	6.674	6.693	6.712	6.731	390
400	6.731	6.750	6. 69	6.788	6.807	6.826	6.845	6.864	6.883	6.902	6.921	400
410	6.921	6.940	6.959	6.979	6.998	7.017	7.036	7.055	7.074	7.093	7.112	410
420	7.112	7.131	7.151	7.170	7.189	7.208	7.227	7.246	7.265	7.285	7.304	420
430	7.304	7.323	7.342	7.361	7.380	7.400	7.419	7.438	7.457	7.476	7.496	430
440	7.496	7.515	7.534	7.553	7.572	7.592	7.611	7.630	7.649	7.669	7.688	440
450	7.688	7.707	7.726	7.746	7.765	7.784	7.804	7.823	7.842	7.861	7.881	450
460	7.881	7.900	7.919	7.939	7.958	7.977	7.996	8.016	8.035	8.054	8.074	460
470	8.074	8.093	8.112	8.132	8.151	8.170	8.190	8.209	8.229	8.248	8.267	470
480	8.267	8.287	8.306	8.325	8.345	8.364	8.383	8.403	8.422	8.422	8.461	480
490	8.461	8.480	8.500	8.519	8.539	8.558	8.577	8.597	8.616	8.636	8.655	490
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
500	8.655	8.674	8.694	8.713	8.733	8.752	8.772	8.791	8.810	8.830	8.849	500
510	8.849	8.869	8.888	8.908	8.927	8.947	8.966	8.986	9.005	9.024	9.044	510
520	9.044	9.063	9.083	9.102	9.122	9.141	9.161	9.180	9.200	9.219	9.239	520
530	9.239	9.258	9.278	9.297	9.317	9.336	9.356	9.375	9.395	9.414	9.434	530
540	9.434	9.453	9.473	9.492	9.512	9.531	9.551	9.570	9.590	9.609	9.629	540
550	9.629	9.648	9.668	9.687	9.707	9.726	9.746	9.765	9.785	9.804	9.824	550
560	9.824	9.843	9.863	9.883	9.902	9.922	9.941	9.961	9.980	10.000	10.019	560
570	10.019	10.039	10.058	10.078	10.097	10.117	10.137	10.156	10.176	10.195	10.215	570
580	10.215	10.234	10.254	10.273	10.293	10.312	10.332	10.352	10.371	10.391	10.410	580
590	10.410	10.430	10.449	10.469	10.488	10.508	10.528	10.547	10.567	10.586	10.606	590
600	10.606	10-625	10.645	10.664	10.684	10.703	10.723	10.743	10.762	10.782	10.801	600
610	10.801	10.821	10.840	10.860	10.879	10.899	10.919	10.938	10.958	10.977	10.997	610
620	10.997	11.016	11.036	11.055	11.075	11.095	11.114	11.134	11.153	11.173	11.192	620
630	11.192	11.212	11.231	11.251	11.270	11.290	11.310	11.329	11.349	11.368	11.388	630
640	11.388	11.407	11.427	11.446	11.466	11.485	11.505	11.525	11.544	11.564	11.583	640
650	11.583	11.603	11.622	11.642	11.661	11.681	11.700	11.720	11.739	11.759	11.778	650
660	11.778	11.798	11.817	11.837	11.857	11.876	11.896	11.915	11.935	11.954	11.974	660
670	11.974	11.993	12.013	12.032	12.052	12.071	12.091	12.110	12.130	12.149	12.169	670
680	12.169	12.188	12.208	12.227	12.247	12.266	12.286	12.305	12.325	12.344	12.364	680
690	12.364	12.383	12.403	12.422	12.442	12.461	12.481	12.500	12-519	12.539	12.558	690
700	12.558	12.578	12.597	12.617	12.636	12.656	12.675	12.695	12.714	12.734	12.753	700
710	12.753	12.772	12.792	12.811	12.831	12.850	12.870	12.889	12.909	12.928	12.947	710
720	12.947	12.967	12.986	13.006	13.025	13.045	13.064	13.083	13.103	13.122	13.142	720
730	13.142	13.161	13.180	13.200	13.219	13.239	13.258	13.277	13.297	13.316	13.336	730
740	13.336	13.355	13.374	13.394	13.413	13.432	13.452	13.471	13.491	13.510	13.529	740
750	13.529	13.549	13.568	13.587	13.607	13.626	13.645	13.665	13.684	13.703	13.723	750
760	13.723	13.742	13.761	13.781	13.800	13.819	13.839	13.858	13.877	13.897	13.916	760
770	13.916	13.935	13.955	13.974	13.993	14.012	14.032	14.051	14 .070	14.090	14.109	770
780	14.109	14.128	14.147	14.167	14.186	14.205	14.224	14.244	14.263	14.282	14.302	780
790	14.302	14.321	14.340	14.359	14.378	14.398	14.417	14.436	14.455	14.475	14.494	790
800	14.494	14.513	14.532	14-551	14.571	14.590	14.609	14.628	14.647	14.667	14.686	800
810	14.686	14.705	14.724	14.743	14.762	14.782	14.801	14.820	14.839	14.858	14.877	810
820	14.877	14.897	14.916	14.935	14.954	14.973	14.992	15.011	15.030	15.050	15.069	820
830	15.069	15.088	15.107	15.126	15.145	15.164	15.183	15.202	15.221	15.241	15.260	830
840	15.260	15.279	15.298	15.317	15.336	15.355	15.374	15.393	15.412	15.431	15.450	840
850	15.450	15.469	15.488	15.507	15.526	15.545	15.564	15.583	15.602	15.621	15.640	850
860	15.640	15.659	15.678	15.697	15.716	15.735	15.754	15.773	15.792	15.811	15.830	860
870	15.830	15.849	15.868	15.887	15.906	15.925	15.944	15.963	15.982	16.001	16.020	870
880	16.020	16.038	16.057	16.076	16.095	16.114	16.133	16.152	16.171	19.190	16.208	880
890	16.208	16.227	16.246	16.265	16.284	16.303	16.322	16.340	16.359	16.378	16.397	890
900	16.397	16.416	16.435	16.453	16.472	16.491	16.510	16.529	16.547	16.566	16.585	900
910	16.585	16.604	16.623	16.641	16.660	16.679	16.698	16.716	16.735	16.754	16.773	910
920	16.773	16.791	16.810	16.829	16.848	16.866	16.885	16.904	16.923	16.941	16.960	920
930	16.960	16.979	16.997	17.016	17.035	17.053	17.072	17.091	17.109	17.128	17.147	930
940	17.147	17.165	17.184	17.203	17.221	17.240	17.258	17.277	17.296	17.314	17.333	940
950	17.333	17.352	17.370	17.389	17.407	17.426	17.444	17.463	17.482	17.500	17.519	950
960	17.519	17.537	17.556	17.574	17.593	17.611	17.630	17.648	17.667	17.686	17.704	960
970	17.704	17.723	17.741	17.760	17.778	17.796	17.815	17.833	17.852	17.870	17.889	970
980	17.889	17.907	17.926	17.944	17.963	17.981	17.999	18.018	18.036	18.055	18.073	980
990	18.073	18.092	18.110	18.128	18.147	18.165	18.184	18.202	18.220	18.239	18.257	990
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

TYPE C

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

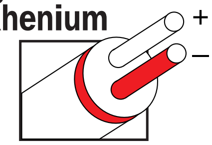


Thermocouple Grade

NONE ESTABLISHED

Tungsten-5% Rhenium vs. Tungsten-26% Rhenium

Extension Grade



MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
-32 to 4208°F
-0 to 2320°C
Extension Grade
32 to 1600°F
0 to 870°C
LIMITS OF ERROR
(whichever is greater)
Standard: 4.5°C to 425°C
1.0% to 2320°C
Special: Not Established
COMMENTS, BARE WIRE ENVIRONMENT:
Vacuum, Inert; Hydrogen; Beware of Embrittlement; Not Practical Below 750°F; Not for Oxidizing Atmosphere
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1000	18.257	18.275	18.294	18.312	18.330	18.349	18.367	18.385	18.404	18.422	18.440	1000
1010	18.440	18.459	18.477	18.495	18.513	18.532	18.550	18.568	18.587	18.605	18.623	1010
1020	18.623	18.641	18.660	18.678	18.696	18.714	18.732	18.751	18.769	18.787	18.805	1020
1030	18.805	18.824	18.842	18.860	18.878	18.896	18.914	18.933	18.951	18.969	18.987	1030
1040	18.987	19.005	19.023	19.041	19.060	19.078	19.096	19.114	19.132	19.150	19.168	1040
1050	19.168	19.186	19.204	19.223	19.241	19.259	19.277	19.295	19.313	19.331	19.349	1050
1060	19.349	19.367	19.385	19.403	19.421	19.439	19.457	19.475	19.493	19.511	19.529	1060
1070	19.529	19.547	19.565	19.583	19.601	19.619	19.637	19.655	19.673	19.691	19.709	1070
1080	19.709	19.727	19.744	19.762	19.780	19.798	19.816	19.834	19.852	19.870	19.888	1080
1090	19.888	19.905	19.923	19.941	19.959	19.977	19.995	20.013	20.030	20.048	20.066	1090
1100	20.066	20.084	20.102	20.120	20.137	20.155	20.173	20.191	20.208	20.226	20.066	1100
1110	20.244	20.262	20.279	20.297	20.315	20.333	20.350	20.368	20.386	20.404	20.421	1110
1120	20.421	20.439	20.457	20.474	20.492	20.510	20.527	20.545	20.563	20.580	20.598	1120
1130	20.598	20.616	20.633	20.651	20.669	20.686	20.704	20.721	20.739	20.757	20.774	1130
1140	20.774	20.792	20.809	20.827	20.845	20.862	20.880	20.897	20.915	20.932	20.950	1140
1150	20.950	20.967	20.985	21.002	21.020	21.037	21.055	21.072	21.090	21.107	21.125	1150
1160	21.125	21.142	21.160	21.177	21.195	21.212	21.230	21.247	21.265	21.282	21.299	1160
1170	21.299	21.317	21.334	21.352	21.369	21.386	21.404	21.421	21.439	21.456	21.473	1170
1180	21.473	21.491	21.508	21.525	21.543	21.560	21.577	21.595	21.612	21.629	21.647	1180
1190	21.647	21.664	21.681	21.698	21.716	21.733	21.750	21.768	21.785	21.802	21.819	1190
1200	21.819	21.837	21.854	21.871	21.888	21.905	21.923	21.940	21.957	21.974	21.991	1200
1210	21.991	22.009	22.026	22.043	22.060	22.077	22.094	22.112	22.129	22.146	22.163	1210
1220	22.163	22.180	22.197	22.214	22.231	22.249	22.266	22.283	22.300	22.317	22.334	1220
1230	22.334	22.35	22.368	22.385	22.402	22.419	22.436	22.453	22.470	22.487	22.504	1230
1240	22.504	22.521	22.538	22.555	22.572	22.589	22.606	22.623	22.640	22.657	22.674	1240
1250	22.674	22.691	22.708	22.725	22.742	22.759	22.776	22.792	22.809	22.826	22.843	1250
1260	22.843	22.860	22.877	22.894	22.911	22.928	22.944	22.961	22.978	22.995	23.012	1260
1270	23.012	23.029	23.045	23.062	23.079	23.096	23.113	23.129	23.146	23.163	23.180	1270
1280	23.180	23.196	23.213	23.230	23.247	23.263	23.280	23.297	23.314	23.330	23.347	1280
1290	23.347	23.364	23.380	23.397	23.414	23.431	23.447	23.464	23.481	23.497	23.514	1290
1300	23.514	23.530	23.547	23.564	23.580	23.597	23.614	23.630	23.647	23.663	23.680	1300
1310	23.680	23.697	23.713	23.730	23.746	23.763	23.779	23.796	23.812	23.829	23.846	1310
1320	23.846	23.862	23.879	23.895	23.912	23.928	23.945	23.961	23.978	23.994	24.010	1320
1330	24.010	24.027	24.043	24.060	24.076	24.093	24.109	24.126	24.142	24.158	24.175	1330
1340	24.175	24.191	24.208	24.224	24.240	24.257	24.273	24.290	24.306	24.322	24.339	1340
1350	24.339	24.355	24.371	24.388	24.404	24.420	24.437	24.453	24.46	24.485	24.502	1350
1360	24.502	24.518	24.534	24.551	24.567	24.583	24.599	24.616	24.632	24.648	24.664	1360
1370	24.664	24.680	24.697	24.713	24.729	24.745	24.762	24.778	24.794	24.810	24.826	1370
1380	24.826	24.842	24.859	24.875	24.891	24.907	24.923	24.939	24.955	24.971	24.988	1380
1390	24.988	25.004	25.020	25.036	25.052	25.068	25.084	25.100	25.116	24.132	25.148	1390
1400	25.148	25.164	25.180	25.196	25.212	25.228	25.244	25.260	25.276	25.292	25.308	1400
1410	25.308	25.324	25.340	25.356	25.372	25.388	25.404	25.420	25.436	25.452	25.468	1410
1420	25.468	25.484	25.500	25.516	25.532	25.547	25.563	25.579	25.595	25.611	25.627	1420
1430	25.627	25.643	25.658	25.674	25.690	25.706	25.722	25.738	25.753	25.769	25.785	1430
1440	25.785	25.801	25.817	25.832	25.848	25.864	25.880	25.896	25.911	25.927	25.943	1440
1450	25.943	25.959	25.974	25.990	26.006	26.021	26.037	26.053	26.069	26.084	26.100	1450
1460	26.100	26.116	26.131	26.147	26.163	26.178	26.194	26.209	26.225	26.241	26.256	1460
1470	26.256	26.272	26.288	26.303	26.319	26.334	26.350	26.366	26.381	26.397	26.412	1470
1480	26.412	26.428	26.443	26.459	26.474	26.490	26.505	26.521	26.537	26.552	26.568	1480
1490	26.568	26.583	26.599	26.614	26.629	26.645	26.660	26.676	26.691	26.707	26.722	1490
°C	0	1	2	3	4	5	6	7	8	9	10	°C

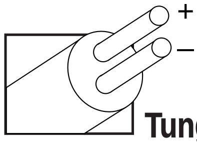
°C	0	1	2	3	4	5	6	7	8	9	10	°C
1500	26.722	26.738	26.753	26.768	26.784	26.799	26.815	26.830	26.845	26.861	26.876	1500
1510	26.876	26.892	26.907	26.922	26.938	26.953	26.968	26.984	26.999	27.014	27.030	1510
1520	27.030	27.045	27.060	27.076	27.091	27.106	27.121	27.137	27.152	27.167	27.183	1520
1530	27.183	27.198	27.213	27.228	27.244	27.259	27.274	27.289	27.304	27.320	27.335	1530
1540	27.335	27.350	27.365	27.380	27.396	27.411	27.426	27.441	27.456	27.471	27.486	1540
1550	27.486	27.502	27.517	27.532	27.547	27.562	27.577	27.592	27.607	27.622	27.637	1550
1560	27.637	27.653	27.668	27.683	27.698	27.713	27.728	27.743	27.758	27.773	27.788	1560
1570	27.788	27.803	27.818	27.833	27.848	27.863	27.878	27.893	27.908	27.923	27.938	1570
1580	27.938	27.953	27.968	27.983	27.997	28.012	28.027	28.042	28.057	28.072	28.087	1580
1590	28.087	28.102	28.117	28.132	28.146	28.161	28.176	28.191	28.206	28.221	28.236	1590
1600	28.236	28.250	28.265	28.280	28.295	28.310	28.324	28.339	28.354	28.369	28.531	1600
1610	28.531	28.398	28.413	28.428	28.443	28.457	28.472	28.487	28.502	28.516	28.531	1610
1620	28.531	28.546	28.560	28.575	28.590	28.604	28.619	28.634	28.648	28.663	28.678	1620
1630	28.678	28.692	28.707	28.722	28.736	28.751	28.765	28.780	28.795	28.809	28.824	1630
1640	28.824	28.838	28.853	28.868	28.882	28.897	28.911	28.926	28.940	28.955	28.969	1640
1650	28.969	28.984	28.998	29.013	29.027	29.042	29.056	29.071	29.085	29.100	29.114	1650
1660	29.114	29.129	29.143	29.158	29.172	29.187	29.201	29.215	29.230	29.244	29.259	1660
1670	29.259	29.273	29.287	29.302	29.316	29.331	29.345	29.359	29.374	29.388	29.402	1670
1680	29.402	29.417	29.431	29.445	29.460	29.474	29.488	29.503	29.517	29.531	29.546	1680
1690	29.546	29.560	29.574	29.588	29.603	29.617	29.631	29.645	29.660	29.674	29.688	1690
1700	29.688	29.702	29.716	29.731	29.745	29.759	29.773	29.787	29.802	29.816	29.830	1700
1710	29.830	29.844	29.858	29.872	29.886	29.901	29.915	29.929	29.943	29.957	29.971	1710
1720	29.971	29.985	29.999	30.013	30.027	30.041	30.056	30.070	30.084	30.098	30.112	1720
1730	30.112	30.126	30.140	30.154	30.168	30.182	30.196	30.210	30.224	30.238	30.252	1730
1740	30.252	30.266	30.280	30.294	30.308	30.321	30.335	30.349	30.363	30.377	30.391	1740
1750	30.391	30.405	30.419	30.433	30.447	30.460	30.474	30.488	30.502	30.516	30.530	1750
1760	30.530	30.544	30.557	30.571	30.585	30.599	30.613	30.627	20.640	30.654	30.668	1760
1770	30.668	30.682	30.695	30.709	30.723	30.737	30.750	30.764	30.778	30.792	30.805	1770
1780	30.805	30.819	30.833	30.846	30.860	30.874	30.887	30.901	30.915	20.928	30.942	1780
1790	30.942	30.956	30.969	30.983	30.997	31.010	31.024	31.038	31.051	31.065	31.078	1790
1800	31.078	31.092	31.105	31.119	31.133	31.146	31.160	31.173	31.187	31.200	31.214	1800
1810	31.214	31.227	31.241	31.254	31.268	31.281	31.295	31.308	31.322	31.335	31.349	1810
1820	31.349	31.362	31.376	31.389	31.403	31.416	31.429	31.443	31.456	31.470	31.483	1820
1830	31.483	31.496	31.510	31.523	31.536	31.550	31.563	31.577	31.590	31.603	31.617	1830
1840	31.617	31.630	31.643	31.656	31.670	31.683	31.696	31.710	31.723	31.736	31.749	1840
1850	31.749	31.763	31.776	31.789	31.802	31.816	31.829	31.842	31.855	31.869	31.882	1850
1860	31.882	31.895	31.908	31.921	31.934	31.948	31.961	31.974	31.987	32.000	32.013	1860
1870	32.013	32.026	32.040	32.053	32.066	32.079	32.092	32.105	32.118	32.131	32.144	1870
1880	32.144	32.157	32.170	31.183	32.196	32.209	32.222	32.235	32.248	32.261	32.274	1880
1890	32.274	32.287	32.300	31.313	32.326	32.339	32.352	32.365	32.378	32.391	32.404	1890
1900	32.404	32.417	32.430	32.443	32.456	32.468	32.481	32.494	32.507	32.520	32.533	1900
1910	32.533	32.546	32.558	32.571	32.584	32.597	32.610	32.623	32.635	32.648	32.661	1910
1920	32.661	32.674	32.686	32.699	32.712	32.725	32.737	32.750	32.763	32.776	32.788	1920
1930	32.788	32.801	32.814	32.826	32.839	32.852	32.864	32.877	32.890	32.902	32.915	1930
1940	32.915	32.928	32.940	32.953	32.966	32.978	32.991	33.003	33.016	33.028	33.041	1940
1950	33.041	33.054	33.066	33.079	33.091	33.104	33.116	33.129	33.141	33.154	33.166	1950
1960	33.166	33.179	33.191	33.204	33.216	33.229	33.241	33.254	33.266	33.278	33.291	1960
1970	33.291	33.303	33.316	33.328	33.341	33.353	33.365	33.378	33.390	33.402	33.415	1970
1980	33.415	33.427	33.439	33.452	33.464	33.476	33.489	33.501	33.513	33.525	33.538	1980
1990	33.538	33.550	33.562	33.575	33.587	33.599	33.611	33.623	33.636	33.648	33.660	1990
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

TYPE C

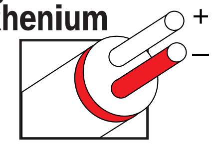
Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
-32 to 4208°F
-0 to 2320°C
Extension Grade
32 to 1600°F
0 to 870°C
LIMITS OF ERROR
(whichever is greater)
Standard: 4.5°C to 425°C
1.0% to 2320°C
Special: Not Established
COMMENTS, BARE WIRE ENVIRONMENT:
Vacuum, Inert; Hydrogen; Beware of Embrittlement; Not Practical Below 750°F; Not for Oxidizing Atmosphere
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade
NONE ESTABLISHED

Tungsten-5% Rhenium vs. Tungsten-26% Rhenium



Extension Grade

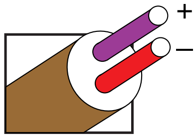
Z

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
2000	33.660	33.672	33.684	33.697	33.709	33.721	33.733	33.745	33.757	33.769	33.782	2000
2010	33.782	33.794	33.806	33.818	33.830	33.842	33.854	33.866	33.878	33.890	33.902	2010
2020	33.902	33.914	33.926	33.938	33.950	33.962	33.974	33.986	33.998	34.010	34.022	2020
2030	34.022	34.034	34.046	34.058	34.070	34.082	34.094	34.106	34.118	34.130	34.142	2030
2040	34.142	34.153	34.165	34.177	34.189	34.201	34.213	34.225	34.236	34.248	34.260	2040
2050	34.260	34.272	34.284	34.295	34.307	34.319	34.331	34.342	34.354	34.366	34.378	2050
2060	34.378	34.389	34.401	34.413	34.424	34.436	34.448	34.459	34.471	34.483	34.494	2060
2070	34.494	34.506	34.518	34.529	34.541	34.552	34.564	34.576	34.587	34.599	34.610	2070
2080	34.610	34.622	34.633	34.645	34.656	34.668	34.679	34.691	34.702	34.714	34.725	2080
2090	34.725	34.737	34.748	34.760	34.771	34.782	34.794	34.805	34.817	34.828	34.839	2090
2100	34.839	34.851	34.862	34.874	34.885	34.896	34.908	34.919	34.930	34.942	34.953	2100
2110	34.953	34.964	34.975	34.987	34.998	35.009	35.020	35.032	35.043	35.054	35.065	2110
2120	35.065	35.077	35.088	35.099	35.110	35.121	35.132	35.144	35.155	35.166	35.177	2120
2130	35.177	35.188	35.199	35.210	35.221	35.232	35.243	35.254	35.265	35.277	35.288	2130
2140	35.288	35.299	35.310	35.321	35.332	35.343	35.353	35.364	35.375	35.386	35.397	2140
2150	35.397	35.408	35.419	35.430	35.441	35.452	35.463	35.474	35.484	35.495	35.506	2150
2160	35.506	35.517	35.528	35.539	35.549	35.560	35.571	35.582	35.592	35.603	35.614	2160
2170	35.614	35.625	35.635	35.646	35.657	35.668	35.678	35.689	35.700	35.710	35.721	2170
2180	35.721	35.731	35.742	35.753	35.763	35.774	35.784	35.795	35.806	35.816	35.827	2180
2190	35.827	35.837	35.848	35.858	35.869	35.879	35.890	35.900	35.911	35.921	35.932	2190
°C	0	1	2	3	4	5	6	7	8	9	10	°C

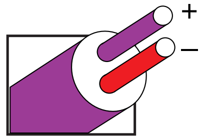
°C	0	1	2	3	4	5	6	7	8	9	10	°C
2200	35.932	35.942	35.953	35.963	35.973	35.984	35.994	36.004	36.015	36.025	36.036	2200
2210	36.036	36.046	36-056	36.067	36.077	36.087	36.097	36.108	36.118	36.128	36.138	2210
2220	36.138	36.149	36.159	36.169	36.179	36.189	36.200	36.210	36.220	36.230	36.240	2220
2230	36.240	36.250	36.260	36.271	36.281	36.291	36.301	36.311	36.321	36.331	36.341	2230
2240	36.341	36.351	36.361	36.371	36.381	36.391	36.401	36.411	36.421	36.431	36.441	2240
2250	36.441	36.451	36.460	36.470	36.480	36.490	36-500	36.510	36.520	36.529	36.539	2250
2260	36.539	36.549	36.559	36.569	36.578	36.588	36.598	36.608	36.617	36.627	36.637	2260
2270	36.637	36.646	36.656	36.666	36.675	36.685	36.695	36.704	36.714	36.723	36.733	2270
2280	36.733	36.743	36.752	36.762	36.771	36.781	36.790	36.800	36.809	36.819	36.828	2280
2290	36.828	36.838	36.847	36.857	36.866	36.875	36.885	36.894	36.903	36.913	36.922	2290
2300	36.922	36.932	36.941	36.950	36.959	36.969	36.978	36.987	36.997	37.006	37.015	2300
2310	37.015	37.024	37.033	37.043	37.052	37.061	37.070	37.079	37.088	37.097	37.107	2310
°C	0	1	2	3	4	5	6	7	8	9	10	°C

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
– 328 to 1652°F
– 200 to 900°C
Extension Grade
32 to 392°F
0 to 200°C
LIMITS OF ERROR
(whichever is greater)
Standard: 1.7°C or 0.5% Above 0°C
1.7°C or 1.0% Below 0°C
Special: 1.0°C or 0.4%
COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Limited Use in Vacuum or Reducing; Highest EMF Change per Degree
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

Nickel-Chromium vs. Copper-Nickel



Extension Grade

Revised Thermocouple Reference Tables

TYPE E

Reference Tables
N.I.S.T. Monograph 175
Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-260	-9.835	-9.833	-9.831	-9.828	-9.825	-9.821	-9.817	-9.813	-9.808	-9.802	-9.797	-260
-250	-9.797	-9.790	-9.784	-9.777	-9.770	-9.762	-9.754	-9.746	-9.737	-9.728	-9.718	-250
-240	-9.718	-9.709	-9.698	-9.688	-9.677	-9.666	-9.654	-9.642	-9.630	-9.617	-9.604	-240
-230	-9.604	-9.591	-9.577	-9.563	-9.548	-9.534	-9.519	-9.503	-9.487	-9.471	-9.455	-230
-220	-9.455	-9.438	-9.421	-9.404	-9.386	-9.368	-9.350	-9.331	-9.313	-9.293	-9.274	-220
-210	-9.274	-9.254	-9.234	-9.214	-9.193	-9.172	-9.151	-9.129	-9.107	-9.085	-9.063	-210
-200	-9.063	-9.040	-9.017	-8.994	-8.971	-8.947	-8.923	-8.899	-8.874	-8.850	-8.825	-200
-190	-8.825	-8.799	-8.774	-8.748	-8.722	-8.696	-8.669	-8.643	-8.616	-8.588	-8.561	-190
-180	-8.561	-8.533	-8.505	-8.477	-8.449	-8.420	-8.391	-8.362	-8.333	-8.303	-8.273	-180
-170	-8.273	-8.243	-8.213	-8.183	-8.152	-8.121	-8.090	-8.059	-8.027	-7.995	-7.963	-170
-160	-7.963	-7.931	-7.899	-7.866	-7.833	-7.800	-7.767	-7.733	-7.700	-7.666	-7.632	-160
-150	-7.632	-7.597	-7.563	-7.528	-7.493	-7.458	-7.423	-7.387	-7.351	-7.315	-7.279	-150
-140	-7.279	-7.243	-7.206	-7.170	-7.133	-7.096	-7.058	-7.021	-6.983	-6.945	-6.907	-140
-130	-6.907	-6.869	-6.831	-6.792	-6.753	-6.714	-6.675	-6.636	-6.596	-6.556	-6.516	-130
-120	-6.516	-6.476	-6.436	-6.396	-6.355	-6.314	-6.273	-6.232	-6.191	-6.149	-6.107	-120
-110	-6.107	-6.065	-6.023	-5.981	-5.939	-5.896	-5.853	-5.810	-5.767	-5.724	-5.681	-110
-100	-5.681	-5.637	-5.593	-5.549	-5.505	-5.461	-5.417	-5.372	-5.327	-5.282	-5.237	-100
-90	-5.237	-5.192	-5.147	-5.101	-5.055	-5.009	-4.963	-4.917	-4.871	-4.824	-4.777	-90
-80	-4.777	-4.731	-4.684	-4.636	-4.589	-4.542	-4.494	-4.446	-4.398	-4.350	-4.302	-80
-70	-4.302	-4.254	-4.205	-4.156	-4.107	-4.058	-4.009	-3.960	-3.911	-3.861	-3.811	-70
-60	-3.811	-3.761	-3.711	-3.661	-3.611	-3.561	-3.510	-3.459	-3.408	-3.357	-3.306	-60
-50	-3.306	-3.255	-3.204	-3.152	-3.100	-3.048	-2.996	-2.944	-2.892	-2.840	-2.787	-50
-40	-2.787	-2.735	-2.682	-2.629	-2.576	-2.523	-2.469	-2.416	-2.362	-2.309	-2.255	-40
-30	-2.255	-2.201	-2.147	-2.093	-2.038	-1.984	-1.929	-1.874	-1.820	-1.765	-1.709	-30
-20	-1.709	-1.654	-1.599	-1.543	-1.488	-1.432	-1.376	-1.320	-1.264	-1.208	-1.152	-20
-10	-1.152	-1.095	-1.039	-0.982	-0.925	-0.868	-0.811	-0.754	-0.697	-0.639	-0.582	-10
0	-0.582	-0.524	-0.466	-0.408	-0.350	-0.292	-0.234	-0.176	-0.117	-0.059	0.000	0

°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.059	0.118	0.176	0.235	0.294	0.354	0.413	0.472	0.532	0.591	0
10	0.591	0.651	0.711	0.770	0.830	0.890	0.950	1.010	1.071	1.131	1.192	10
20	1.192	1.252	1.313	1.373	1.434	1.495	1.556	1.617	1.678	1.740	1.801	20
30	1.801	1.862	1.924	1.986	2.047	2.109	2.171	2.233	2.295	2.357	2.420	30
40	2.420	2.482	2.545	2.607	2.670	2.733	2.795	2.858	2.921	2.984	3.048	40
50	3.048	3.111	3.174	3.238	3.301	3.365	3.429	3.492	3.556	3.620	3.685	50
60	3.685	3.749	3.813	3.877	3.942	4.006	4.071	4.136	4.200	4.265	4.330	60
70	4.330	4.395	4.460	4.526	4.591	4.656	4.722	4.788	4.853	4.919	4.985	70
80	4.985	5.051	5.117	5.183	5.249	5.315	5.382	5.448	5.514	5.581	5.648	80
90	5.648	5.714	5.781	5.848	5.915	5.982	6.049	6.117	6.184	6.251	6.319	90
100	6.319	6.386	6.454	6.522	6.590	6.658	6.725	6.794	6.862	6.930	6.998	100
110	6.998	7.066	7.135	7.203	7.272	7.341	7.409	7.478	7.547	7.616	7.685	110
120	7.685	7.754	7.823	7.892	7.962	8.031	8.101	8.170	8.240	8.309	8.379	120
130	8.379	8.449	8.519	8.589	8.659	8.729	8.799	8.869	8.940	9.010	9.081	130
140	9.081	9.151	9.222	9.292	9.363	9.434	9.505	9.576	9.647	9.718	9.789	140
150	9.789	9.860	9.931	10.003	10.074	10.145	10.217	10.288	10.360	10.432	10.503	150
160	10.503	10.575	10.647	10.719	10.791	10.863	10.935	11.007	11.080	11.152	11.224	160
170	11.224	11.297	11.369	11.442	11.514	11.587	11.660	11.733	11.805	11.878	11.951	170
180	11.951	12.024	12.097	12.170	12.243	12.317	12.390	12.463	12.537	12.610	12.684	180
190	12.684	12.757	12.831	12.904	12.978	13.052	13.126	13.199	13.273	13.347	13.421	190
200	13.421	13.495	13.569	13.644	13.718	13.792	13.866	13.941	14.015	14.090	14.164	200
210	14.164	14.239	14.313	14.388	14.463	14.537	14.612	14.687	14.762	14.837	14.912	210
220	14.912	14.987	15.062	15.137	15.212	15.287	15.362	15.438	15.513	15.588	15.664	220
230	15.664	15.739	15.815	15.890	15.966	16.041	16.117	16.193	16.269	16.344	16.420	230
240	16.420	16.496	16.572	16.648	16.724	16.800	16.876	16.952	17.028	17.104	17.181	240
250	17.181	17.257	17.333	17.409	17.486	17.562	17.639	17.715	17.792	17.868	17.945	250
260	17.945	18.021	18.098	18.175	18.252	18.328	18.405	18.482	18.559	18.636	18.713	260
270	18.713	18.790	18.867	18.944	19.021	19.098	19.175	19.252	19.330	19.407	19.484	270
280	19.484	19.561	19.639	19.716	19.794	19.871	19.948	20.026	20.103	20.181	20.259	280
290	20.259	20.336	20.414	20.492	20.569	20.647	20.725	20.803	20.880	20.958	21.036	290
300	21.036	21.114	21.192	21.270	21.348	21.426	21.504	21.582	21.660	21.739	21.817	300
310	21.817	21.895	21.973	22.051	22.130	22.208	22.286	22.365	22.443	22.522	22.600	310
320	22.600	22.678	22.757	22.835	22.914	22.993	23.071	23.150	23.228	23.307	23.386	320
330	23.386	23.464	23.543	23.622	23.701	23.780	23.858	23.937	24.016	24.095	24.174	330
340	24.174	24.253	24.332	24.411	24.490	24.569	24.648	24.727	24.806	24.885	24.964	340
°C	0	1	2	3	4	5	6	7	8	9	10	°C

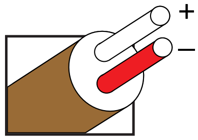
°C	0	1	2	3	4	5	6	7	8	9	10	°C
350	24.964	25.044	25.123	25.202	25.281	25.360	25.440	25.519	25.598	25.678	25.757	350
360	25.757	25.836	25.916	25.995	26.075	26.154	26.233	26.313	26.392	26.472	26.552	360
370	26.552	26.631	26.711	26.790	26.870	26.950	27.029	27.109	27.189	27.268	27.348	370
380	27.348	27.428	27.507	27.587	27.667	27.747	27.827	27.907	27.986	28.066	28.146	380
390	28.146	28.226	28.306	28.386	28.466	28.546	28.626	28.706	28.786	28.866	28.946	390
400	28.946	29.026	29.106	29.186	29.266	29.346	29.427	29.507	29.587	29.667	29.747	400
410	29.747	29.827	29.908	29.988	30.068	30.148	30.229	30.309	30.389	30.470	30.550	410
420	30.550	30.630	30.711	30.791	30.871	30.952	31.032	31.112	31.193	31.273	31.354	420
430	31.354	31.434	31.515	31.595	31.676	31.756	31.837	31.917	31.998	32.078	32.159	430
440	32.159	32.239	32.320	32.400	32.481	32.562	32.642	32.723	32.803	32.884	32.965	440
450	32.965	33.045	33.126	33.207	33.287	33.368	33.449	33.529	33.610	33.691	33.772	450
460	33.772	33.852	33.933	34.014	34.095	34.175	34.256	34.337	34.418	34.498	34.579	460
470	34.579	34.660	34.741	34.822	34.902	34.983	35.064	35.145	35.226	35.307	35.387	470
480	35.387	35.468	35.549	35.630	35.711	35.792	35.873	35.954	36.034	36.115	36.196	480
490	36.196	36.277	36.358	36.439	36.520	36.601	36.682	36.763	36.843	36.924	37.005	490
500	37.005	37.086	37.167	37.248	37.329	37.410	37.491	37.572	37.653	37.734	37.815	500
510	37.815	37.896	37.977	38.058	38.139	38.220	38.300	38.381	38.462	38.543	38.624	510
520	38.624	38.705	38.786	38.867	38.948	39.029	39.110	39.191	39.272	39.353	39.434	520
530	39.434	39.515	39.596	39.677	39.758	39.839	39.920	40.001	40.082	40.163	40.243	530
540	40.243	40.324	40.405	40.486	40.567	40.648	40.729	40.810	40.891	40.972	41.053	540
550	41.053	41.134	41.215	41.296	41.377	41.457	41.538	41.619	41.700	41.781	41.862	550
560	41.862	41.943	42.024	42.105	42.185	42.266	42.347	42.428	42.509	42.590	42.671	560
570	42.671	42.751	42.832	42.913	42.994	43.075	43.156	43.236	43.317	43.398	43.479	570
580	43.479	43.560	43.640	43.721	43.802	43.883	43.963	44.044	44.125	44.206	44.286	580
590	44.286	44.367	44.448	44.529	44.609	44.690	44.771	44.851	44.932	45.013	45.093	590
600	45.093	45.174	45.255	45.335	45.416	45.497	45.577	45.658	45.738	45.819	45.900	600
610	45.900	45.980	46.061	46.141	46.222	46.302	46.383	46.463	46.544	46.624	46.705	610
620	46.705	46.785	46.866	46.946	47.027	47.107	47.188	47.268	47.349	47.429	47.509	620
630	47.509	47.590	47.670	47.751	47.831	47.911	47.992	48.072	48.152	48.233	48.313	630
640	48.313	48.393	48.474	48.554	48.634	48.715	48.795	48.875	48.955	49.035	49.116	640
650	49.116	49.196	49.276	49.356	49.436	49.517	49.597	49.677	49.757	49.837	49.917	650
660	49.917	49.997	50.077	50.157	50.238	50.318	50.398	50.478	50.558	50.638	50.718	660
670	50.718	50.798	50.878	50.958	51.038	51.118	51.197	51.277	51.357	51.437	51.517	670
680	51.517	51.597	51.677	51.757	51.837	51.916	51.996	52.076	52.156	52.236	52.315	680
690	52.315	52.395	52.475	52.555	52.634	52.714	52.794	52.873	52.953	53.033	53.112	690
700	53.112	53.192	53.272	53.351	53.431	53.510	53.590	53.670	53.749	53.829	53.908	700
710	53.908	53.988	54.067	54.147	54.226	54.306	54.385	54.465	54.544	54.624	54.703	710
720	54.703	54.782	54.862	54.941	55.021	55.100	55.179	55.259	55.338	55.417	55.497	720
730	55.497	55.576	55.655	55.734	55.814	55.893	55.972	56.051	56.131	56.210	56.289	730
740	56.289	56.368	56.447	56.526	56.606	56.685	56.764	56.843	56.922	57.001	57.080	740
750	57.080	57.159	57.238	57.317	57.396	57.475	57.554	57.633	57.712	57.791	57.870	750
760	57.870	57.949	58.028	58.107	58.186	58.265	58.343	58.422	58.501	58.580	58.659	760
770	58.659	58.738	58.816	58.895	58.974	59.053	59.131	59.210	59.289	59.367	59.446	770
780	59.446	59.525	59.604	59.682	59.761	59.839	59.918	59.997	60.075	60.154	60.232	780
790	60.232	60.311	60.390	60.468	60.547	60.625	60.704	60.782	60.860	60.939	61.017	790
800	61.017	61.096	61.174	61.253	61.331	61.409	61.488	61.566	61.644	61.723	61.801	800
810	61.801	61.879	61.958	62.036	62.114	62.192	62.271	62.349	62.427	62.505	62.583	810
820	62.583	62.662	62.740	62.818	62.896	62.974	63.052	63.130	63.208	63.286	63.364	820
830	63.364	63.442	63.520	63.598	63.676	63.754	63.832	63.910	63.988	64.066	64.144	830
840	64.144	64.222	64.300	64.377	64.455	64.533	64.611	64.689	64.766	64.844	64.922	840
850	64.922	65.000	65.077	65.155	65.233	65.310	65.388	65.465	65.543	65.621	65.698	850
860	65.698	65.776	65.853	65.931	66.008	66.086	66.163	66.241	66.318	66.396	66.473	860
870	66.473	66.550	66.628	66.705	66.782	66.860	66.937	67.014	67.092	67.169	67.246	870
880	67.246	67.323	67.400	67.478	67.555	67.632	67.709	67.786	67.863	67.940	68.017	880
890	68.017	68.094	68.171	68.248	68.325	68.402	68.479	68.556	68.633	68.710	68.787	890
900	68.787	68.863	68.940	69.017	69.094	69.171	69.247	69.324	69.401	69.477	69.554	900
910	69.554	69.631	69.707	69.784	69.860	69.937	70.013	70.090	70.166	70.243	70.319	910
920	70.319	70.396	70.472	70.548	70.625	70.701	70.777	70.854	70.930	71.006	71.082	920
930	71.082	71.159	71.235	71.311	71.387	71.463	71.539	71.615	71.692	71.768	71.844	930
940	71.844	71.920	71.996	72.072	72.147	72.223	72.299	72.375	72.451	72.527	72.603	940
950	72.603	72.678	72.754	72.830	72.906	72.981	73.057	73.133	73.208	73.284	73.360	950
960	73.360	73.435	73.511	73.586	73.662	73.738	73.813	73.889	73.964	74.040	74.115	960
970	74.115	74.190	74.266	74.341	74.417	74.492	74.567	74.643	74.718	74.793	74.869	970
980	74.869	74.944	75.019	75.095	75.170	75.245	75.320	75.395	75.471	75.546	75.621	980
990	75.621	75.696	75.771	75.847	75.922	75.997	76.072	76.147	76.223	76.298	76.373	990
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

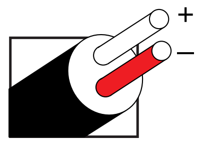
TYPE J

Reference Tables
N.I.S.T. Monograph 175
Revised to ITS-90

Thermocouple Grade



Iron vs. Copper-Nickel



Extension Grade

MAXIMUM TEMPERATURE RANGE

Thermocouple Grade
32 to 1382°F
0 to 750°C

Extension Grade
32 to 392°F
0 to 200°C

LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75%
Special: 1.1°C or 0.4%

COMMENTS, BARE WIRE ENVIRONMENT:
Reducing, Vacuum, Inert; Limited Use in Oxidizing at High Temperatures; Not Recommended for Low Temperatures

TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

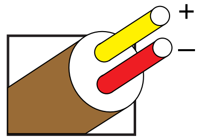
Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-200	-8.095	-8.076	-8.057	-8.037	-8.017	-7.996	-7.976	-7.955	-7.934	-7.912	-7.890	-200
-190	-7.890	-7.868	-7.846	-7.824	-7.801	-7.778	-7.755	-7.731	-7.707	-7.683	-7.659	-190
-180	-7.659	-7.634	-7.610	-7.585	-7.559	-7.534	-7.508	-7.482	-7.456	-7.429	-7.403	-180
-170	-7.403	-7.376	-7.348	-7.321	-7.293	-7.265	-7.237	-7.209	-7.181	-7.152	-7.123	-170
-160	-7.123	-7.094	-7.064	-7.035	-7.005	-6.975	-6.944	-6.914	-6.883	-6.853	-6.821	-160
-150	-6.821	-6.790	-6.759	-6.727	-6.695	-6.663	-6.631	-6.598	-6.566	-6.533	-6.500	-150
-140	-6.500	-6.467	-6.433	-6.400	-6.366	-6.332	-6.298	-6.263	-6.229	-6.194	-6.159	-140
-130	-6.159	-6.124	-6.089	-6.054	-6.018	-5.982	-5.946	-5.910	-5.874	-5.838	-5.801	-130
-120	-5.801	-5.764	-5.727	-5.690	-5.653	-5.616	-5.578	-5.541	-5.503	-5.465	-5.426	-120
-110	-5.426	-5.388	-5.350	-5.311	-5.272	-5.233	-5.194	-5.155	-5.116	-5.076	-5.037	-110
-100	-5.037	-4.997	-4.957	-4.917	-4.877	-4.836	-4.796	-4.755	-4.714	-4.674	-4.633	-100
-90	-4.633	-4.591	-4.550	-4.509	-4.467	-4.425	-4.384	-4.342	-4.300	-4.257	-4.215	-90
-80	-4.215	-4.173	-4.130	-4.088	-4.045	-4.002	-3.959	-3.916	-3.872	-3.829	-3.786	-80
-70	-3.786	-3.742	-3.698	-3.654	-3.610	-3.566	-3.522	-3.478	-3.434	-3.389	-3.344	-70
-60	-3.344	-3.300	-3.255	-3.210	-3.165	-3.120	-3.075	-3.029	-2.984	-2.938	-2.893	-60
-50	-2.893	-2.847	-2.801	-2.755	-2.709	-2.663	-2.617	-2.571	-2.524	-2.478	-2.431	-50
-40	-2.431	-2.385	-2.338	-2.291	-2.244	-2.197	-2.150	-2.103	-2.055	-2.008	-1.961	-40
-30	-1.961	-1.913	-1.865	-1.818	-1.770	-1.722	-1.674	-1.626	-1.578	-1.530	-1.482	-30
-20	-1.482	-1.433	-1.385	-1.336	-1.288	-1.239	-1.190	-1.142	-1.093	-1.044	-0.995	-20
-10	-0.995	-0.946	-0.896	-0.847	-0.798	-0.749	-0.699	-0.650	-0.600	-0.550	-0.501	-10
0	-0.501	-0.451	-0.401	-0.351	-0.301	-0.251	-0.201	-0.151	-0.101	-0.050	0.000	0

°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.050	0.101	0.151	0.202	0.253	0.303	0.354	0.405	0.456	0.507	0
10	0.507	0.558	0.609	0.660	0.711	0.762	0.814	0.865	0.916	0.968	1.019	10
20	1.019	1.071	1.122	1.174	1.226	1.277	1.329	1.381	1.433	1.485	1.537	20
30	1.537	1.589	1.641	1.693	1.745	1.797	1.849	1.902	1.954	2.006	2.059	30
40	2.059	2.111	2.164	2.216	2.269	2.322	2.374	2.427	2.480	2.532	2.585	40
50	2.585	2.638	2.691	2.744	2.797	2.850	2.903	2.956	3.009	3.062	3.116	50
60	3.116	3.169	3.222	3.275	3.329	3.382	3.436	3.489	3.543	3.596	3.650	60
70	3.650	3.703	3.757	3.810	3.864	3.918	3.971	4.025	4.079	4.133	4.187	70
80	4.187	4.240	4.294	4.348	4.402	4.456	4.510	4.564	4.618	4.672	4.726	80
90	4.726	4.781	4.835	4.889	4.943	4.997	5.052	5.106	5.160	5.215	5.269	90
100	5.269	5.323	5.378	5.432	5.487	5.541	5.595	5.650	5.705	5.759	5.814	100
110	5.814	5.868	5.923	5.977	6.032	6.087	6.141	6.196	6.251	6.306	6.360	110
120	6.360	6.415	6.470	6.525	6.579	6.634	6.689	6.744	6.799	6.854	6.909	120
130	6.909	6.964	7.019	7.074	7.129	7.184	7.239	7.294	7.349	7.404	7.459	130
140	7.459	7.514	7.569	7.624	7.679	7.734	7.789	7.844	7.900	7.955	8.010	140
150	8.010	8.065	8.120	8.175	8.231	8.286	8.341	8.396	8.452	8.507	8.562	150
160	8.562	8.618	8.673	8.728	8.783	8.839	8.894	8.949	9.005	9.060	9.115	160
170	9.115	9.171	9.226	9.282	9.337	9.392	9.448	9.503	9.559	9.614	9.669	170
180	9.669	9.725	9.780	9.836	9.891	9.947	10.002	10.057	10.113	10.168	10.224	180
190	10.224	10.279	10.335	10.390	10.446	10.501	10.557	10.612	10.668	10.723	10.779	190
200	10.779	10.834	10.890	10.945	11.001	11.056	11.112	11.167	11.223	11.278	11.334	200
210	11.334	11.389	11.445	11.501	11.556	11.612	11.667	11.723	11.778	11.834	11.889	210
220	11.889	11.945	12.000	12.056	12.111	12.167	12.222	12.278	12.334	12.389	12.445	220
230	12.445	12.500	12.556	12.611	12.667	12.722	12.778	12.833	12.889	12.944	13.000	230
240	13.000	13.056	13.111	13.167	13.222	13.278	13.333	13.389	13.444	13.500	13.555	240
250	13.555	13.611	13.666	13.722	13.777	13.833	13.888	13.944	13.999	14.055	14.110	250
260	14.110	14.166	14.221	14.277	14.332	14.388	14.443	14.499	14.554	14.609	14.665	260
270	14.665	14.720	14.776	14.831	14.887	14.942	14.998	15.053	15.109	15.164	15.219	270
280	15.219	15.275	15.330	15.386	15.441	15.496	15.552	15.607	15.663	15.718	15.773	280
290	15.773	15.829	15.884	15.940	15.995	16.050	16.106	16.161	16.216	16.272	16.327	290
300	16.327	16.383	16.438	16.493	16.549	16.604	16.659	16.715	16.770	16.825	16.881	300
310	16.881	16.936	16.991	17.046	17.102	17.157	17.212	17.268	17.323	17.378	17.434	310
320	17.434	17.489	17.544	17.599	17.655	17.710	17.765	17.820	17.876	17.931	17.986	320
330	17.986	18.041	18.097	18.152	18.207	18.262	18.318	18.373	18.428	18.483	18.538	330
340	18.538	18.594	18.649	18.704	18.759	18.814	18.870	18.925	18.980	19.035	19.090	340
350	19.090	19.146	19.201	19.256	19.311	19.366	19.422	19.477	19.532	19.587	19.642	350
360	19.642	19.697	19.753	19.808	19.863	19.918	19.973	20.028	20.083	20.139	20.194	360
370	20.194	20.249	20.304	20.359	20.414	20.469	20.525	20.580	20.635	20.690	20.745	370
380	20.745	20.800	20.855	20.911	20.966	21.021	21.076	21.131	21.186	21.241	21.297	380
390	21.297	21.352	21.407	21.462	21.517	21.572	21.627	21.683	21.738	21.793	21.848	390
400	21.848	21.903	21.958	22.014	22.069	22.124	22.179	22.234	22.289	22.345	22.400	400
410	22.400	22.455	22.510	22.565	22.620	22.676	22.731	22.786	22.841	22.896	22.952	410
420	22.952	23.007	23.062	23.117	23.172	23.228	23.283	23.338	23.393	23.449	23.504	420
430	23.504	23.559	23.614	23.670	23.725	23.780	23.835	23.891	23.946	24.001	24.057	430
440	24.057	24.112	24.167	24.223	24.278	24.333	24.389	24.444	24.499	24.555	24.610	440
450	24.610	24.665	24.721	24.776	24.832	24.887	24.943	24.998	25.053	25.109	25.164	450
460	25.164	25.220	25.275	25.331	25.386	25.442	25.497	25.553	25.608	25.664	25.720	460
470	25.720	25.775	25.831	25.886	25.942	25.998	26.053	26.109	26.165	26.220	26.276	470
480	26.276	26.332	26.387	26.443	26.499	26.555	26.610	26.666	26.722	26.778	26.834	480
490	26.834	26.889	26.945	27.001	27.057	27.113	27.169	27.225	27.281	27.337	27.393	490
°C	0	1	2	3	4	5	6	7	8	9	10	°C

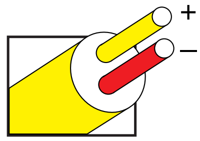
°C	0	1	2	3	4	5	6	7	8	9	10	°C
500	27.393	27.449	27.505	27.561	27.617	27.673	27.729	27.785	27.841	27.897	27.953	500
510	27.953	28.010	28.066	28.122	28.178	28.234	28.291	28.347	28.403	28.460	28.516	510
520	28.516	28.572	28.629	28.685	28.741	28.798	28.854	28.911	28.967	29.024	29.080	520
530	29.080	29.137	29.194	29.250	29.307	29.363	29.420	29.477	29.534	29.590	29.647	530
540	29.647	29.704	29.761	29.818	29.874	29.931	29.988	30.045	30.102	30.159	30.216	540
550	30.216	30.273	30.330	30.387	30.444	30.502	30.559	30.616	30.673	30.730	30.788	550
560	30.788	30.845	30.902	30.960	31.017	31.074	31.132	31.189	31.247	31.304	31.362	560
570	31.362	31.419	31.477	31.535	31.592	31.650	31.708	31.766	31.823	31.881	31.939	570
580	31.939	31.997	32.055	32.113	32.171	32.229	32.287	32.345	32.403	32.461	32.519	580
590	32.519	32.577	32.636	32.694	32.752	32.810	32.869	32.927	32.985	33.044	33.102	590
600	33.102	33.161	33.219	33.278	33.337	33.395	33.454	33.513	33.571	33.630	33.689	600
610	33.689	33.748	33.807	33.866	33.925	33.984	34.043	34.102	34.161	34.220	34.279	610
620	34.279	34.338	34.397	34.457	34.516	34.575	34.635	34.694	34.754	34.813	34.873	620
630	34.873	34.932	34.992	35.051	35.111	35.171	35.230	35.290	35.350	35.410	35.470	630
640	35.470	35.530	35.590	35.650	35.710	35.770	35.830	35.890	35.950	36.010	36.071	640
650	36.071	36.131	36.191	36.252	36.312	36.373	36.433	36.494	36.554	36.615	36.675	650
660	36.675	36.736	36.797	36.858	36.918	36.979	37.040	37.101	37.162	37.223	37.284	660
670	37.284	37.345	37.406	37.467	37.528	37.590	37.651	37.712	37.773	37.835	37.896	670
680	37.896	37.958	38.019	38.081	38.142	38.204	38.265	38.327	38.389	38.450	38.512	680
690	38.512	38.574	38.636	38.698	38.760	38.822	38.884	38.946	39.008	39.070	39.132	690
700	39.132	39.194	39.256	39.318	39.381	39.443	39.505	39.568	39.630	39.693	39.755	700
710	39.755	39.818	39.880	39.943	40.005	40.068	40.131	40.193	40.256	40.319	40.382	710
720	40.382	40.445	40.508	40.570	40.633	40.696	40.759	40.822	40.886	40.949	41.012	720
730	41.012	41.075	41.138	41.201	41.265	41.328	41.391	41.455	41.518	41.581	41.645	730
740	41.645	41.708	41.772	41.835	41.899	41.962	42.026	42.090	42.153	42.217	42.281	740
750	42.281	42.344	42.408	42.472	42.536	42.599	42.663	42.727	42.791	42.855	42.919	750
760	42.919	42.983	43.047	43.111	43.175	43.239	43.303	43.367	43.431	43.495	43.559	760
770	43.559	43.624	43.688	43.752	43.817	43.881	43.945	44.010	44.074	44.139	44.203	770
780	44.203	44.267	44.332	44.396	44.461	44.525	44.590	44.655	44.719	44.784	44.848	780
790	44.848	44.913	44.977	45.042	45.107	45.171	45.236	45.301	45.365	45.430	45.494	790
800	45.494	45.559	45.624	45.688	45.753	45.818	45.882	45.947	46.011	46.076	46.141	800
810	46.141	46.205	46.270	46.334	46.399	46.464	46.528	46.593	46.657	46.722	46.786	810
820	46.786	46.851	46.915	46.980	47.044	47.109	47.173	47.238	47.302	47.367	47.431	820
830	47.431	47.495	47.560	47.624	47.688	47.753	47.817	47.881	47.946	48.010	48.074	830
840	48.074	48.138	48.202	48.267	48.331	48.395	48.459	48.523	48.587	48.651	48.715	840
850	48.715	48.779	48.843	48.907	48.971	49.034	49.098	49.162	49.226	49.290	49.353	850
860	49.353	49.417	49.481	49.544	49.608	49.672	49.735	49.799	49.862	49.926	49.989	860
870	49.989	50.052	50.116	50.179	50.243	50.306	50.369	50.432	50.495	50.559	50.622	870
880	50.622	50.685	50.748	50.811	50.874	50.937	51.000	51.063	51.126	51.188	51.251	880
890	51.251	51.314	51.377	51.439	51.502	51.565	51.627	51.690	51.752	51.815	51.877	890
900	51.877	51.940	52.002	52.064	52.127	52.189	52.251	52.314	52.376	52.438	52.500	900
910	52.500	52.562	52.624	52.686	52.748	52.810	52.872	52.934	52.996	53.057	53.119	910
920	53.119	53.181	53.243	53.304	53.366	53.427	53.489	53.550	53.612	53.673	53.735	920
930	53.735	53.796	53.857	53.919	53.980	54.041	54.102	54.164	54.225	54.286	54.347	930
940	54.347	54.408	54.469	54.530	54.591	54.652	54.713	54.773	54.834	54.895	54.956	940
950	54.956	55.016	55.077	55.138	55.198	55.259	55.319	55.380	55.440	55.501	55.561	950
960	55.561	55.622	55.682	55.742	55.803	55.863	55.923	55.983	56.043	56.104	56.164	960
970	56.164	56.224	56.284	56.344	56.404	56.464	56.524	56.584	56.643	56.703	56.763	970
980	56.763	56.823	56.883	56.942	57.002	57.062	57.121	57.181	57.240	57.300	57.360	980
990	57.360	57.419	57.479	57.538	57.597	57.657	57.716	57.776	57.835	57.894	57.953	990
1000	57.953	58.013	58.072	58.131	58.190	58.249	58.309	58.368	58.427	58.486	58.545	1000
1010	58.545	58.604	58.663	58.722	58.781	58.840	58.899	58.957	59.016	59.075	59.134	1010
1020	59.134	59.193	59.252	59.310	59.369	59.428	59.487	59.545	59.604	59.663	59.721	1020
1030	59.721	59.780	59.838	59.897	59.956	60.014	60.073	60.131	60.190	60.248	60.307	1030
1040	60.307	60.365	60.423	60.482	60.540	60.599	60.657	60.715	60.774	60.832	60.890	1040
1050	60.890	60.949	61.007	61.065	61.123	61.182	61.240	61.298	61.356	61.415	61.473	1050
1060	61.473	61.531	61.589	61.647	61.705	61.763	61.822	61.880	61.938	61.996	62.054	1060
1070	62.054	62.112	62.170	62.228	62.286	62.344	62.402	62.460	62.518	62.576	62.634	1070
1080	62.634	62.692	62.750	62.808	62.866	62.924	62.982	63.040	63.098	63.156	63.214	1080
1090	63.214	63.271	63.329	63.387	63.445	63.503	63.561	63.619	63.677	63.734	63.792	1090
1100	63.792	63.850	63.908	63.966	64.024	64.081	64.139	64.197	64.255	64.313	64.370	1100
1110	64.370	64.428	64.486	64.544	64.602	64.659	64.717	64.775	64.833	64.890	64.948	1110
1120	64.948	65.006	65.064	65.121	65.179	65.237	65.295	65.352	65.410	65.468	65.525	1120
1130	65.525	65.583	65.641	65.699	65.756	65.814	65.872	65.929	65.987	66.045	66.102	1130
1140	66.102	66.160	66.218	66.275	66.333	66.391	66.448	66.506	66.564	66.621	66.679	1140
1150	66.679	66.737	66.794	66.852	66.910	66.967	67.025	67.082	67.140	67.198	67.255	1150
1160	67.255	67.313	67.370	67.428	67.486	67.543	67.601	67.658	67.716	67.773	67.831	1160
1170	67.831	67.888	67.946	68.003	68.061	68.119	68.176	68.234	68.291	68.348	68.406	1170
1180	68.406	68.463	68.521	68.578	68.636	68.693	68.751	68.808	68.865	68.923	68.980	1180
1190	68.980	69.037	69.095	69.152	69.209	69.267	69.324	69.381	69.439	69.496	69.553	1190
°C	0	1	2	3	4	5	6	7	8	9	10	°C

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
– 328 to 2282°F
– 200 to 1250°C
Extension Grade
32 to 392°F
0 to 200°C
LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75% Above 0°C
2.2°C or 2.0% Below 0°C
Special: 1.1°C or 0.4%
COMMENTS, BARE WIRE ENVIRONMENT:
Clean Oxidizing and Inert; Limited Use in Vacuum or Reducing; Wide Temperature Range; Most Popular Calibration
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

Nickel-Chromium vs. Nickel-Aluminum



Extension Grade

Revised Thermocouple Reference Tables

TYPE K

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

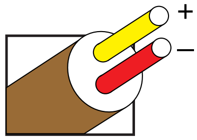
°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-260	-6.458	-6.457	-6.456	-6.455	-6.453	-6.452	-6.450	-6.448	-6.446	-6.444	-6.441	-260
-250	-6.441	-6.438	-6.435	-6.432	-6.429	-6.425	-6.421	-6.417	-6.413	-6.408	-6.404	-250
-240	-6.404	-6.399	-6.393	-6.388	-6.382	-6.377	-6.370	-6.364	-6.358	-6.351	-6.344	-240
-230	-6.344	-6.337	-6.329	-6.322	-6.314	-6.306	-6.297	-6.289	-6.280	-6.271	-6.262	-230
-220	-6.262	-6.252	-6.243	-6.233	-6.223	-6.213	-6.202	-6.192	-6.181	-6.170	-6.158	-220
-210	-6.158	-6.147	-6.135	-6.123	-6.111	-6.099	-6.087	-6.074	-6.061	-6.048	-6.035	-210
-200	-6.035	-6.021	-6.007	-5.994	-5.980	-5.965	-5.951	-5.936	-5.922	-5.907	-5.891	-200
-190	-5.891	-5.876	-5.861	-5.845	-5.829	-5.813	-5.797	-5.780	-5.763	-5.747	-5.730	-190
-180	-5.730	-5.713	-5.695	-5.678	-5.660	-5.642	-5.624	-5.606	-5.588	-5.569	-5.550	-180
-170	-5.550	-5.531	-5.512	-5.493	-5.474	-5.454	-5.435	-5.415	-5.395	-5.374	-5.354	-170
-160	-5.354	-5.333	-5.313	-5.292	-5.271	-5.250	-5.228	-5.207	-5.185	-5.163	-5.141	-160
-150	-5.141	-5.119	-5.097	-5.074	-5.052	-5.029	-5.006	-4.983	-4.960	-4.936	-4.913	-150
-140	-4.913	-4.889	-4.865	-4.841	-4.817	-4.793	-4.768	-4.744	-4.719	-4.694	-4.669	-140
-130	-4.669	-4.644	-4.618	-4.593	-4.567	-4.542	-4.516	-4.490	-4.463	-4.437	-4.411	-130
-120	-4.411	-4.384	-4.357	-4.330	-4.303	-4.276	-4.249	-4.221	-4.194	-4.166	-4.138	-120
-110	-4.138	-4.110	-4.082	-4.054	-4.025	-3.997	-3.968	-3.939	-3.911	-3.882	-3.852	-110
-100	-3.852	-3.823	-3.794	-3.764	-3.734	-3.705	-3.675	-3.645	-3.614	-3.584	-3.554	-100
-90	-3.554	-3.523	-3.492	-3.462	-3.431	-3.400	-3.368	-3.337	-3.306	-3.274	-3.243	-90
-80	-3.243	-3.211	-3.179	-3.147	-3.115	-3.083	-3.050	-3.018	-2.986	-2.953	-2.920	-80
-70	-2.920	-2.887	-2.854	-2.821	-2.788	-2.755	-2.721	-2.688	-2.654	-2.620	-2.587	-70
-60	-2.587	-2.553	-2.519	-2.485	-2.450	-2.416	-2.382	-2.347	-2.312	-2.278	-2.243	-60
-50	-2.243	-2.208	-2.173	-2.138	-2.103	-2.067	-2.032	-1.996	-1.961	-1.925	-1.889	-50
-40	-1.889	-1.854	-1.818	-1.782	-1.745	-1.709	-1.673	-1.637	-1.600	-1.564	-1.527	-40
-30	-1.527	-1.490	-1.453	-1.417	-1.380	-1.343	-1.305	-1.268	-1.231	-1.194	-1.156	-30
-20	-1.156	-1.119	-1.081	-1.043	-1.006	-0.968	-0.930	-0.892	-0.854	-0.816	-0.778	-20
-10	-0.778	-0.739	-0.701	-0.663	-0.624	-0.586	-0.547	-0.508	-0.470	-0.431	-0.392	-10
0	-0.392	-0.353	-0.314	-0.275	-0.236	-0.197	-0.157	-0.118	-0.079	-0.039	0.000	0
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397	0
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798	10
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.163	1.203	20
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.530	1.571	1.612	30
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023	40
50	2.023	2.064	2.106	2.147	2.188	2.230	2.271	2.312	2.354	2.395	2.436	50
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.810	2.851	60
70	2.851	2.893	2.934	2.976	3.017	3.059	3.100	3.142	3.184	3.225	3.267	70
80	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682	80
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.013	4.055	4.096	90
100	4.096	4.138	4.179	4.220	4.262	4.303	4.344	4.385	4.427	4.468	4.509	100
110	4.509	4.550	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.920	110
120	4.920	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.328	120
130	5.328	5.369	5.410	5.450	5.491	5.532	5.572	5.613	5.653	5.694	5.735	130
140	5.735	5.775	5.815	5.856	5.896	5.937	5.977	6.017	6.058	6.098	6.138	140
150	6.138	6.179	6.219	6.259	6.299	6.339	6.380	6.420	6.460	6.500	6.540	150
160	6.540	6.580	6.620	6.660	6.701	6.741	6.781	6.821	6.861	6.901	6.941	160
170	6.941	6.981	7.021	7.060	7.100	7.140	7.180	7.220	7.260	7.300	7.340	170
180	7.340	7.380	7.420	7.460	7.500	7.540	7.579	7.619	7.659	7.699	7.739	180
190	7.739	7.779	7.819	7.859	7.899	7.939	7.979	8.019	8.059	8.099	8.138	190
200	8.138	8.178	8.218	8.258	8.298	8.338	8.378	8.418	8.458	8.499	8.539	200
210	8.539	8.579	8.619	8.659	8.699	8.739	8.779	8.819	8.860	8.900	8.940	210
220	8.940	8.980	9.020	9.061	9.101	9.141	9.181	9.222	9.262	9.302	9.343	220
230	9.343	9.383	9.423	9.464	9.504	9.545	9.585	9.626	9.666	9.707	9.747	230
240	9.747	9.788	9.828	9.869	9.909	9.950	9.991	10.031	10.072	10.113	10.153	240
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
250	10.153	10.194	10.235	10.276	10.316	10.357	10.398	10.439	10.480	10.520	10.561	250
260	10.561	10.602	10.643	10.684	10.725	10.766	10.807	10.848	10.889	10.930	10.971	260
270	10.971	11.012	11.053	11.094	11.135	11.176	11.217	11.259	11.300	11.341	11.382	270
280	11.382	11.423	11.465	11.506	11.547	11.588	11.630	11.671	11.712	11.753	11.795	280
290	11.795	11.836	11.877	11.919	11.960	12.001	12.043	12.084	12.126	12.167	12.209	290
300	12.209	12.250	12.291	12.333	12.374	12.416	12.457	12.499	12.540	12.582	12.624	300
310	12.624	12.665	12.707	12.748	12.790	12.831	12.873	12.915	12.956	12.998	13.040	310
320	13.040	13.081	13.123	13.165	13.206	13.248	13.290	13.331	13.373	13.415	13.457	320
330	13.457	13.498	13.540	13.582	13.624	13.665	13.707	13.749	13.791	13.833	13.874	330
340	13.874	13.916	13.958	14.000	14.042	14.084	14.126	14.167	14.209	14.251	14.293	340
350	14.293	14.335	14.377	14.419	14.461	14.503	14.545	14.587	14.629	14.671	14.713	350
360	14.713	14.755	14.797	14.839	14.881	14.923	14.965	15.007	15.049	15.091	15.133	360
370	15.133	15.175	15.217	15.259	15.301	15.343	15.385	15.427	15.469	15.511	15.554	370
380	15.554	15.596	15.638	15.680	15.722	15.764	15.806	15.849	15.891	15.933	15.975	380
390	15.975	16.017	16.059	16.102	16.144	16.186	16.228	16.270	16.313	16.355	16.397	390
400	16.397	16.439	16.482	16.524	16.566	16.608	16.651	16.693	16.735	16.778	16.820	400
410	16.820	16.862	16.904	16.947	16.989	17.031	17.074	17.116	17.158	17.201	17.243	410
420	17.243	17.285	17.328	17.370	17.413	17.455	17.497	17.540	17.582	17.624	17.667	420
430	17.667	17.709	17.752	17.794	17.837	17.879	17.921	17.964	18.006	18.049	18.091	430
440	18.091	18.134	18.176	18.218	18.261	18.303	18.346	18.388	18.431	18.473	18.516	440
450	18.516	18.558	18.601	18.643	18.686	18.728	18.771	18.813	18.856	18.898	18.941	450
460	18.941	18.983	19.026	19.068	19.111	19.154	19.196	19.239	19.281	19.324	19.366	460
470	19.366	19.409	19.451	19.494	19.537	19.579	19.622	19.664	19.707	19.750	19.792	470
480	19.792	19.835	19.877	19.920	19.962	20.005	20.048	20.090	20.133	20.175	20.218	480
490	20.218	20.261	20.303	20.346	20.389	20.431	20.474	20.516	20.559	20.602	20.644	490
500	20.644	20.687	20.730	20.772	20.815	20.857	20.900	20.943	20.985	21.028	21.071	500
510	21.071	21.113	21.156	21.199	21.241	21.284	21.326	21.369	21.412	21.454	21.497	510
520	21.497	21.540	21.582	21.625	21.668	21.710	21.753	21.796	21.838	21.881	21.924	520
530	21.924	21.966	22.009	22.052	22.094	22.137	22.179	22.222	22.265	22.307	22.350	530
540	22.350	22.393	22.435	22.478	22.521	22.563	22.606	22.649	22.691	22.734	22.776	540
550	22.776	22.819	22.862	22.904	22.947	22.990	23.032	23.075	23.117	23.160	23.203	550
560	23.203	23.245	23.288	23.331	23.373	23.416	23.458	23.501	23.544	23.586	23.629	560
570	23.629	23.671	23.714	23.757	23.799	23.842	23.884	23.927	23.970	24.012	24.055	570
580	24.055	24.097	24.140	24.182	24.225	24.267	24.310	24.353	24.395	24.438	24.480	580
590	24.480	24.523	24.565	24.608	24.650	24.693	24.735	24.778	24.820	24.863	24.905	590
600	24.905	24.948	24.990	25.033	25.075	25.118	25.160	25.203	25.245	25.288	25.330	600
610	25.330	25.373	25.415	25.458	25.500	25.543	25.585	25.627	25.670	25.712	25.755	610
620	25.755	25.797	25.840	25.882	25.924	25.967	26.009	26.052	26.094	26.136	26.179	620
630	26.179	26.221	26.263	26.306	26.348	26.390	26.433	26.475	26.517	26.560	26.602	630
640	26.602	26.644	26.687	26.729	26.771	26.814	26.856	26.898	26.940	26.983	27.025	640
650	27.025	27.067	27.109	27.152	27.194	27.236	27.278	27.320	27.363	27.405	27.447	650
660	27.447	27.489	27.531	27.574	27.616	27.658	27.700	27.742	27.784	27.826	27.869	660
670	27.869	27.911	27.953	27.995	28.037	28.079	28.121	28.163	28.205	28.247	28.289	670
680	28.289	28.332	28.374	28.416	28.458	28.500	28.542	28.584	28.626	28.668	28.710	680
690	28.710	28.752	28.794	28.835	28.877	28.919	28.961	29.003	29.045	29.087	29.129	690
700	29.129	29.171	29.213	29.255	29.297	29.338	29.380	29.422	29.464	29.506	29.548	700
710	29.548	29.589	29.631	29.673	29.715	29.757	29.798	29.840	29.882	29.924	29.965	710
720	29.965	30.007	30.049	30.090	30.132	30.174	30.216	30.257	30.299	30.341	30.382	720
730	30.382	30.424	30.466	30.507	30.549	30.590	30.632	30.674	30.715	30.757	30.798	730
740	30.798	30.840	30.881	30.923	30.964	31.006	31.047	31.089	31.130	31.172	31.213	740
750	31.213	31.255	31.296	31.338	31.379	31.421	31.462	31.504	31.545	31.586	31.628	750
760	31.628	31.669	31.710	31.752	31.793	31.834	31.876	31.917	31.958	32.000	32.041	760
770	32.041	32.082	32.124	32.165	32.206	32.247	32.289	32.330	32.371	32.412	32.453	770
780	32.453	32.495	32.536	32.577	32.618	32.659	32.700	32.742	32.783	32.824	32.865	780
790	32.865	32.906	32.947	32.988	33.029	33.070	33.111	33.152	33.193	33.234	33.275	790
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

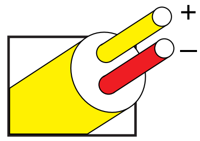
TYPE K

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90



Thermocouple Grade

Nickel-Chromium vs. Nickel-Aluminum



Extension Grade

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
– 328 to 2282°F
– 200 to 1250°C
Extension Grade
32 to 392°F
0 to 200°C

LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75% Above 0°C
2.2°C or 2.0% Below 0°C
Special: 1.1°C or 0.4%

COMMENTS, BARE WIRE ENVIRONMENT:
Clean Oxidizing and Inert; Limited Use in Vacuum or Reducing; Wide Temperature Range; Most Popular Calibration

TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
800	33.275	33.316	33.357	33.398	33.439	33.480	33.521	33.562	33.603	33.644	33.685	800
810	33.685	33.726	33.767	33.808	33.848	33.889	33.930	33.971	34.012	34.053	34.093	810
820	34.093	34.134	34.175	34.216	34.257	34.297	34.338	34.379	34.420	34.460	34.501	820
830	34.501	34.542	34.582	34.623	34.664	34.704	34.745	34.786	34.826	34.867	34.908	830
840	34.908	34.948	34.989	35.029	35.070	35.110	35.151	35.192	35.232	35.273	35.313	840
850	35.313	35.354	35.394	35.435	35.475	35.516	35.556	35.596	35.637	35.677	35.718	850
860	35.718	35.758	35.798	35.839	35.879	35.920	35.960	36.000	36.041	36.081	36.121	860
870	36.121	36.162	36.202	36.242	36.282	36.323	36.363	36.403	36.443	36.484	36.524	870
880	36.524	36.564	36.604	36.644	36.685	36.725	36.765	36.805	36.845	36.885	36.925	880
890	36.925	36.965	37.006	37.046	37.086	37.126	37.166	37.206	37.246	37.286	37.326	890
900	37.326	37.366	37.406	37.446	37.486	37.526	37.566	37.606	37.646	37.686	37.725	900
910	37.725	37.765	37.805	37.845	37.885	37.925	37.965	38.005	38.044	38.084	38.124	910
920	38.124	38.164	38.204	38.243	38.283	38.323	38.363	38.402	38.442	38.482	38.522	920
930	38.522	38.561	38.601	38.641	38.680	38.720	38.760	38.799	38.839	38.878	38.918	930
940	38.918	38.958	38.997	39.037	39.076	39.116	39.155	39.195	39.235	39.274	39.314	940
950	39.314	39.353	39.393	39.432	39.471	39.511	39.550	39.590	39.629	39.669	39.708	950
960	39.708	39.747	39.787	39.826	39.866	39.905	39.944	39.984	40.023	40.062	40.101	960
970	40.101	40.141	40.180	40.219	40.259	40.298	40.337	40.376	40.415	40.455	40.494	970
980	40.494	40.533	40.572	40.611	40.651	40.690	40.729	40.768	40.807	40.846	40.885	980
990	40.885	40.924	40.963	41.002	41.042	41.081	41.120	41.159	41.198	41.237	41.276	990
1000	41.276	41.315	41.354	41.393	41.431	41.470	41.509	41.548	41.587	41.626	41.665	1000
1010	41.665	41.704	41.743	41.781	41.820	41.859	41.898	41.937	41.976	42.014	42.053	1010
1020	42.053	42.092	42.131	42.169	42.208	42.247	42.286	42.324	42.363	42.402	42.440	1020
1030	42.440	42.479	42.518	42.556	42.595	42.633	42.672	42.711	42.749	42.788	42.826	1030
1040	42.826	42.865	42.903	42.942	42.980	43.019	43.057	43.096	43.134	43.173	43.211	1040
1050	43.211	43.250	43.288	43.327	43.365	43.403	43.442	43.480	43.518	43.557	43.595	1050
1060	43.595	43.633	43.672	43.710	43.748	43.787	43.825	43.863	43.901	43.940	43.978	1060
1070	43.978	44.016	44.054	44.092	44.130	44.169	44.207	44.245	44.283	44.321	44.359	1070
1080	44.359	44.397	44.435	44.473	44.512	44.550	44.588	44.626	44.664	44.702	44.740	1080
1090	44.740	44.778	44.816	44.853	44.891	44.929	44.967	45.005	45.043	45.081	45.119	1090
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1100	45.119	45.157	45.194	45.232	45.270	45.308	45.346	45.383	45.421	45.459	45.497	1100
1110	45.497	45.534	45.572	45.610	45.647	45.685	45.723	45.760	45.798	45.836	45.873	1110
1120	45.873	45.911	45.948	45.986	46.024	46.061	46.099	46.136	46.174	46.211	46.249	1120
1130	46.249	46.286	46.324	46.361	46.398	46.436	46.473	46.511	46.548	46.585	46.623	1130
1140	46.623	46.660	46.697	46.735	46.772	46.809	46.847	46.884	46.921	46.958	46.995	1140
1150	46.995	47.033	47.070	47.107	47.144	47.181	47.218	47.256	47.293	47.330	47.367	1150
1160	47.367	47.404	47.441	47.478	47.515	47.552	47.589	47.626	47.663	47.700	47.737	1160
1170	47.737	47.774	47.811	47.848	47.884	47.921	47.958	47.995	48.032	48.069	48.105	1170
1180	48.105	48.142	48.179	48.216	48.252	48.289	48.326	48.363	48.399	48.436	48.473	1180
1190	48.473	48.509	48.546	48.582	48.619	48.656	48.692	48.729	48.765	48.802	48.838	1190
1200	48.838	48.875	48.911	48.948	48.984	49.021	49.057	49.093	49.130	49.166	49.202	1200
1210	49.202	49.239	49.275	49.311	49.348	49.384	49.420	49.456	49.493	49.529	49.565	1210
1220	49.565	49.601	49.637	49.674	49.710	49.746	49.782	49.818	49.854	49.890	49.926	1220
1230	49.926	49.962	49.998	50.034	50.070	50.106	50.142	50.178	50.214	50.250	50.286	1230
1240	50.286	50.322	50.358	50.393	50.429	50.465	50.501	50.537	50.572	50.608	50.644	1240
1250	50.644	50.680	50.715	50.751	50.787	50.822	50.858	50.894	50.929	50.965	51.000	1250
1260	51.000	51.036	51.071	51.107	51.142	51.178	51.213	51.249	51.284	51.320	51.355	1260
1270	51.355	51.391	51.426	51.461	51.497	51.532	51.567	51.603	51.638	51.673	51.708	1270
1280	51.708	51.744	51.779	51.814	51.849	51.885	51.920	51.955	51.990	52.025	52.060	1280
1290	52.060	52.095	52.130	52.165	52.200	52.235	52.270	52.305	52.340	52.375	52.410	1290
1300	52.410	52.445	52.480	52.515	52.550	52.585	52.620	52.654	52.689	52.724	52.759	1300
1310	52.759	52.794	52.828	52.863	52.898	52.932	52.967	53.002	53.037	53.071	53.106	1310
1320	53.106	53.140	53.175	53.210	53.244	53.279	53.313	53.348	53.382	53.417	53.451	1320
1330	53.451	53.486	53.520	53.555	53.589	53.623	53.658	53.692	53.727	53.761	53.795	1330
1340	53.795	53.830	53.864	53.898	53.932	53.967	54.001	54.035	54.069	54.104	54.138	1340
1350	54.138	54.172	54.206	54.240	54.274	54.308	54.343	54.377	54.411	54.445	54.479	1350
1360	54.479	54.513	54.547	54.581	54.615	54.649	54.683	54.717	54.751	54.785	54.819	1360
1370	54.819	54.852	54.886									1370
°C	0	1	2	3	4	5	6	7	8	9	10	°C

MAXIMUM TEMPERATURE RANGE

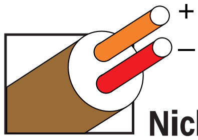
Thermocouple Grade
– 450 to 2372°F
– 270 to 1300°C

Extension Grade
32 to 392°F
0 to 200°C

LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75% Above 0°C
2.2°C or 2.0% Below 0°C
Special: 1.1°C or 0.4%

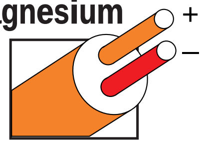
COMMENTS, BARE WIRE ENVIRONMENT:
Alternative to Type K; More Stable
at High Temperatures

TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

Nickel-14.2% Chromium-1.4% Silicon vs. Nickel-4.4% Silicon-0.1% Magnesium



Extension Grade

Revised Thermocouple Reference Tables

TYPE N

Reference Tables
N.I.S.T. Monograph 175 Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-260	- 4.345	- 4.345	- 4.344	- 4.344	- 4.343	- 4.342	- 4.341	- 4.340	- 4.339	- 4.337	-4.336	-260
-250	-4.338	-4.334	-4.332	-4.330	-4.328	-4.326	-4.324	-4.321	-4.319	-4.318	-4.313	-250
-240	-4.313	-4.310	-4.307	-4.304	-4.300	-4.297	-4.293	-4.289	-4.285	-4.281	-4.277	-240
-230	-4.277	-4.273	-4.268	-4.263	-4.258	-4.254	-4.248	-4.243	-4.238	-4.232	-4.226	-230
-220	-4.226	-4.221	-4.215	-4.209	-4.202	-4.196	-4.189	-4.183	-4.176	- 4.169	-4.162	-220
-210	-4.162	-4.154	-4.147	-4.140	-4.132	-4.124	-4.116	-4.108	-4.100	-4.091	-4.083	-210
-200	-4.083	-4.074	-4.066	-4.057	-4.048	-4.038	-4.029	-4.020	-4.010	-4.000	-3.990	-200
-190	-3.990	-3.980	-3.970	-3.960	-3.950	-3.939	-3.928	-3.918	-3.907	-3.898	-3.884	-190
-180	-3.884	-3.873	-3.862	-3.850	-3.838	-3.827	-3.815	-3.803	-3.790	-3.778	-3.786	-180
-170	-3.766	-3.753	-3.740	-3.728	-3.715	-3.702	-3.688	-3.675	-3.662	-3.648	-3.634	-170
-160	-3.634	-3.621	-3.607	-3.593	-3.578	-3.564	-3.550	-3.535	-3.521	-3.506	-3.491	-160
-150	-3.491	-3.476	-3.461	-3.446	-3.431	-3.415	-3.400	-3.384	-3.368	-3.352	-3.336	-150
-140	-3.336	-3.320	-3.304	-3.288	-3.271	-3.255	-3.238	-3.221	-3.205	-3.188	-3.171	-140
-130	-3.171	-3.153	-3.136	-3.119	-3.101	-3.084	-3.066	-3.048	-3.030	-3.012	-2.994	-130
-120	-2.994	-2.976	-2.958	-2.939	-2.921	-2.902	-2.883	-2.865	-2.846	-2.827	-2.808	-120
-110	-2.808	-2.789	-2.769	-2.750	-2.730	-2.711	-2.691	-2.672	-2.652	-2.632	-2.612	-110
-100	-2.612	-2.592	-2.571	-2.551	-2.531	-2.510	-2.490	-2.469	-2.448	-2.428	-2.407	-100
-90	-2.407	-2.386	-2.385	-2.344	-2.322	-2.301	-2.280	-2.258	-2.237	-2.215	-2.193	-90
-80	-2.193	-2.172	-2.150	-2.128	-2.106	-2.084	-2.082	-2. 039	-2.017	-1.995	-1.972	-80
-70	-1.972	-1.950	-1.927	-1.905	-1.882	-1.859	-1.836	-1.813	-1.790	-1.767	-1.744	-70
-60	-1.744	-1.721	-1.698	-1.674	-1.651	-1.627	-1.604	-1.580	-1.557	-1.533	-1.509	-60
-50	-1.509	-1.485	-1.462	-1.438	-1.414	-1.390	-1.366	-1.341	-1.317	-1.293	-1.269	-50
-40	-1.269	-1.244	-1.220	-1.195	-1.171	-1.146	-1.122	-1.097	-1.072	-1.048	-1.023	-40
-30	-1.023	-0.998	-0.973	-0.948	-0.923	-0.898	-0.873	-0.848	-0.823	-0.798	-0.772	-30
-20	-0.772	-0.747	-0.722	-0.696	-0.671	-0.646	-0.620	-0.595	-0.589	-0.544	-0.518	-20
-10	-0.518	-0.492	-0.467	-0.441	-0.415	-0.390	-0.364	-0.338	-0.312	-0.286	-0.260	-10
0	-0.260	-0.234	-0.209	-0.183	-0.157	-0.131	-0.104	-0.078	-0.052	-0.026	0.000	0

°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.026	0.052	0.078	0.104	0.130	0.156	0.182	0.208	0.235	0.261	0
10	0.261	0.287	0.313	0.340	0.366	0.393	0.419	0.446	0.472	0.499	0.525	10
20	0.525	0.552	0.578	0.605	0.632	0.659	0.685	0.712	0.739	0.766	0.793	20
30	0.793	0.820	0.847	0.874	0.901	0.928	0.955	0.983	1.010	1.037	1.065	30
40	1.065	1.092	1.119	1.147	1.174	1.202	1.229	1.257	1.284	1.312	1.340	40
50	1.340	1.368	1.395	1.423	1.451	1.479	1.507	1.535	1.563	1.501	1.619	50
60	1.619	1.647	1.675	1.703	1.732	1.760	1.788	1.817	1.845	1.873	1.902	60
70	1.902	1.930	1.959	1.988	2.016	2.045	2.074	2.102	2.131	2.160	2.189	70
80	2.189	2.218	2.247	2.276	2.305	2.334	2.363	2.392	2.421	2.450	2.480	80
90	2.480	2.509	2.538	2.568	2.597	2.826	2.656	2.685	2.715	2.744	2.774	90
100	2.774	2.804	2.833	2.863	2.893	2.923	2.953	2.983	3.012	3.042	3.072	100
110	3.072	3.102	3.133	3.163	3.193	3.223	3.253	3.283	3.314	3.344	3.374	110
120	3.374	3.405	3.435	3.466	3.496	3.527	3.557	3.588	3.619	3.649	3.680	120
130	3.680	3.711	3.742	3.772	3.803	3.834	3.865	3.896	3.927	3.958	3.989	130
140	3.989	4.020	4.051	4.083	4.114	4.145	4.176	4.208	4.239	4.270	4.302	140
150	4.302	4.333	4.365	4.396	4.428	4.459	4.491	4.523	4.554	4.586	4.618	I5O
160	4.618	4.650	4.681	4.713	4.745	4.777	4.809	4.841	4.873	4.905	4.937	160
170	4.937	4.969	5.001	5.033	5.066	5.098	5.130	5.162	5.195	5.227	5.259	170
180	5.259	5.292	5.324	5.357	5.389	5.422	5.454	5.487	5.520	5.552	5.585	ISO
190	5.585	5.618	5.650	5.683	5.716	5.749	5.782	5.815	5.847	5.880	5.913	190
200	5.913	5.946	5.979	6.013	6.046	6.079	6.112	6.145	6.178	6.211	6.245	200
210	6.245	6.278	6.311	6.345	6.378	6.411	6.445	6.478	6.512	6.545	6.579	210
220	6.579	68.612	e.e"	6.680	8.713	15.747	6.781	6.814	6.848	6.882	6.918	220
230	6.916	6.949	6.983	7.017	7.051	7.085	7.119	7.153	7.187	7.221	7.255	230
240	7.255	7.289	7.323	7.357	7.392	7.426	7.460	7.494	7.528	7.583	7.597	240
250	7.597	7.631	7.666	7.700	7.734	7.769	7.803	7.838	7.872	7.907	7.941	250
260	7.941	7.976	8.010	8.045	8.080	8.114	8.149	8.184	8.218	8.253	8.288	260
270	8.288	8.323	8.358	8.392	8.427	8.462	8.497	8.532	8.567	8.602	8.637	270
280	8.637	8.672	8.707	8.742	8.777	8.812	8.847	8.882	8.918	8.953	8.988	280
290	8.988	9.023	9.058	9.094	9.129	9.164	9.200	9.235	9.270	9.306	9.341	290

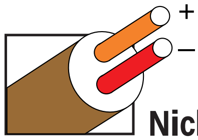
°C	0	1	2	3	4	5	6	7	8	9	10	°C
300	9.341	9.377	9.412	9.448	9.483	9.519	9.554	9.590	9.625	9.661	9.696	300
310	9.696	9.732	9.768	9.803	9.839	9.875	9.910	9.946	9.982	10.018	10.054	310
320	10.054	10.089	10.125	10.161	10.197	10.233	10.269	10.305	10.341	10.377	10.413	320
330	10.413	10.449	10.485	10.521	10.557	10.593	10.629	10.665	10.701	10.737	10.774	330
340	10.774	10.810	10.846	10.882	10.918	10.955	10.991	11.027	11.064	11.100	11.136	340
350	11.136	11.173	11.209	11.245	11.282	11.318	11.355	11.391	11.428	11.464	11.501	350
360	11.501	11.537	11.574	1.610	11.647	11.683	11.720	11.757	11.793	11.830	11.867	360
370	11.867	11.903	11.940	11.977	12.013	12.050	12.087	12.124	12.160	12.197	12.234	370
380	12.234	12.271	12.308	12.345	12.382	12.418	12.455	12.492	12.529	12.566	12.603	380
390	12.603	12.640	12.677	12.714	12.751	12.788	12.825	12.862	12.899	12.937	12.974	390
400	12.974	13.011	13.048	13.085	13.122	13.159	13.197	13.234	13.271	13.308	13.346	400
410	13.346	13.383	13.420	13.457	13.495	13.532	13.569	13.607	13.644	13.682	13.719	410
420	13.719	13.756	13.794	13.831	13.869	13.906	13.944	13.981	14.019	14.056	14.094	420
430	14.094	14.131	14.169	14.206	14.244	14.281	14.319	14.356	14.394	14.432	14.469	430
440	14.469	14.507	14.545	14.582	14.620	14.658	14.695	14.733	14.771	14.809	14.846	440
450	14.848	14.884	14.922	14.960	14.998	15.035	15.073	15.111	15.149	15.187	15.225	450
460	15.225	15.262	15.300	15.338	15.376	15.414	15.452	15.490	15.528	15.566	15.604	460
470	15.604	15.642	15.680	15.718	15.756	15.794	15.832	15.870	15.908	15.946	15.984	470
480	15.984	16.022	16.060	I 6.099	16.137	16.175	16.213	16.251	16.289	16.327	16.366	480
490	16.366	16.404	16.442	16.480	16.518	16.557	16.595	16.633	16.671	16.710	16.748	490
500	16.748	16.786	I 6.824	16.883	16.901	16.939	16.978	17.016	17.054	17.093	17.131	Soo
510	17.131	17.169	17.208	17.246	17.285	17.323	17.361	17.400	17.438	17.477	17.515	510
520	17.515	17.554	17.592	17.630	17.669	17.707	17.746	17.784	17.823	17.861	17.900	520
530	17.900	17.938	17.977	18.016	18.054	18.093	18.131	18.170	18.208	18.247	18.286	530
540	18.286	18.324	18.363	18.401	18.440	18.479	18.517	18.556	18.595	18.633	18.672	540
550	18.672	18.711	18.749	18.788	18.827	18.865	18.904	18.943	18.982	19.020	19.059	550
560	19.059	19.096	19.136	19.175	19.214	19.253	19.292	19.330	19.369	19.408	19.447	560
570	19.447	19.485	19.524	19.563	19.602	19.641	19.680	19.718	19.757	19.796	19.835	570
580	19.835	19.874	19.913	19.952	19.990	20.029	20.068	20.107	20.146	20.185	20.224	580
590	20.224	20.263	20.302	20.341	20.379	20.418	20.457	20.496	20.535	20.574	20.613	590
600	20.613	20.652	20.69l	20.730	20.769	20.808	20.847	20.886	20.925	20.964	21.003	600
610	21.003	21.042	21.081	21.120	21.159	21.198	21.237	21.276	21.315	21.354	21.393	610
620	21.393	21.432	21.471	21.510	21.549	21.588	21.628	21.667	21.706	21.745	21.784	620
630	21.784	21.823	21.862	21.901	21.940	21.979	22.018	22.058	22.097	22.136	22.175	630
640	22.175	22.214	22.253	22.292	22.331	22.370	22.410	22.449	22.488	22.527	22.566	640
650	22.556	22.605	22.644	22.684	22.723	22.762	22.801	22.840	22.879	22.919	22.958	650
660	22.958	22.997	23.036	23.075	23.115	23.154	23.193	23.232	23.271	23.311	23.350	660
670	23.350	23.389	23.428	23.467	23.507	23.546	23.585	23.624	23.663	23.703	23.742	670
680	23.742	23.781	23.820	23.860	23.899	23.938	23.977	24.016	24.056	24.095	24.134	680
690	24.134	24.173	24.213	24.252	24.291	24.330	24.370	24.409	24.448	24.487	24.527	690
700	24.527	24.566	24.605	24.644	24.684	24.723	24.762	24.801	24.841	24.880	24.919	700
710	24.919	24.959	24.998	25.037	25.076	25.116	25.155	25.194	25.233	25.273	25.312	710
720	25.312	25.351	25.391	25.430	25.469	25.508	25.548	25.587	25.626	25.666	25.705	720
730	25.705	25.744	25.783	25.823	25.862	25.901	25.941	25.980	26.019	26.058	26.098	730
740	26.098	26.137	26.176	26.216	26.255	26.294	26.333	26.373	26.412	26.451	26.491	740
750	26.491	26.530	26.569	26.608	26.648	26.687	26.726	26.766	26.805	26.844	26.883	75O
760	26.883	26.923	26.962	27.001	27.041	27.080	27.119	27.158	27.198	27.237	27.276	760
770	27.276	27.316	27.355	27.394	27.433	27.473	27.512	27.551	27.591	27.630	27.669	770
780	27.669	27.708	27.748	27.787	27.826	27.866	27.905	27.944	27.983	28.023	28.062	780
790	28.062	28.101	28.140	28.180	28.219	28.258	28.297	28.337	28.376	28.415	28.455	790
800	28.455	28.494	28.533	28.572	28.612	28.651	28.690	28.729	28.769	28.808	28.847	800
810	28.847	28.886	28.926	28.965	29.004	29.043	29.083	29.122	29.161	29.200	29.239	810
820	29.239	29.279	29.318	29.357	29.396	29.436	29.475	29.514	29.553	29.592	29.632	820
830	29.632	29.671	29.710	29.749	29.789	29.828	29.867	29.906	29.945	29.985	30.024	830
840	30.024	30.063	30.102	30.141	30.181	30.220	30.259	30.298	30.337	30.376	30.416	840
850	30.416	30.455	30.494	30.533	30.572	30.611	30.651	30.690	30.729	30.768	30.807	850
860	30.807	30.846	30.886	30.925	30.964	31.003	31.042	31.081	31.120	31.160	31.199	860
870	31.199	31.238	31.277	31.316	31.355	31.394	31.433	31.473	31.512	31.551	31.590	870
880	31.590	31.629	31.668	31.707	31.746	31.785	31.824	31.863	31.903	31.942	31.981	880
890	31.981	32.020	32.059	32.098	32.137	32.176	32.215	32.254	32.293	32.332	32.371	890

Revised Thermocouple Reference Tables

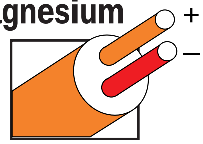
TYPE N

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Thermocouple Grade



Nickel-14.2% Chromium-1.4% Silicon vs. Nickel-4.4% Silicon-0.1% Magnesium



Extension Grade

MAXIMUM TEMPERATURE RANGE

Thermocouple Grade
– 450 to 2372°F
– 270 to 1300°C

Extension Grade
32 to 392°F
0 to 200°C

LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75% Above 0°C
2.2°C or 2.0% Below 0°C
Special: 1.1°C or 0.4%

COMMENTS, BARE WIRE ENVIRONMENT:
Alternative to Type K; More Stable at High Temperatures

TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
900	32.371	32.410	32.449	32.488	32.527	32.566	32.605	32.644	32.683	32.722	32.761	900
910	32.761	32.800	32.839	32.878	32.917	32.956	32.995	33.034	33.073	33.112	33.151	910
920	33.151	33.190	33.229	33.268	33.307	33.346	33.385	33.424	33.463	33.502	33.541	920
930	33.541	33.580	33.619	33.658	33.697	33.736	33.774	33.813	33.852	33.891	33.930	930
940	33.930	33.969	34.008	34.047	34.086	34.124	34.163	34.202	34.241	34.280	34.319	940
950	34.319	34.358	34.396	34.435	34.474	34.513	34.552	34.591	34.629	34.668	34.707	950
960	34.707	34.746	34.785	34.823	34.862	34.901	34.940	34.979	35.017	35.056	35.095	960
970	35.095	35.134	35.172	35.211	35.250	35.289	35.327	35.366	35.405	35.444	35.482	970
980	35.482	35.521	35.560	35.598	35.637	35.676	35.714	35.753	35.792	35.831	35.889	980
990	35.869	35.908	35.946	35.985	36.024	36.062	36.101	36.140	36.178	36.217	36.256	990
1000	36.256	38.294	36.333	36.371	36.410	36.449	36.487	36.526	36.564	36.603	36.641	1000
1010	36.841	36.680	36.718	38.757	38.796	38.834	36.873	36.911	36.950	36.988	37.027	1010
1020	37.027	37.065	37.104	37.142	37.181	37.219	37.258	37.296	37.334	37.373	37.411	1020
1030	37.411	37.450	37.488	37.527	37.565	37.603	37.642	37.680	37.719	37.757	37.795	1030
1040	37.795	37.834	37.872	37.911	37.949	37.987	38.026	38.064	38.102	38.141	38.179	1040
1050	38.179	38.217	38.256	38.294	38.332	38.370	38.409	38.447	38.485	38.524	38.562	1050
1060	38.562	38.600	38.638	38.677	38.715	38.753	38.791	38.829	38.868	38.906	38.944	1060
1070	38.944	38.982	39.020	39.059	39.097	39.135	39.173	39.211	39.249	39.287	39.326	1070
1080	39.326	39.364	39.402	39.440	39.478	39.516	30.554	39.592	39.630	39.668	39.706	1000
1090	39.708	39.744	39.783	39.821	39.859	39.897	39.935	39.973	40.011	40.049	40.087	1090
1100	40.087	40.125	40.163	40.201	40.238	40.276	40.314	40.352	40.390	40.428	40.466	1100
1110	40.466	40.504	40.542	40.580	40.818	40.655	40.693	40.731	40.769	40.807	40.845	1110
1120	40.845	40.883	40.920	40.958	40.996	41.034	41.072	41.109	41.147	41.185	41.223	1120
1130	41.223	41.260	41.298	41.336	41.374	41.411	41.449	41.487	41.525	41.562	41.6OO	1130
1140	41.600	41.638	41.675	41.713	41.751	41.788	41.826	41.864	41.901	41.939	41.976	1140
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1150	41.976	42.014	42.052	42.089	42.127	42.164	42.202	42.239	42.277	42.314	42.352	1150
1160	42.352	42.390	42.427	42.465	42.502	42.540	42.577	42.614	42.652	42.689	42.727	1160
1170	42.727	42.764	42.802	42.839	42.877	42.914	42.951	42.989	43.026	43.064	43.101	1170
1180	43.101	43.138	43.176	43.213	43.250	43.288	43.325	43.362	43.399	43.437	43.474	1190
1190	43.474	43.511	43.549	43.586	43.623	43.660	43.698	43.735	43.772	43.809	43.846	1190
1200	43.846	43.884	43.921	43.958	43.995	44.032	44.069	44.106	44.144	44.181	44.218	1900
1210	44.218	44.255	44.292	44.329	44.366	44.403	44.440	44.477	44.514	44.551	44.551	1210
1220	44.588	44.625	44.662	44.699	44.736	44.773	44.810	44.847	44.884	44.921	44.958	1220
1230	44.958	44.995	45.032	45.069	45.105	45.142	45.179	45.216	45.253	45.290	45.326	1230
1240	45.326	45.363	45.400	45.437	45.474	45.510	45.547	45.584	45.621	45.657	45.694	1240
1250	45.694	45.731	45.767	45.804	45.841	45.877	45.914	45.951	45.987	46.024	46.080	1250
1260	46.060	46.097	46.133	46.170	46.207	46.243	46.280	46.316	46.353	46.389	46.425	1260
1270	46.425	46.462	46.498	46.535	46.571	46.608	46.844	46.880	46.717	46.753	46.789	1270
1280	46.789	46.826	46.862	46.898	46.935	46.971	47.007	47.043	47.079	47.116	47.152	1280
1290	47.152	47.188	47.224	47.260	47.296	47.333	47.369	47.405	47.441	47.477	47.513	1290
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

TYPE R

Reference Tables
N.I.S.T. Monograph 175
Revised to ITS-90

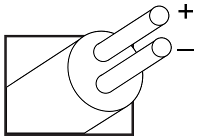
Z

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
32 to 2642°F
0 to 1450°C
Extension Grade
32 to 300°F
0 to 150°C

LIMITS OF ERROR
(whichever is greater)
Standard: 1.5°C or 0.25%
Special: 0.6°C or 0.1%

COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Do Not Insert in Metal Tubes; Beware of Contamination; High Temperature

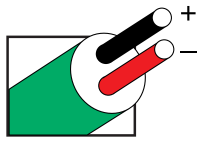
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

NONE ESTABLISHED

Platinum-13% Rhodium vs. Platinum



Extension Grade

Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-40	-0.226	-0.223	-0.219	-0.215	-0.211	-0.208	-0.204	-0.200	-0.196	-0.192	-0.188	-40
-30	-0.188	-0.184	-0.180	-0.175	-0.171	-0.167	-0.163	-0.158	-0.154	-0.150	-0.145	-30
-20	-0.145	-0.141	-0.137	-0.132	-0.128	-0.123	-0.119	-0.114	-0.109	-0.105	-0.100	-20
-10	-0.100	-0.095	-0.091	-0.086	-0.081	-0.076	-0.071	-0.066	-0.061	-0.056	-0.051	-10
0	-0.051	-0.046	-0.041	-0.036	-0.031	-0.026	-0.021	-0.016	-0.011	-0.005	0.000	0

°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.005	0.011	0.016	0.021	0.027	0.032	0.038	0.043	0.049	0.054	0
10	0.054	0.060	0.065	0.071	0.077	0.082	0.088	0.094	0.100	0.105	0.111	10
20	0.111	0.117	0.123	0.129	0.135	0.141	0.147	0.153	0.159	0.165	0.171	20
30	0.171	0.177	0.183	0.189	0.195	0.201	0.207	0.214	0.220	0.226	0.232	30
40	0.232	0.239	0.245	0.251	0.258	0.264	0.271	0.277	0.284	0.290	0.296	40
50	0.296	0.303	0.310	0.316	0.323	0.329	0.336	0.343	0.349	0.356	0.363	50
60	0.363	0.369	0.376	0.383	0.390	0.397	0.403	0.410	0.417	0.424	0.431	60
70	0.431	0.438	0.445	0.452	0.459	0.466	0.473	0.480	0.487	0.494	0.501	70
80	0.501	0.508	0.516	0.523	0.530	0.537	0.544	0.552	0.559	0.566	0.573	80
90	0.573	0.581	0.588	0.595	0.603	0.610	0.618	0.625	0.632	0.640	0.647	90
100	0.647	0.655	0.662	0.670	0.677	0.685	0.693	0.700	0.708	0.715	0.723	100
110	0.723	0.731	0.738	0.746	0.754	0.761	0.769	0.777	0.785	0.792	0.800	110
120	0.800	0.808	0.816	0.824	0.832	0.839	0.847	0.855	0.863	0.871	0.879	120
130	0.879	0.887	0.895	0.903	0.911	0.919	0.927	0.935	0.943	0.951	0.959	130
140	0.959	0.967	0.976	0.984	0.992	1.000	1.008	1.016	1.025	1.033	1.041	140
150	1.041	1.049	1.058	1.066	1.074	1.082	1.091	1.099	1.107	1.116	1.124	150
160	1.124	1.132	1.141	1.149	1.158	1.166	1.175	1.183	1.191	1.200	1.208	160
170	1.208	1.217	1.225	1.234	1.242	1.251	1.260	1.268	1.277	1.285	1.294	170
180	1.294	1.303	1.311	1.320	1.329	1.337	1.346	1.355	1.363	1.372	1.381	180
190	1.381	1.389	1.398	1.407	1.416	1.425	1.433	1.442	1.451	1.460	1.469	190
200	1.469	1.477	1.486	1.495	1.504	1.513	1.522	1.531	1.540	1.549	1.558	200
210	1.558	1.567	1.575	1.584	1.593	1.602	1.611	1.620	1.629	1.639	1.648	210
220	1.648	1.657	1.666	1.675	1.684	1.693	1.702	1.711	1.720	1.729	1.739	220
230	1.739	1.748	1.757	1.766	1.775	1.784	1.794	1.803	1.812	1.821	1.831	230
240	1.831	1.840	1.849	1.858	1.868	1.877	1.886	1.895	1.905	1.914	1.923	240
250	1.923	1.933	1.942	1.951	1.961	1.970	1.980	1.989	1.998	2.008	2.017	250
260	2.017	2.027	2.036	2.046	2.055	2.064	2.074	2.083	2.093	2.102	2.112	260
270	2.112	2.121	2.131	2.140	2.150	2.159	2.169	2.179	2.188	2.198	2.207	270
280	2.207	2.217	2.226	2.236	2.246	2.255	2.265	2.275	2.284	2.294	2.304	280
290	2.304	2.313	2.323	2.333	2.342	2.352	2.362	2.371	2.381	2.391	2.401	290
300	2.401	2.410	2.420	2.430	2.440	2.449	2.459	2.469	2.479	2.488	2.498	300
310	2.498	2.508	2.518	2.528	2.538	2.547	2.557	2.567	2.577	2.587	2.597	310
320	2.597	2.607	2.617	2.626	2.636	2.646	2.656	2.666	2.676	2.686	2.696	320
330	2.696	2.706	2.716	2.726	2.736	2.746	2.756	2.766	2.776	2.786	2.796	330
340	2.796	2.806	2.816	2.826	2.836	2.846	2.856	2.866	2.876	2.886	2.896	340
350	2.896	2.906	2.916	2.926	2.937	2.947	2.957	2.967	2.977	2.987	2.997	350
360	2.997	3.007	3.018	3.028	3.038	3.048	3.058	3.068	3.079	3.089	3.099	360
370	3.099	3.109	3.119	3.130	3.140	3.150	3.160	3.171	3.181	3.191	3.201	370
380	3.201	3.212	3.222	3.232	3.242	3.253	3.263	3.273	3.284	3.294	3.304	380
390	3.304	3.315	3.325	3.335	3.346	3.356	3.366	3.377	3.387	3.397	3.408	390
400	3.408	3.418	3.428	3.439	3.449	3.460	3.470	3.480	3.491	3.501	3.512	400
410	3.512	3.522	3.533	3.543	3.553	3.564	3.574	3.585	3.595	3.606	3.616	410
420	3.616	3.627	3.637	3.648	3.658	3.669	3.679	3.690	3.700	3.711	3.721	420
430	3.721	3.732	3.742	3.753	3.764	3.774	3.785	3.795	3.806	3.816	3.827	430
440	3.827	3.838	3.848	3.859	3.869	3.880	3.891	3.901	3.912	3.922	3.933	440
450	3.933	3.944	3.954	3.965	3.976	3.986	3.997	4.008	4.018	4.029	4.040	450
460	4.040	4.050	4.061	4.072	4.083	4.093	4.104	4.115	4.125	4.136	4.147	460
470	4.147	4.158	4.168	4.179	4.190	4.201	4.211	4.222	4.233	4.244	4.255	470
480	4.255	4.265	4.276	4.287	4.298	4.309	4.319	4.330	4.341	4.352	4.363	480
490	4.363	4.373	4.384	4.395	4.406	4.417	4.428	4.439	4.449	4.460	4.471	490
500	4.471	4.482	4.493	4.504	4.515	4.526	4.537	4.548	4.558	4.569	4.580	500
510	4.580	4.591	4.602	4.613	4.624	4.635	4.646	4.657	4.668	4.679	4.690	510
520	4.690	4.701	4.712	4.723	4.734	4.745	4.756	4.767	4.778	4.789	4.800	520
530	4.800	4.811	4.822	4.833	4.844	4.855	4.866	4.877	4.888	4.899	4.910	530
540	4.910	4.922	4.933	4.944	4.955	4.966	4.977	4.988	4.999	5.010	5.021	540
°C	0	1	2	3	4	5	6	7	8	9	10	°C

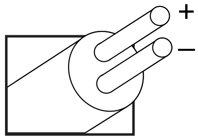
°C	0	1	2	3	4	5	6	7	8	9	10	°C
550	5.021	5.033	5.044	5.055	5.066	5.077	5.088	5.099	5.111	5.122	5.133	550
560	5.133	5.144	5.155	5.166	5.178	5.189	5.200	5.211	5.222	5.234	5.245	560
570	5.245	5.256	5.267	5.279	5.290	5.301	5.312	5.323	5.335	5.346	5.357	570
580	5.357	5.369	5.380	5.391	5.402	5.414	5.425	5.436	5.448	5.459	5.470	580
590	5.470	5.481	5.493	5.504	5.515	5.527	5.538	5.549	5.561	5.572	5.583	590
600	5.583	5.595	5.606	5.618	5.629	5.640	5.652	5.663	5.674	5.686	5.697	600
610	5.697	5.709	5.720	5.731	5.743	5.754	5.766	5.777	5.789	5.800	5.812	610
620	5.812	5.823	5.834	5.846	5.857	5.869	5.880	5.892	5.903	5.915	5.926	620
630	5.926	5.938	5.949	5.961	5.972	5.984	5.995	6.007	6.018	6.030	6.041	630
640	6.041	6.053	6.065	6.076	6.088	6.099	6.111	6.122	6.134	6.146	6.157	640
650	6.157	6.169	6.180	6.192	6.204	6.215	6.227	6.238	6.250	6.262	6.273	650
660	6.273	6.285	6.297	6.308	6.320	6.332	6.343	6.355	6.367	6.378	6.390	660
670	6.390	6.402	6.413	6.425	6.437	6.448	6.460	6.472	6.484	6.495	6.507	670
680	6.507	6.519	6.531	6.542	6.554	6.566	6.578	6.589	6.601	6.613	6.625	680
690	6.625	6.636	6.648	6.660	6.672	6.684	6.695	6.707	6.719	6.731	6.743	690
700	6.743	6.755	6.766	6.778	6.790	6.802	6.814	6.826	6.838	6.849	6.861	700
710	6.861	6.873	6.885	6.897	6.909	6.921	6.933	6.945	6.956	6.968	6.980	710
720	6.980	6.992	7.004	7.016	7.028	7.040	7.052	7.064	7.076	7.088	7.100	720
730	7.100	7.112	7.124	7.136	7.148	7.160	7.172	7.184	7.196	7.208	7.220	730
740	7.220	7.232	7.244	7.256	7.268	7.280	7.292	7.304	7.316	7.328	7.340	740
750	7.340	7.352	7.364	7.376	7.389	7.401	7.413	7.425	7.437	7.449	7.461	750
760	7.461	7.473	7.485	7.498	7.510	7.522	7.534	7.546	7.558	7.570	7.583	760
770	7.583	7.595	7.607	7.619	7.631	7.644	7.656	7.668	7.680	7.692	7.705	770
780	7.705	7.717	7.729	7.741	7.753	7.766	7.778	7.790	7.802	7.815	7.827	780
790	7.827	7.839	7.851	7.864	7.876	7.888	7.901	7.913	7.925	7.938	7.950	790
800	7.950	7.962	7.974	7.987	7.999	8.011	8.024	8.036	8.048	8.061	8.073	800
810	8.073	8.086	8.098	8.110	8.123	8.135	8.147	8.160	8.172	8.185	8.197	810
820	8.197	8.209	8.222	8.234	8.247	8.259	8.272	8.284	8.296	8.309	8.321	820
830	8.321	8.334	8.346	8.359	8.371	8.384	8.396	8.409	8.421	8.434	8.446	830
840	8.446	8.459	8.471	8.484	8.496	8.509	8.521	8.534	8.546	8.559	8.571	840
850	8.571	8.584	8.597	8.609	8.622	8.634	8.647	8.659	8.672	8.685	8.697	850
860	8.697	8.710	8.722	8.735	8.748	8.760	8.773	8.785	8.798	8.811	8.823	860
870	8.823	8.836	8.849	8.861	8.874	8.887	8.899	8.912	8.925	8.937	8.950	870
880	8.950	8.963	8.975	8.988	9.001	9.014	9.026	9.039	9.052	9.065	9.077	880
890	9.077	9.090	9.103	9.115	9.128	9.141	9.154	9.167	9.179	9.192	9.205	890
900	9.205	9.218	9.230	9.243	9.256	9.269	9.282	9.294	9.307	9.320	9.333	900
910	9.333	9.346	9.359	9.371	9.384	9.397	9.410	9.423	9.436	9.449	9.461	910
920	9.461	9.474	9.487	9.500	9.513	9.526	9.539	9.552	9.565	9.578	9.590	920
930	9.590	9.603	9.616	9.629	9.642	9.655	9.668	9.681	9.694	9.707	9.720	930
940	9.720	9.733	9.746	9.759	9.772	9.785	9.798	9.811	9.824	9.837	9.850	940
950	9.850	9.863	9.876	9.889	9.902	9.915	9.928	9.941	9.954	9.967	9.980	950
960	9.980	9.993	10.006	10.019	10.032	10.046	10.059	10.072	10.085	10.098	10.111	960
970	10.111	10.124	10.137	10.150	10.163	10.177	10.190	10.203	10.216	10.229	10.242	970
980	10.242	10.255	10.268	10.282	10.295	10.308	10.321	10.334	10.347	10.361	10.374	980
990	10.374	10.387	10.400	10.413	10.427	10.440	10.453	10.466	10.480	10.493	10.506	990
1000	10.506	10.519	10.532	10.546	10.559	10.572	10.585	10.599	10.612	10.625	10.638	1000
1010	10.638	10.652	10.665	10.678	10.692	10.705	10.718	10.731	10.745	10.758	10.771	1010
1020	10.771	10.785	10.798	10.811	10.825	10.838	10.851	10.865	10.878	10.891	10.905	1020
1030	10.905	10.918	10.932	10.945	10.958	10.972	10.985	10.998	11.012	11.025	11.039	1030
1040	11.039	11.052	11.065	11.079	11.092	11.106	11.119	11.132	11.146	11.159	11.173	1040
1050	11.173	11.186	11.200	11.213	11.227	11.240	11.253	11.267	11.280	11.294	11.307	1050
1060	11.307	11.321	11.334	11.348	11.361	11.375	11.388	11.402	11.415	11.429	11.442	1060
1070	11.442	11.456	11.469	11.483	11.496	11.510	11.524	11.537	11.551	11.564	11.578	1070
1080	11.578	11.591	11.605	11.618	11.632	11.646	11.659	11.673	11.686	11.700	11.714	1080
1090	11.714	11.727	11.741	11.754	11.768	11.782	11.795	11.809	11.822	11.836	11.850	1090
1100	11.850	11.863	11.877	11.891	11.904	11.918	11.931	11.945	11.959	11.972	11.986	1100
1110	11.986	12.000	12.013	12.027	12.041	12.054	12.068	12.082	12.096	12.109	12.123	1110
1120	12.123	12.137	12.150	12.164	12.178	12.191	12.205	12.219	12.233	12.246	12.260	1120
1130	12.260	12.274	12.288	12.301	12.315	12.329	12.342	12.356	12.370	12.384	12.397	1130
1140	12.397	12.411	12.425	12.439	12.453	12.466	12.480	12.494	12.508	12.521	12.535	1140
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

TYPE R

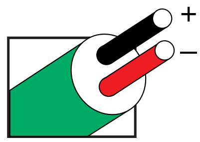
Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Thermocouple Grade



NONE ESTABLISHED

Platinum-13% Rhodium vs. Platinum



Extension Grade

MAXIMUM TEMPERATURE RANGE

Thermocouple Grade
32 to 2642°F
0 to 1450°C

Extension Grade
32 to 300°F
0 to 150°C

LIMITS OF ERROR
(whichever is greater)
Standard: 1.5°C or 0.25%
Special: 0.6°C or 0.1%

COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Do Not Insert in Metal Tubes; Beware of Contamination; High Temperature

TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1150	12.535	12.549	12.563	12.577	12.590	12.604	12.618	12.632	12.646	12.659	12.673	1150
1160	12.673	12.687	12.701	12.715	12.729	12.742	12.756	12.770	12.784	12.798	12.812	1160
1170	12.812	12.825	12.839	12.853	12.867	12.881	12.895	12.909	12.922	12.936	12.950	1170
1180	12.950	12.964	12.978	12.992	13.006	13.019	13.033	13.047	13.061	13.075	13.089	1180
1190	13.089	13.103	13.117	13.131	13.145	13.158	13.172	13.186	13.200	13.214	13.228	1190
1200	13.228	13.242	13.256	13.270	13.284	13.298	13.311	13.325	13.339	13.353	13.367	1200
1210	13.367	13.381	13.395	13.409	13.423	13.437	13.451	13.465	13.479	13.493	13.507	1210
1220	13.507	13.521	13.535	13.549	13.563	13.577	13.590	13.604	13.618	13.632	13.646	1220
1230	13.646	13.660	13.674	13.688	13.702	13.716	13.730	13.744	13.758	13.772	13.786	1230
1240	13.786	13.800	13.814	13.828	13.842	13.856	13.870	13.884	13.898	13.912	13.926	1240
1250	13.926	13.940	13.954	13.968	13.982	13.996	14.010	14.024	14.038	14.052	14.066	1250
1260	14.066	14.081	14.095	14.109	14.123	14.137	14.151	14.165	14.179	14.193	14.207	1260
1270	14.207	14.221	14.235	14.249	14.263	14.277	14.291	14.305	14.319	14.333	14.347	1270
1280	14.347	14.361	14.375	14.390	14.404	14.418	14.432	14.446	14.460	14.474	14.488	1280
1290	14.488	14.502	14.516	14.530	14.544	14.558	14.572	14.586	14.601	14.615	14.629	1290
1300	14.629	14.643	14.657	14.671	14.685	14.699	14.713	14.727	14.741	14.755	14.770	1300
1310	14.770	14.784	14.798	14.812	14.826	14.840	14.854	14.868	14.882	14.896	14.911	1310
1320	14.911	14.925	14.939	14.953	14.967	14.981	14.995	15.009	15.023	15.037	15.052	1320
1330	15.052	15.066	15.080	15.094	15.108	15.122	15.136	15.150	15.164	15.179	15.193	1330
1340	15.193	15.207	15.221	15.235	15.249	15.263	15.277	15.291	15.306	15.320	15.334	1340
1350	15.334	15.348	15.362	15.376	15.390	15.404	15.419	15.433	15.447	15.461	15.475	1350
1360	15.475	15.489	15.503	15.517	15.531	15.546	15.560	15.574	15.588	15.602	15.616	1360
1370	15.616	15.630	15.645	15.659	15.673	15.687	15.701	15.715	15.729	15.743	15.758	1370
1380	15.758	15.772	15.786	15.800	15.814	15.828	15.842	15.856	15.871	15.885	15.899	1380
1390	15.899	15.913	15.927	15.941	15.955	15.969	15.984	15.998	16.012	16.026	16.040	1390
1400	16.040	16.054	16.068	16.082	16.097	16.111	16.125	16.139	16.153	16.167	16.181	1400
1410	16.181	16.196	16.210	16.224	16.238	16.252	16.266	16.280	16.294	16.309	16.323	1410
1420	16.323	16.337	16.351	16.365	16.379	16.393	16.407	16.422	16.436	16.450	16.464	1420
1430	16.464	16.478	16.492	16.506	16.520	16.534	16.549	16.563	16.577	16.591	16.605	1430
1440	16.605	16.619	16.633	16.647	16.662	16.676	16.690	16.704	16.718	16.732	16.746	1440
1450	16.746	16.760	16.774	16.789	16.803	16.817	16.831	16.845	16.859	16.873	16.887	1450
1460	16.887	16.901	16.915	16.930	16.944	16.958	16.972	16.986	17.000	17.014	17.028	1460
1470	17.028	17.042	17.056	17.071	17.085	17.099	17.113	17.127	17.141	17.155	17.169	1470
1480	17.169	17.183	17.197	17.211	17.225	17.240	17.254	17.268	17.282	17.296	17.310	1480
1490	17.310	17.324	17.338	17.352	17.366	17.380	17.394	17.408	17.423	17.437	17.451	1490
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1500	17.451	17.465	17.479	17.493	17.507	17.521	17.535	17.549	17.563	17.577	17.591	1500
1510	17.591	17.605	17.619	17.633	17.647	17.661	17.676	17.690	17.704	17.718	17.732	1510
1520	17.732	17.746	17.760	17.774	17.788	17.802	17.816	17.830	17.844	17.858	17.872	1520
1530	17.872	17.886	17.900	17.914	17.928	17.942	17.956	17.970	17.984	17.998	18.012	1530
1540	18.012	18.026	18.040	18.054	18.068	18.082	18.096	18.110	18.124	18.138	18.152	1540
1550	18.152	18.166	18.180	18.194	18.208	18.222	18.236	18.250	18.264	18.278	18.292	1550
1560	18.292	18.306	18.320	18.334	18.348	18.362	18.376	18.390	18.404	18.417	18.431	1560
1570	18.431	18.445	18.459	18.473	18.487	18.501	18.515	18.529	18.543	18.557	18.571	1570
1580	18.571	18.585	18.599	18.613	18.627	18.640	18.654	18.668	18.682	18.696	18.710	1580
1590	18.710	18.724	18.738	18.752	18.766	18.779	18.793	18.807	18.821	18.835	18.849	1590
1600	18.849	18.863	18.877	18.891	18.904	18.918	18.932	18.946	18.960	18.974	18.988	1600
1610	18.988	19.002	19.015	19.029	19.043	19.057	19.071	19.085	19.098	19.112	19.126	1610
1620	19.126	19.140	19.154	19.168	19.181	19.195	19.209	19.223	19.237	19.250	19.264	1620
1630	19.264	19.278	19.292	19.306	19.319	19.333	19.347	19.361	19.375	19.388	19.402	1630
1640	19.402	19.416	19.430	19.444	19.457	19.471	19.485	19.499	19.512	19.526	19.540	1640
1650	19.540	19.554	19.567	19.581	19.595	19.609	19.622	19.636	19.650	19.663	19.677	1650
1660	19.677	19.691	19.705	19.718	19.732	19.746	19.759	19.773	19.787	19.800	19.814	1660
1670	19.814	19.828	19.841	19.855	19.869	19.882	19.896	19.910	19.923	19.937	19.951	1670
1680	19.951	19.964	19.978	19.992	20.005	20.019	20.032	20.046	20.060	20.073	20.087	1680
1690	20.087	20.100	20.114	20.127	20.141	20.154	20.168	20.181	20.195	20.208	20.222	1690
1700	20.222	20.235	20.249	20.262	20.275	20.289	20.302	20.316	20.329	20.342	20.356	1700
1710	20.356	20.369	20.382	20.396	20.409	20.422	20.436	20.449	20.462	20.475	20.488	1710
1720	20.488	20.502	20.515	20.528	20.541	20.554	20.567	20.581	20.594	20.607	20.620	1720
1730	20.620	20.633	20.646	20.659	20.672	20.685	20.698	20.711	20.724	20.736	20.749	1730
1740	20.749	20.762	20.775	20.788	20.801	20.813	20.826	20.839	20.852	20.864	20.877	1740
1750	20.877	20.890	20.902	20.915	20.928	20.940	20.953	20.965	20.978	20.990	21.003	1750
1760	21.003	21.015	21.027	21.040	21.052	21.065	21.077	21.089	21.101			1760
°C	0	1	2	3	4	5	6	7	8	9	10	°C

MAXIMUM TEMPERATURE RANGE

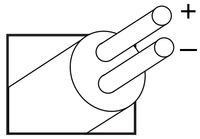
Thermocouple Grade
32 to 2642°F
0 to 1450°C

Extension Grade
32 to 300°F
0 to 150°C

LIMITS OF ERROR
(whichever is greater)
Standard: 1.5°C or 0.25%
Special: 0.6°C or 0.1%

COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Do Not Insert in Metal Tubes; Beware of Contamination; High Temperature

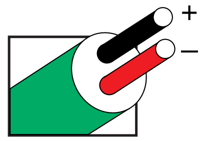
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

NONE ESTABLISHED

Platinum-10% Rhodium vs. Platinum



Extension Grade

Revised Thermocouple Reference Tables

TYPE S

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-40	-0.236	-0.232	-0.228	-0.224	-0.219	-0.215	-0.211	-0.207	-0.203	-0.199	-0.194	-40
-30	-0.194	-0.190	-0.186	-0.181	-0.177	-0.173	-0.168	-0.164	-0.159	-0.155	-0.150	-30
-20	-0.150	-0.146	-0.141	-0.136	-0.132	-0.127	-0.122	-0.117	-0.113	-0.108	-0.103	-20
-10	-0.103	-0.098	-0.093	-0.088	-0.083	-0.078	-0.073	-0.068	-0.063	-0.058	-0.053	-10
0	-0.053	-0.048	-0.042	-0.037	-0.032	-0.027	-0.021	-0.016	-0.011	-0.005	0.000	0

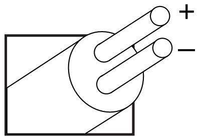
°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.005	0.011	0.016	0.022	0.027	0.033	0.038	0.044	0.050	0.055	0
10	0.055	0.061	0.067	0.072	0.078	0.084	0.090	0.095	0.101	0.107	0.113	10
20	0.113	0.119	0.125	0.131	0.137	0.143	0.149	0.155	0.161	0.167	0.173	20
30	0.173	0.179	0.185	0.191	0.197	0.204	0.210	0.216	0.222	0.229	0.235	30
40	0.235	0.241	0.248	0.254	0.260	0.267	0.273	0.280	0.286	0.292	0.299	40
50	0.299	0.305	0.312	0.319	0.325	0.332	0.338	0.345	0.352	0.358	0.365	50
60	0.365	0.372	0.378	0.385	0.392	0.399	0.405	0.412	0.419	0.426	0.433	60
70	0.433	0.440	0.446	0.453	0.460	0.467	0.474	0.481	0.488	0.495	0.502	70
80	0.502	0.509	0.516	0.523	0.530	0.538	0.545	0.552	0.559	0.566	0.573	80
90	0.573	0.580	0.588	0.595	0.602	0.609	0.617	0.624	0.631	0.639	0.646	90
100	0.646	0.653	0.661	0.668	0.675	0.683	0.690	0.698	0.705	0.713	0.720	100
110	0.720	0.727	0.735	0.743	0.750	0.758	0.765	0.773	0.780	0.788	0.795	110
120	0.795	0.803	0.811	0.818	0.826	0.834	0.841	0.849	0.857	0.865	0.872	120
130	0.872	0.880	0.888	0.896	0.903	0.911	0.919	0.927	0.935	0.942	0.950	130
140	0.950	0.958	0.966	0.974	0.982	0.990	0.998	1.006	1.013	1.021	1.029	140
150	1.029	1.037	1.045	1.053	1.061	1.069	1.077	1.085	1.094	1.102	1.110	150
160	1.110	1.118	1.126	1.134	1.142	1.150	1.158	1.167	1.175	1.183	1.191	160
170	1.191	1.199	1.207	1.216	1.224	1.232	1.240	1.249	1.257	1.265	1.273	170
180	1.273	1.282	1.290	1.298	1.307	1.315	1.323	1.332	1.340	1.348	1.357	180
190	1.357	1.365	1.373	1.382	1.390	1.399	1.407	1.415	1.424	1.432	1.441	190
200	1.441	1.449	1.458	1.466	1.475	1.483	1.492	1.500	1.509	1.517	1.526	200
210	1.526	1.534	1.543	1.551	1.560	1.569	1.577	1.586	1.594	1.603	1.612	210
220	1.612	1.620	1.629	1.638	1.646	1.655	1.663	1.672	1.681	1.690	1.698	220
230	1.698	1.707	1.716	1.724	1.733	1.742	1.751	1.759	1.768	1.777	1.786	230
240	1.786	1.794	1.803	1.812	1.821	1.829	1.838	1.847	1.856	1.865	1.874	240
250	1.874	1.882	1.891	1.900	1.909	1.918	1.927	1.936	1.944	1.953	1.962	250
260	1.962	1.971	1.980	1.989	1.998	2.007	2.016	2.025	2.034	2.043	2.052	260
270	2.052	2.061	2.070	2.078	2.087	2.096	2.105	2.114	2.123	2.132	2.141	270
280	2.141	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.214	2.223	2.232	280
290	2.232	2.241	2.250	2.259	2.268	2.277	2.287	2.296	2.305	2.314	2.323	290
300	2.323	2.332	2.341	2.350	2.360	2.369	2.378	2.387	2.396	2.405	2.415	300
310	2.415	2.424	2.433	2.442	2.451	2.461	2.470	2.479	2.488	2.497	2.507	310
320	2.507	2.516	2.525	2.534	2.544	2.553	2.562	2.571	2.581	2.590	2.599	320
330	2.599	2.609	2.618	2.627	2.636	2.646	2.655	2.664	2.674	2.683	2.692	330
340	2.692	2.702	2.711	2.720	2.730	2.739	2.748	2.758	2.767	2.776	2.786	340
350	2.786	2.795	2.805	2.814	2.823	2.833	2.842	2.851	2.861	2.870	2.880	350
360	2.880	2.889	2.899	2.908	2.917	2.927	2.936	2.946	2.955	2.965	2.974	360
370	2.974	2.983	2.993	3.002	3.012	3.021	3.031	3.040	3.050	3.059	3.069	370
380	3.069	3.078	3.088	3.097	3.107	3.116	3.126	3.135	3.145	3.154	3.164	380
390	3.164	3.173	3.183	3.192	3.202	3.212	3.221	3.231	3.240	3.250	3.259	390
400	3.259	3.269	3.279	3.288	3.298	3.307	3.317	3.326	3.336	3.346	3.355	400
410	3.355	3.365	3.374	3.384	3.394	3.403	3.413	3.423	3.432	3.442	3.451	410
420	3.451	3.461	3.471	3.480	3.490	3.500	3.509	3.519	3.529	3.538	3.548	420
430	3.548	3.558	3.567	3.577	3.587	3.596	3.606	3.616	3.626	3.635	3.645	430
440	3.645	3.655	3.664	3.674	3.684	3.694	3.703	3.713	3.723	3.732	3.742	440
450	3.742	3.752	3.762	3.771	3.781	3.791	3.801	3.810	3.820	3.830	3.840	450
460	3.840	3.850	3.859	3.869	3.879	3.889	3.898	3.908	3.918	3.928	3.938	460
470	3.938	3.947	3.957	3.967	3.977	3.987	3.997	4.006	4.016	4.026	4.036	470
480	4.036	4.046	4.056	4.065	4.075	4.085	4.095	4.105	4.115	4.125	4.134	480
490	4.134	4.144	4.154	4.164	4.174	4.184	4.194	4.204	4.213	4.223	4.233	490
500	4.233	4.243	4.253	4.263	4.273	4.283	4.293	4.303	4.313	4.323	4.332	500
510	4.332	4.342	4.352	4.362	4.372	4.382	4.392	4.402	4.412	4.422	4.432	510
520	4.432	4.442	4.452	4.462	4.472	4.482	4.492	4.502	4.512	4.522	4.532	520
530	4.532	4.542	4.552	4.562	4.572	4.582	4.592	4.602	4.612	4.622	4.632	530
540	4.632	4.642	4.652	4.662	4.672	4.682	4.692	4.702	4.712	4.722	4.732	540

°C	0	1	2	3	4	5	6	7	8	9	10	°C
550	4.732	4.742	4.752	4.762	4.772	4.782	4.793	4.803	4.813	4.823	4.833	550
560	4.833	4.843	4.853	4.863	4.873	4.883	4.893	4.904	4.914	4.924	4.934	560
570	4.934	4.944	4.954	4.964	4.974	4.984	4.995	5.005	5.015	5.025	5.035	570
580	5.035	5.045	5.055	5.066	5.076	5.086	5.096	5.106	5.116	5.127	5.137	580
590	5.137	5.147	5.157	5.167	5.178	5.188	5.198	5.208	5.218	5.228	5.239	590
600	5.239	5.249	5.259	5.269	5.280	5.290	5.300	5.310	5.320	5.331	5.341	600
610	5.341	5.351	5.361	5.372	5.382	5.392	5.402	5.413	5.423	5.433	5.443	610
620	5.443	5.454	5.464	5.474	5.485	5.495	5.505	5.515	5.526	5.536	5.546	620
630	5.546	5.557	5.567	5.577	5.588	5.598	5.608	5.618	5.629	5.639	5.649	630
640	5.649	5.660	5.670	5.680	5.691	5.701	5.712	5.722	5.732	5.743	5.753	640
650	5.753	5.763	5.774	5.784	5.794	5.805	5.815	5.826	5.836	5.846	5.857	650
660	5.857	5.867	5.878	5.888	5.898	5.909	5.919	5.930	5.940	5.950	5.961	660
670	5.961	5.971	5.982	5.992	6.003	6.013	6.024	6.034	6.044	6.055	6.065	670
680	6.065	6.076	6.086	6.097	6.107	6.118	6.128	6.139	6.149	6.160	6.170	680
690	6.170	6.181	6.191	6.202	6.212	6.223	6.233	6.244	6.254	6.265	6.275	690
700	6.275	6.286	6.296	6.307	6.317	6.328	6.338	6.349	6.360	6.370	6.381	700
710	6.381	6.391	6.402	6.412	6.423	6.434	6.444	6.455	6.465	6.476	6.486	710
720	6.486	6.497	6.508	6.518	6.529	6.539	6.550	6.561	6.571	6.582	6.593	720
730	6.593	6.603	6.614	6.624	6.635	6.646	6.656	6.667	6.678	6.688	6.699	730
740	6.699	6.710	6.720	6.731	6.742	6.752	6.763	6.774	6.784	6.795	6.806	740
750	6.806	6.817	6.827	6.838	6.849	6.859	6.870	6.881	6.892	6.902	6.913	750
760	6.913	6.924	6.934	6.945	6.956	6.967	6.977	6.988	6.999	7.010	7.020	760
770	7.020	7.031	7.042	7.053	7.064	7.074	7.085	7.096	7.107	7.117	7.128	770
780	7.128	7.139	7.150	7.161	7.172	7.182	7.193	7.204	7.215	7.226	7.236	780
790	7.236	7.247	7.258	7.269	7.280	7.291	7.302	7.312	7.323	7.334	7.345	790
800	7.345	7.356	7.367	7.378	7.388	7.399	7.410	7.421	7.432	7.443	7.454	800
810	7.454	7.465	7.476	7.487	7.497	7.508	7.519	7.530	7.541	7.552	7.563	810
820	7.563	7.574	7.585	7.596	7.607	7.618	7.629	7.640	7.651	7.662	7.673	820
830	7.673	7.684	7.695	7.706	7.717	7.728	7.739	7.750	7.761	7.772	7.783	830
840	7.783	7.794	7.805	7.816	7.827	7.838	7.849	7.860	7.871	7.882	7.893	840
850	7.893	7.904	7.915	7.926	7.937	7.948	7.959	7.970	7.981	7.992	8.003	850
860	8.003	8.014	8.026	8.037	8.048	8.059	8.070	8.081	8.092	8.103	8.114	860
870	8.114	8.125	8.137	8.148	8.159	8.170	8.181	8.192	8.203	8.214	8.226	870
880	8.226	8.237	8.248	8.259	8.270	8.281	8.293	8.304	8.315	8.326	8.337	880
890	8.337	8.348	8.360	8.371	8.382	8.393	8.404	8.416	8.427	8.438	8.449	890
900	8.449	8.460	8.472	8.483	8.494	8.505	8.517	8.528	8.539	8.550	8.562	900
910	8.562	8.573	8.584	8.595	8.607	8.618	8.629	8.640	8.652	8.663	8.674	910
920	8.674	8.685	8.697	8.708	8.719	8.731	8.742	8.753	8.765	8.776	8.787	920
930	8.787	8.798	8.810	8.821	8.832	8.844	8.855	8.866	8.878	8.889	8.900	930
940	8.900	8.912	8.923	8.935	8.946	8.957	8.969	8.980	8.991	9.003	9.014	940
950	9.014	9.025	9.037	9.048	9.060	9.071	9.082	9.094	9.105	9.117	9.128	950
960	9.128	9.139	9.151	9.162	9.174	9.185	9.197	9.208	9.219	9.231	9.242	960
970	9.242	9.254	9.265	9.277	9.288	9.300	9.311	9.323	9.334	9.345	9.357	970
980	9.357	9.368	9.380	9.391	9.403	9.414	9.426	9.437	9.449	9.460	9.472	980
990	9.472	9.483	9.495	9.506	9.518	9.529	9.541	9.552	9.564	9.576	9.587	990
1000	9.587	9.599	9.610	9.622	9.633	9.645	9.656	9.668	9.680	9.691	9.703	1000
1010	9.703	9.714	9.726	9.737	9.749	9.761	9.772	9.784	9.795	9.807	9.819	1010
1020	9.819	9.830	9.842	9.853	9.865	9.877	9.888	9.900	9.911	9.923	9.935	1020
1030	9.935	9.946	9.958	9.970	9.981	9.993	10.005	10.016	10.028	10.040	10.051	1030
1040	10.051	10.063	10.075	10.086	10.098	10.110	10.121	10.133	10.145	10.156	10.168	1040
1050	10.168	10.180	10.191	10.203	10.215	10.227	10.238	10.250	10.262	10.273	10.285	1050
1060	10.285	10.297	10.309	10.320	10.332	10.344	10.356	10.367	10.379	10.391	10.403	1060
1070	10.403	10.414	10.426	10.438	10.450	10.461	10.473	10.485	10.497	10.509	10.520	1070
1080	10.520	10.532	10.544	10.556	10.567	10.579	10.591	10.603	10.615	10.626	10.638	1080
1090	10.638	10.650	10.662	10.674	10.686	10.697	10.709	10.721	10.733	10.745	10.757	1090
1100	10.757	10.768	10.780	10.792	10.804	10.816	10.828	10.839	10.851	10.863	10.875	1100
1110	10.875	10.887	10.899	10.911	10.922	10.934	10.946	10.958	10.970	10.982	10.994	1110
1120	10.994	11.006	11.017	11.029	11.041	11.053	11.065	11.077	11.089	11.101	11.113	1120
1130	11.113	11.125	11.136	11.148	11.160	11.172	11.184	11.196	11.208	11.220	11.232	1130
1140	11.232	11.244	11.256	11.268	11.280	11.291	11.303	11.315	11.327	11.339	11.351	1140

Revised Thermocouple Reference Tables

TYPE S

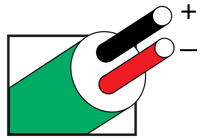
Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90



Thermocouple Grade

NONE ESTABLISHED

Platinum-10% Rhodium vs. Platinum



Extension Grade

MAXIMUM TEMPERATURE RANGE

Thermocouple Grade
32 to 2642°F
0 to 1450°C

Extension Grade
32 to 300°F
0 to 150°C

LIMITS OF ERROR
(whichever is greater)
Standard: 1.5°C or 0.25%
Special: 0.6°C or 0.1%

COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Do Not Insert in Metal Tubes; Beware of Contamination; High Temperature

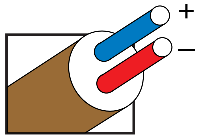
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1150	11.351	11.363	11.375	11.387	11.399	11.411	11.423	11.435	11.447	11.459	11.471	1150
1160	11.471	11.483	11.495	11.507	11.519	11.531	11.542	11.554	11.566	11.578	11.590	1160
1170	11.590	11.602	11.614	11.626	11.638	11.650	11.662	11.674	11.686	11.698	11.710	1170
1180	11.710	11.722	11.734	11.746	11.758	11.770	11.782	11.794	11.806	11.818	11.830	1180
1190	11.830	11.842	11.854	11.866	11.878	11.890	11.902	11.914	11.926	11.939	11.951	1190
1200	11.951	11.963	11.975	11.987	11.999	12.011	12.023	12.035	12.047	12.059	12.071	1200
1210	12.071	12.083	12.095	12.107	12.119	12.131	12.143	12.155	12.167	12.179	12.191	1210
1220	12.191	12.203	12.216	12.228	12.240	12.252	12.264	12.276	12.288	12.300	12.312	1220
1230	12.312	12.324	12.336	12.348	12.360	12.372	12.384	12.397	12.409	12.421	12.433	1230
1240	12.433	12.445	12.457	12.469	12.481	12.493	12.505	12.517	12.529	12.542	12.554	1240
1250	12.554	12.566	12.578	12.590	12.602	12.614	12.626	12.638	12.650	12.662	12.675	1250
1260	12.675	12.687	12.699	12.711	12.723	12.735	12.747	12.759	12.771	12.783	12.796	1260
1270	12.796	12.808	12.820	12.832	12.844	12.856	12.868	12.880	12.892	12.905	12.917	1270
1280	12.917	12.929	12.941	12.953	12.965	12.977	12.989	13.001	13.014	13.026	13.038	1280
1290	13.038	13.050	13.062	13.074	13.086	13.098	13.111	13.123	13.135	13.147	13.159	1290
1300	13.159	13.171	13.183	13.195	13.208	13.220	13.232	13.244	13.256	13.268	13.280	1300
1310	13.280	13.292	13.305	13.317	13.329	13.341	13.353	13.365	13.377	13.390	13.402	1310
1320	13.402	13.414	13.426	13.438	13.450	13.462	13.474	13.487	13.499	13.511	13.523	1320
1330	13.523	13.535	13.547	13.559	13.572	13.584	13.596	13.608	13.620	13.632	13.644	1330
1340	13.644	13.657	13.669	13.681	13.693	13.705	13.717	13.729	13.742	13.754	13.766	1340
1350	13.766	13.778	13.790	13.802	13.814	13.826	13.839	13.851	13.863	13.875	13.887	1350
1360	13.887	13.899	13.911	13.924	13.936	13.948	13.960	13.972	13.984	13.996	14.009	1360
1370	14.009	14.021	14.033	14.045	14.057	14.069	14.081	14.094	14.106	14.118	14.130	1370
1380	14.130	14.142	14.154	14.166	14.178	14.191	14.203	14.215	14.227	14.239	14.251	1380
1390	14.251	14.263	14.276	14.288	14.300	14.312	14.324	14.336	14.348	14.360	14.373	1390
1400	14.373	14.385	14.397	14.409	14.421	14.433	14.445	14.457	14.470	14.482	14.494	1400
1410	14.494	14.506	14.518	14.530	14.542	14.554	14.567	14.579	14.591	14.603	14.615	1410
1420	14.615	14.627	14.639	14.651	14.664	14.676	14.688	14.700	14.712	14.724	14.736	1420
1430	14.736	14.748	14.760	14.773	14.785	14.797	14.809	14.821	14.833	14.845	14.857	1430
1440	14.857	14.869	14.881	14.894	14.906	14.918	14.930	14.942	14.954	14.966	14.978	1440
1450	14.978	14.990	15.002	15.015	15.027	15.039	15.051	15.063	15.075	15.087	15.099	1450
1460	15.099	15.111	15.123	15.135	15.148	15.160	15.172	15.184	15.196	15.208	15.220	1460
1470	15.220	15.232	15.244	15.256	15.268	15.280	15.292	15.304	15.317	15.329	15.341	1470
1480	15.341	15.353	15.365	15.377	15.389	15.401	15.413	15.425	15.437	15.449	15.461	1480
1490	15.461	15.473	15.485	15.497	15.509	15.521	15.534	15.546	15.558	15.570	15.582	1490
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1500	15.582	15.594	15.606	15.618	15.630	15.642	15.654	15.666	15.678	15.690	15.702	1500
1510	15.702	15.714	15.726	15.738	15.750	15.762	15.774	15.786	15.798	15.810	15.822	1510
1520	15.822	15.834	15.846	15.858	15.870	15.882	15.894	15.906	15.918	15.930	15.942	1520
1530	15.942	15.954	15.966	15.978	15.990	16.002	16.014	16.026	16.038	16.050	16.062	1530
1540	16.062	16.074	16.086	16.098	16.110	16.122	16.134	16.146	16.158	16.170	16.182	1540
1550	16.182	16.194	16.205	16.217	16.229	16.241	16.253	16.265	16.277	16.289	16.301	1550
1560	16.301	16.313	16.325	16.337	16.349	16.361	16.373	16.385	16.396	16.408	16.420	1560
1570	16.420	16.432	16.444	16.456	16.468	16.480	16.492	16.504	16.516	16.527	16.539	1570
1580	16.539	16.551	16.563	16.575	16.587	16.599	16.611	16.623	16.634	16.646	16.658	1580
1590	16.658	16.670	16.682	16.694	16.706	16.718	16.729	16.741	16.753	16.765	16.777	1590
1600	16.777	16.789	16.801	16.812	16.824	16.836	16.848	16.860	16.872	16.883	16.895	1600
1610	16.895	16.907	16.919	16.931	16.943	16.954	16.966	16.978	16.990	17.002	17.013	1610
1620	17.013	17.025	17.037	17.049	17.061	17.072	17.084	17.096	17.108	17.120	17.131	1620
1630	17.131	17.143	17.155	17.167	17.178	17.190	17.202	17.214	17.225	17.237	17.249	1630
1640	17.249	17.261	17.272	17.284	17.296	17.308	17.319	17.331	17.343	17.355	17.366	1640
1650	17.366	17.378	17.390	17.401	17.413	17.425	17.437	17.448	17.460	17.472	17.483	1650
1660	17.483	17.495	17.507	17.518	17.530	17.542	17.553	17.565	17.577	17.588	17.600	1660
1670	17.600	17.612	17.623	17.635	17.647	17.658	17.670	17.682	17.693	17.705	17.717	1670
1680	17.717	17.728	17.740	17.751	17.763	17.775	17.786	17.798	17.809	17.821	17.832	1680
1690	17.832	17.844	17.855	17.867	17.878	17.890	17.901	17.913	17.924	17.936	17.947	1690
1700	17.947	17.959	17.970	17.982	17.993	18.004	18.016	18.027	18.039	18.050	18.061	1700
1710	18.061	18.073	18.084	18.095	18.107	18.118	18.129	18.140	18.152	18.163	18.174	1710
1720	18.174	18.185	18.196	18.208	18.219	18.230	18.241	18.252	18.263	18.274	18.285	1720
1730	18.285	18.297	18.308	18.319	18.330	18.341	18.352	18.362	18.373	18.384	18.395	1730
1740	18.395	18.406	18.417	18.428	18.439	18.449	18.460	18.471	18.482	18.493	18.503	1740
1750	18.503	18.514	18.525	18.535	18.546	18.557	18.567	18.578	18.588	18.599	18.609	1750
1760	18.609	18.620	18.630	18.641	18.651	18.661	18.672	18.682	18.693			1760
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

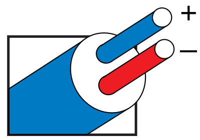


Thermocouple Grade

TYPE T

Reference Tables
N.I.S.T. Monograph 175
Revised to ITS-90

Copper vs. Copper-Nickel



Extension Grade

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
– 328 to 662°F
– 200 to 350°C
Extension Grade
– 76 to 212°F
– 60 to 100°C
LIMITS OF ERROR
(whichever is greater)
Standard: 1.0°C or 0.75% Above 0°C
1.0°C or 1.5% Below 0°C
Special: 0.5°C or 0.4%
COMMENTS, BARE WIRE ENVIRONMENT:
Mild Oxidizing, Reducing Vacuum or Inert; Good Where Moisture Is Present; Low Temperature and Cryogenic Applications
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-260	-6.258	-6.256	-6.255	-6.253	-6.251	-6.248	-6.245	-6.242	-6.239	-6.236	-6.232	-260
-250	-6.232	-6.228	-6.223	-6.219	-6.214	-6.209	-6.204	-6.198	-6.193	-6.187	-6.180	-250
-240	-6.180	-6.174	-6.167	-6.160	-6.153	-6.146	-6.138	-6.130	-6.122	-6.114	-6.105	-240
-230	-6.105	-6.096	-6.087	-6.078	-6.068	-6.059	-6.049	-6.038	-6.028	-6.017	-6.007	-230
-220	-6.007	-5.996	-5.985	-5.973	-5.962	-5.950	-5.938	-5.926	-5.914	-5.901	-5.888	-220
-210	-5.888	-5.876	-5.863	-5.850	-5.836	-5.823	-5.809	-5.795	-5.782	-5.767	-5.753	-210
-200	-5.753	-5.739	-5.724	-5.710	-5.695	-5.680	-5.665	-5.650	-5.634	-5.619	-5.603	-200
-190	-5.603	-5.587	-5.571	-5.555	-5.539	-5.523	-5.506	-5.489	-5.473	-5.456	-5.439	-190
-180	-5.439	-5.421	-5.404	-5.387	-5.369	-5.351	-5.334	-5.316	-5.297	-5.279	-5.261	-180
-170	-5.261	-5.242	-5.224	-5.205	-5.186	-5.167	-5.148	-5.128	-5.109	-5.089	-5.070	-170
-160	-5.070	-5.050	-5.030	-5.010	-4.989	-4.969	-4.949	-4.928	-4.907	-4.886	-4.865	-160
-150	-4.865	-4.844	-4.823	-4.802	-4.780	-4.759	-4.737	-4.715	-4.693	-4.671	-4.648	-150
-140	-4.648	-4.626	-4.604	-4.581	-4.558	-4.535	-4.512	-4.489	-4.466	-4.443	-4.419	-140
-130	-4.419	-4.395	-4.372	-4.348	-4.324	-4.300	-4.275	-4.251	-4.226	-4.202	-4.177	-130
-120	-4.177	-4.152	-4.127	-4.102	-4.077	-4.052	-4.026	-4.000	-3.975	-3.949	-3.923	-120
-110	-3.923	-3.897	-3.871	-3.844	-3.818	-3.791	-3.765	-3.738	-3.711	-3.684	-3.657	-110
-100	-3.657	-3.629	-3.602	-3.574	-3.547	-3.519	-3.491	-3.463	-3.435	-3.407	-3.379	-100
-90	-3.379	-3.350	-3.322	-3.293	-3.264	-3.235	-3.206	-3.177	-3.148	-3.118	-3.089	-90
-80	-3.089	-3.059	-3.030	-3.000	-2.970	-2.940	-2.910	-2.879	-2.849	-2.818	-2.788	-80
-70	-2.788	-2.757	-2.726	-2.695	-2.664	-2.633	-2.602	-2.571	-2.539	-2.507	-2.476	-70
-60	-2.476	-2.444	-2.412	-2.380	-2.348	-2.316	-2.283	-2.251	-2.218	-2.186	-2.153	-60
-50	-2.153	-2.120	-2.087	-2.054	-2.021	-1.987	-1.954	-1.920	-1.887	-1.853	-1.819	-50
-40	-1.819	-1.785	-1.751	-1.717	-1.683	-1.648	-1.614	-1.579	-1.545	-1.510	-1.475	-40
-30	-1.475	-1.440	-1.405	-1.370	-1.335	-1.299	-1.264	-1.228	-1.192	-1.157	-1.121	-30
-20	-1.121	-1.085	-1.049	-1.013	-0.976	-0.940	-0.904	-0.867	-0.830	-0.794	-0.757	-20
-10	-0.757	-0.720	-0.683	-0.646	-0.608	-0.571	-0.534	-0.496	-0.459	-0.421	-0.383	-10
0	-0.383	-0.345	-0.307	-0.269	-0.231	-0.193	-0.154	-0.116	-0.077	-0.039	0.000	0

°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.039	0.078	0.117	0.156	0.195	0.234	0.273	0.312	0.352	0.391	0
10	0.391	0.431	0.470	0.510	0.549	0.589	0.629	0.669	0.709	0.749	0.790	10
20	0.790	0.830	0.870	0.911	0.951	0.992	1.033	1.074	1.114	1.155	1.196	20
30	1.196	1.238	1.279	1.320	1.362	1.403	1.445	1.486	1.528	1.570	1.612	30
40	1.612	1.654	1.696	1.738	1.780	1.823	1.865	1.908	1.950	1.993	2.036	40

°C	0	1	2	3	4	5	6	7	8	9	10	°C
50	2.036	2.079	2.122	2.165	2.208	2.251	2.294	2.338	2.381	2.425	2.468	50
60	2.468	2.512	2.556	2.600	2.643	2.687	2.732	2.776	2.820	2.864	2.909	60
70	2.909	2.953	2.998	3.043	3.087	3.132	3.177	3.222	3.267	3.312	3.358	70
80	3.358	3.403	3.448	3.494	3.539	3.585	3.631	3.677	3.722	3.768	3.814	80
90	3.814	3.860	3.907	3.953	3.999	4.046	4.092	4.138	4.185	4.232	4.279	90
100	4.279	4.325	4.372	4.419	4.466	4.513	4.561	4.608	4.655	4.702	4.750	100
110	4.750	4.798	4.845	4.893	4.941	4.988	5.036	5.084	5.132	5.180	5.228	110
120	5.228	5.277	5.325	5.373	5.422	5.470	5.519	5.567	5.616	5.665	5.714	120
130	5.714	5.763	5.812	5.861	5.910	5.959	6.008	6.057	6.107	6.156	6.206	130
140	6.206	6.255	6.305	6.355	6.404	6.454	6.504	6.554	6.604	6.654	6.704	140
150	6.704	6.754	6.805	6.855	6.905	6.956	7.006	7.057	7.107	7.158	7.209	150
160	7.209	7.260	7.310	7.361	7.412	7.463	7.515	7.566	7.617	7.668	7.720	160
170	7.720	7.771	7.823	7.874	7.926	7.977	8.029	8.081	8.133	8.185	8.237	170
180	8.237	8.289	8.341	8.393	8.445	8.497	8.550	8.602	8.654	8.707	8.759	180
190	8.759	8.812	8.865	8.917	8.970	9.023	9.076	9.129	9.182	9.235	9.288	190
200	9.288	9.341	9.395	9.448	9.501	9.555	9.608	9.662	9.715	9.769	9.822	200
210	9.822	9.876	9.930	9.984	10.038	10.092	10.146	10.200	10.254	10.308	10.362	210
220	10.362	10.417	10.471	10.525	10.580	10.634	10.689	10.743	10.798	10.853	10.907	220
230	10.907	10.962	11.017	11.072	11.127	11.182	11.237	11.292	11.347	11.403	11.458	230
240	11.458	11.513	11.569	11.624	11.680	11.735	11.791	11.846	11.902	11.958	12.013	240
250	12.013	12.069	12.125	12.181	12.237	12.293	12.349	12.405	12.461	12.518	12.574	250
260	12.574	12.630	12.687	12.743	12.799	12.856	12.912	12.969	13.026	13.082	13.139	260
270	13.139	13.196	13.253	13.310	13.366	13.423	13.480	13.537	13.595	13.652	13.709	270
280	13.709	13.766	13.823	13.881	13.938	13.995	14.053	14.110	14.168	14.226	14.283	280
290	14.283	14.341	14.399	14.456	14.514	14.572	14.630	14.688	14.746	14.804	14.862	290
300	14.862	14.920	14.978	15.036	15.095	15.153	15.211	15.270	15.328	15.386	15.445	300
310	15.445	15.503	15.562	15.621	15.679	15.738	15.797	15.856	15.914	15.973	16.032	310
320	16.032	16.091	16.150	16.209	16.268	16.327	16.387	16.446	16.505	16.564	16.624	320
330	16.624	16.683	16.742	16.802	16.861	16.921	16.980	17.040	17.100	17.159	17.219	330
340	17.219	17.279	17.339	17.399	17.458	17.518	17.578	17.638	17.698	17.759	17.819	340
350	17.819	17.879	17.939	17.999	18.060	18.120	18.180	18.241	18.301	18.362	18.422	350
360	18.422	18.483	18.543	18.604	18.665	18.725	18.786	18.847	18.908	18.969	19.030	360
370	19.030	19.091	19.152	19.213	19.274	19.335	19.396	19.457	19.518	19.579	19.641	370
380	19.641	19.702	19.763	19.825	19.886	19.947	20.009	20.070	20.132	20.193	20.255	380
390	20.255	20.317	20.378	20.440	20.502	20.563	20.625	20.687	20.748	20.810	20.872	390
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Tungsten vs. Tungsten-26% Rhenium - Type G*

Temperature in Degrees F | Reference Junction at 32°F

DEGREES F	0°	20°	40°	60°	80°	DEGREES F	0°	20°	40°	60°	80°
0°	-.016	-.007	0.006	0.026	0.050	**2200°**	18.701	18.936	19.170	19.405	19.639
100°	0.079	0.113	0.153	0.197	0.246	**2300°**	19.873	20.106	20.340	20.573	20.806
200°	0.299	0.357	0.420	0.487	0.559	**2400°**	21.038	21.270	21.502	21.734	21.965
300°	0.634	0.714	0.799	0.887	0.979	**2500°**	22.195	22.425	22.655	22.884	23.113
400°	1.075	1.175	1.279	1.387	1.498	**2600°**	23.341	23.569	23.796	24.023	24.249
500°	1.613	1.731	1.853	1.978	2.106	**2700°**	24.474	24.699	24.923	25.146	25.369
600°	2.238	2.373	2.511	2.652	2.796	**2800°**	25.591	25.812	26.033	26.253	26.472
700°	2.943	3.093	3.246	3.401	3.559	**2900°**	26.690	26.907	27.124	27.340	27.555
800°	3.720	3.884	4.049	4.218	4.389	**3000°**	27.769	27.983	28.195	28.407	28.618
900°	4.562	4.737	4.915	5.095	5.277	**3100°**	28.827	29.036	29.244	29.451	29.657
1000°	5.461	5.647	5.836	6.026	6.218	**3200°**	29.862	30.066	30.269	30.471	30.672
1100°	6.412	6.607	6.805	7.004	7.205	**3300°**	30.871	31.070	31.268	31.464	31.660
1200°	7.407	7.611	7.816	8.023	8.232	**3400°**	31.854	32.047	32.240	32.430	32.620
1300°	8.441	8.652	8.865	9.078	9.293	**3500°**	32.809	32.996	33.182	33.367	33.551
1400°	9.509	9.726	9.945	10.164	10.384	**3600°**	33.733	33.914	34.094	34.273	34.450
1500°	10.606	10.828	11.051	11.275	11.500	**3700°**	34.626	34.801	34.974	35.146	35.317
1600°	11.725	11.952	12.179	12.407	12.635	**3800°**	35.486	35.654	35.821	35.986	36.150
1700°	12.864	13.094	13.324	13.555	13.786	**3900°**	36.312	36.473	36.632	36.790	36.946
1800°	14.018	14.250	14.482	14.715	14.948	**4000°**	37.101	37.254	37.406	37.557	37.705
1900°	15.182	15.415	15.649	15.884	16.118	**4100°**	37.853	37.998	38.142	38.285	38.425
2000°	16.353	16.587	16.822	17.057	17.292	**4200°**	38.564				
2100°	17.527	17.762	17.997	18.232	18.467						

Adopted March 4, 1974

Tungsten-5% Rhenium vs. Tungsten-26% Rhenium - Type C*

Temperature in Degrees F | Reference Junction at 32°F

DEGREES F	0°	20°	40°	60°	80°	DEGREES F	0°	20°	40°	60°	80°
0°	-.234	-.089	0.059	0.211	0.365	**2200°**	21.896	22.087	22.277	22.466	22.655
100°	0.522	0.682	0.845	1.010	1.178	**2300°**	22.843	23.030	23.217	23.403	23.588
200°	1.348	1.520	1.695	1.872	2.051	**2400°**	23.772	23.956	24.138	24.320	24.502
300°	2.232	2.415	2.600	2.786	2.975	**2500°**	24.682	24.862	25.041	25.219	25.397
400°	3.165	3.357	3.551	3.746	3.942	**2600°**	25.574	25.750	25.925	26.100	26.274
500°	4.140	4.339	4.540	4.742	4.945	**2700°**	26.447	26.619	26.791	26.962	27.132
600°	5.149	5.354	5.560	5.767	5.975	**2800°**	27.301	27.470	27.637	27.805	27.971
700°	6.184	6.394	6.604	6.815	7.027	**2900°**	28.137	28.301	28.466	28.629	28.791
800°	7.240	7.453	7.667	7.881	8.095	**3000°**	28.953	29.114	29.275	29.434	29.593
900°	8.310	8.526	8.741	8.957	9.174	**3100°**	29.751	29.908	30.065	30.221	30.376
1000°	9.390	9.607	9.824	10.041	10.258	**3200°**	30.530	30.683	30.836	30.988	31.139
1100°	10.475	10.693	10.910	11.127	11.344	**3300°**	31.289	31.438	31.587	31.735	31.882
1200°	11.561	11.778	11.995	12.212	12.429	**3400°**	32.028	32.173	32.318	32.461	32.604
1300°	12.645	12.861	13.077	13.292	13.508	**3500°**	32.746	32.887	33.027	33.166	33.305
1400°	13.723	13.937	14.152	14.366	14.579	**3600°**	33.442	33.579	33.714	33.849	33.982
1500°	14.792	15.005	15.217	15.429	15.640	**3700°**	34.115	34.247	34.378	34.507	34.636
1600°	15.851	16.062	16.271	16.481	16.689	**3800°**	34.763	34.890	35.015	35.140	35.263
1700°	16.898	17.105	17.312	17.519	17.725	**3900°**	35.385	35.506	35.626	35.744	35.862
1800°	17.930	18.134	18.339	18.542	18.745	**4000°**	35.978	36.093	36.206	36.319	36.430
1900°	18.947	19.148	19.349	19.549	19.748	**4100°**	36.539	36.647	36.754	36.860	36.964
2000°	19.947	20.145	20.343	20.539	20.735	**4200°**	37.066				
2100°	20.930	21.125	21.319	21.512	21.704						

Adopted March 4, 1974

Tungsten-3% Rhenium vs. Tungsten-25% Rhenium - Type D*

Temperature in Degrees F | Reference Junction at 32°F

DEGREES F	0°	20°	40°	60°	80°	DEGREES F	0°	20°	40°	60°	80°
0°	-.163	-.063	0.043	0.154	0.269	**2200°**	22.228	22.440	22.651	22.863	23.073
100°	0.390	0.515	0.644	0.778	0.916	**2300°**	23.283	23.492	23.701	23.909	24.116
200°	1.058	1.204	1.354	1.507	1.664	**2400°**	24.323	24.529	24.735	24.940	25.145
300°	1.824	1.988	2.154	2.324	2.497	**2500°**	25.348	25.551	25.754	25.956	26.157
400°	2.673	2.851	3.032	3.216	3.402	**2600°**	26.358	26.558	26.757	26.956	27.154
500°	3.590	3.781	3.973	4.168	4.365	**2700°**	27.352	27.548	27.745	27.940	28.135
600°	4.564	4.765	4.967	5.171	5.377	**2800°**	28.329	28.523	28.715	28.908	29.099
700°	5.584	5.793	6.003	6.214	6.427	**2900°**	29.290	29.480	29.669	29.858	30.046
800°	6.640	6.855	7.071	7.288	7.506	**3000°**	30.233	30.419	30.605	30.790	30.974
900°	7.725	7.945	8.165	8.386	8.608	**3100°**	31.158	31.340	31.522	31.703	31.884
1000°	8.830	9.053	9.277	9.501	9.726	**3200°**	32.063	32.242	32.420	32.596	32.772
1100°	9.951	10.176	10.402	10.628	10.854	**3300°**	32.948	33.122	33.295	33.467	33.639
1200°	11.080	11.307	11.534	11.761	11.988	**3400°**	33.809	33.979	34.147	34.314	34.481
1300°	12.215	12.443	12.670	12.897	13.125	**3500°**	34.646	34.810	34.973	35.135	35.295
1400°	13.352	13.579	13.807	14.034	14.262	**3600°**	35.455	35.613	35.770	35.926	36.080
1500°	14.489	14.717	14.944	15.171	15.398	**3700°**	36.233	36.384	36.535	36.683	36.831
1600°	15.624	15.850	16.076	16.302	16.527	**3800°**	36.976	37.120	37.263	37.404	37.543
1700°	16.752	16.976	17.200	17.424	17.647	**3900°**	37.681	37.816	37.950	38.082	38.213
1800°	17.870	18.093	18.315	18.537	18.758	**4000°**	38.341	38.467	38.591	38.714	38.834
1900°	18.979	19.199	19.419	19.638	19.857	**4100°**	38.951	39.067	39.180	39.291	39.400
2000°	20.075	20.293	20.510	20.726	20.943	**4200°**	39.506				
2100°	21.158	21.373	21.588	21.802	22.015						

Adopted March 4, 1974

*Not an ANSI designation

Tungsten-Rhenium Thermocouples Calibration Equivalents

CALIBRATIONS G AND C

The nominal emf versus temperature values for WM26Re (type G) and W5ReM26Re (type C) thermocouples are defined by fifth degree polynominals. The emf in absolute millivolts (IPTS68) is determined, using the equation and coefficients shown below, from the temperature in Fahrenheit degrees.

Gen. Form: $EMF = AT + BT^2 + CT^3 + DT^4 + ET^5 + K$

Temp. Range: 32˚F to 4200˚F (0 to 2315˚C)

CALIBRATION D

A similar equation is used to generate emf versus temperature values for W3ReM25Re thermocouples. For this combination, however, the curve is broken into two functions and the temperature is expressed in Celsius degrees.

Gen. Form: $EMF = AT + BT^2 + CT^3 + DT^4 + ET^5$

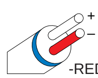
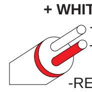
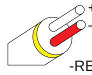
Temp. Range: 32 to 4208˚F (0 to 2320˚C)

THERMOCOUPLE WIRE IDENTIFICATION GUIDE

Coefficients	W/W26Re	W5Re/W26Re
A	0.2883146×10^{-3}	0.7190027×10^{-2}
B	0.6783829×10^{-5}	0.3956443×10^{-5}
C	$-0.1795965 \times 10^{-8}$	$-0.1842722 \times 10^{-8}$
D	$0.2125270 \times 10^{-12}$	$0.3471851 \times 10^{-12}$
E	$-0.1176051 \times 10^{-16}$	$-0.2616792 \times 10^{-16}$
K	$-0.1580014 \times 10^{-1}$	-0.234471

Coefficients	T<783˚C	T≥ 783 ˚C
A	9.5685256×10^{-3}	9.9109462×10^{-3}
B	2.0592621×10^{-5}	1.8666488×10^{-5}
C	$-1.8464573 \times 10^{-8}$	$-1.4935266 \times 10^{-8}$
D	$7.9498033 \times 10^{-12}$	$5.3743821 \times 10^{-12}$
E	$-1.4240735 \times 10^{-15}$	$-7.9026726 \times 10^{-16}$

THERMOCOUPLE WIRE IDENTIFICATION GUIDE

Letter Code	Alloy Combination +Lead	Alloy Combination -Lead	Color Coding Ext. Grade	Maximum Useful Temperature Range	EMF(mV) Over Useful Temperature Range	Standard Limits of Error	Comments Environment Bare WIre
G	TUNGSTEN W	TUNGSTEN 26% RHENIUM W-26% Re	+ WHITE  + – -RED WHITE - BLUE TRACE	32 TO 4208˚F 0 TO 2320˚C Thermocouple Grade 32 to 500˚F 0 to 260˚C Extension Grade	0 TO 38.564	4.5˚C TO 425˚C 1.0% TO 2320˚C	Vacuum Inert Hydrogen. Beware of Embrittlement. Not Practical Below 750˚F Not for Oxidizing Atmosphere
C	TUNGSTEN 5% RHENIUM W-5% Re	TUNGSTEN 26% RHENIUM W-26% Re	+ WHITE  + – -RED WHITE - RED TRACE	32 TO 4208˚F 0 TO 2320˚C Thermocouple Grade 32 to 1600˚F 0 to 870˚C Extension Grade	0 TO 37.066	4.5˚C TO 425˚C 1.0% TO 2320˚C	Vacuum Inert Hydrogen. Beware of Embrittlement. Not Practical Below 750˚F Not for Oxidizing Atmosphere
D	TUNGSTEN 3% RHENIUM W-3% Re	TUNGSTEN 25% RHENIUM W-56% Re	+ WHITE  + – -RED WHITE - YELLOW TRACE	32 TO 4208˚F 0 TO 2320˚C Thermocouple Grade 32 to 5000˚F 0 to 260˚C Extension Grade	0 TO 39.506	4.5˚C TO 425˚C 1.0% TO 2320˚C	Vacuum Inert Hydrogen. Beware of Embrittlement. Not Practical Below 750˚F Not for Oxidizing Atmosphere

ITS-90 Thermocouple Direct & Inverse Polynomials

Direct Polynomials provide the thermoelectric voltage (µV) from a known temperature (°C); Inverse Polynomials provide the temperature (°C) from a known thermoelectric voltage (µV).

Type J Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature t_{90}, for the indicated temperature ranges. The equations are of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	**-210 to 760°C**	**760 to 1,200°C**
c_0 =	0.000 000 000 0	2.964 562 568 1 x 10^{5}
c_1 =	5.038 118 781 5 x10^{1}	-1.497 612 778 6 x 10^{3}
c_2 =	3.047 583 693 0 x 10^{-2}	3.178 710 392 4
c_3 =	-8.568 106 572 0 x 10^{-5}	-3.184 768 670 1 x 10^{-3}
c_4 =	1.322 819 529 5 x 10^{-7}	1.572 081 900 4 x 10^{-6}
c_5 =	-1.705 295 833 7 x 10^{-10}	-3.069 136 905 6 x 10^{-10}
c_6 =	2.094 809 069 7 x 10^{-13}	
c_7 =	-1.253 839 533 6 x 10^{-16}	
c_8 =	1.563 172 569 7 x 10^{-20}	

Type J Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1E + c_2E^2 + \ldots c_iE^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	**-210 to 0°C**	**0 to 760°C**	**760 to 1,200°C**
Voltage Range:	**-8,095 to 0 µV**	**0 to 42,919 µV**	**42,919 to 69,553 µV**
c_0 =	0.000 000 0	0.000 000	-3.113 581 87 x 10^{3}
c_1 =	1.952 826 8 x 10^{-2}	1.978 425 x 10^{-2}	3.005 436 84 x 10^{-1}
c_2 =	-1.228 618 5 x 10^{-6}	-2.001 204 x 10^{-7}	-9.947 732 30 x 10^{-6}
c_3 =	-1.075 217 8 x 10^{-9}	1.036 969 x 10^{-11}	1.702 766 30 x 10^{-10}
c_4 =	-5.908 693 3 x 10^{-13}	-2.549 687 x 10^{-16}	-1.430 334 68 x 10^{-15}
c_5 =	-1.725 671 3 x 10^{-16}	3.585 153 x 10^{-21}	4.738 860 84 x 10^{-21}
c_6 =	-2.813 151 3 x 10^{-20}	-5.344 285 x 10^{-26}	
c_7 =	-2.396 337 0 x 10^{-24}	5.099 890 x 10^{-31}	
c_8 =	-8.382 332 1 x 10^{-29}		
Error Range:	0.03 to -0.05°C	0.04 to -0.04°C	0.03 to -0.04°C

Type K Thermocouples - coefficients α_0, α_1 and α_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90} for the indicated temperature ranges. The equation below 0°C is of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i$$

the equation above 0°C is of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i + \alpha_0 e^{\alpha 1 (t_{90} - 126.9686)^2}$$

where e is the natural logarithm constant, E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:		**Coefficients**
-270 to 0°C	c_0 =	0.000 000 000 0 ....
	c_1 =	3.945 012 802 5 x 10^{1}
	c_2 =	2.362 237 359 8 x 10^{-2}
	c_3 =	-3.285 890 678 4 x 10^{-4}
	c_4 =	-4.990 482 877 7 x 10^{-6}
	c_5 =	-6.750 905 917 3 x 10^{-8}
	c_6 =	-5.741 032 742 8 x 10^{-10}
	c_7 =	-3.108 887 289 4 x 10^{-12}
	c_8 =	-1.045 160 936 5 x 10^{-14}
	c_9 =	-1.988 926 687 8 x 10^{-17}
	c_{10} =	-1.632 269 748 6 x 10^{-20}
0 to 1372°C	c_0 =	-1.760 041 368 6 x 10^{1}
	c_1 =	3.892 120 497 5 x 10^{1}
	c_2 =	1.855 877 003 2 x 10^{-2}
	c_3 =	-9.945 759 287 4 x 10^{-5}
	c_4 =	3.184 094 571 9 x 10^{-7}
	c_5 =	-5.607 284 488 9 x 10^{-10}
	c_6 =	5.607 505 905 9 x 10^{-13}
	c_7 =	-3.202 072 000 3 x 10^{-16}
	c_8 =	9.715 114 715 2 x 10^{-20}
	c_9 =	-1.210 472 127 5 x 10^{-23}
	α_0 =	1.185 976 x 10^{2}
	α_1 =	-1.183 432 x 10^{-4}

Type K Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_o + c_1E + c_2E^2 \quad c_iE^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	**-200 to 0°C**	**0 to 500°C**	**500 to 1,372°C**
Voltage Range:	**-5891 to 0 µV**	**0 to 20,644 µV**	**20,644 to 54,886 µV**
c_0 =	0.000 000 0	0.000 000	-1.318 058 x 10^{2}
c_1 =	2.517 346 2 x 10^{-2}	2.508 355 x 10^{-2}	4.830 222 x 10^{-2}
c_2 =	-1.166 287 8 x 10^{-6}	7.860 106 x 10^{-8}	-1.646 031 x 10^{-6}
c_3 =	-1.083 363 8 x 10^{-9}	-2.503 131 x 10^{-10}	5.464 731 x 10^{-11}
c_4 =	-8.977 354 0 x 10^{-13}	8.315 270 x 10^{-14}	-9.650 715 x 10^{-16}
c_5 =	-3.734 237 7 x 10^{-16}	-1.228 034 x 10^{-17}	8.802 193 x 10^{-21}
c_6 =	-8.663 264 3 x 10^{-20}	9.804 036 x 10^{-22}	-3.110 810 x 10^{-26}
c_7 =	-1.045 059 8 x 10^{-23}	-4.413 030 x 10^{-26}	
c_8 =	-5.192 057 7 x 10^{-28}	1.057 734 x 10^{-30}	
c_9 =		-1.052 755 x 10^{-35}	
Error Range:	0.04°C to -0.02°C	0.04°C to -0.05°C	0.06°C to -0.05°C

ITS-90 Thermocouple Direct & Inverse Polynomials Cont'd

Type T Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90}, for the indicated temperature ranges. The equations are of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-270 to 0°C	0 to 400°
c_0 =	0.000 000 000 0....	0.000 000 000 0....
c_1 =	3.874 810 636 4 x10^{1}	3.874 810 636 4 x10^{1}
c_2 =	4.419 443 434 7 x 10^{-2}	3.329 222 788 0 x10^{-2}
c_3 =	1.184 432 310 5 x 10^{-4}	2.061 824 340 4 x 10^{-4}
c_4 =	2.003 297 355 4 x 10^{-5}	-2.188 225 684 6 x 10^{-6}
c_5 =	9.013 801 955 9 x 10^{-7}	1.099 688 092 8 x 10^{-8}
c_6 =	2.265 115 659 3 x 10^{-8}	-3.081 575 877 2 x 10^{-11}
c_7 =	3.607 115 420 5 x 10^{-10}	4.547 913 529 0 x 10^{-14}
c_8 =	3.849 393 988 3 x 10^{-12}	-2.751 290 167 3 x 10^{-17}
c_9 =	2.821 352 192 5 x 10^{-14}	
c_{10} =	1.425 159 477 9 x 10^{-16}	
c_{11} =	4.876 866 228 6 x 10^{-19}	
c_{12} =	1.079 553 927 0 x 10^{-21}	
c_{13} =	1.394 502 706 2 x 10^{-24}	
c_{14} =	7.979 515 392 7 x 10^{-28}	

Type T Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1E + c_2E^2 + \ldots c_iE^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-200 to 0°C	0 to 400°C
Voltage: Range:	-5,603 to 0 μV	0 to 20,872 μV
c_0 =	0.000 000 0....	0.000 000 ....
c_1 =	2.594 919 2 x 10^{-2}	2.592 800 x 10^{-2}
c_2 =	-2.131 696 7 x 10^{-7}	-7.602 961 x 10^{-7}
c_3 =	7.901 869 2 x 10^{-10}	4.637 791 x 10^{-11}
c_4 =	4.252 777 7 x 10^{-13}	-2.165 394 x 10^{-15}
c_5 =	1.330 447 3 x 10^{-16}	6.048 144 x 10^{-20}
c_6 =	2.024 144 6 x 10^{-20}	-7.293 422 x 10^{-25}
c_7 =	1.266 817 1 x 10^{-24}	
Error Range:	0.04 to -0.02°C	0.03 to -0.03°C

Type E Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90}, for the indicated temperature ranges. The equations are of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-270 to 0°C	0 to 400°C
c_0 =	0.000 000 000 0	0.000 000 000 0 ....
c_1 =	5.866 550 870 8 x10^{1}	5.866 550 871 0 x10^{1}
c_2 =	4.541 097 712 4 x 10^{-2}	4.503 227 558 2 x10^{-2}
c_3 =	-7.799 804 868 6 x 10^{-4}	2.890 840 721 2 x 10^{-5}
c_4 =	-2.580 016 084 3 x 10^{-5}	-3.305 689 665 2 x 10^{-7}
c_5 =	-5.945 258 305 7 x 10^{-7}	6.502 440 327 0 x 10^{-10}
c_6 =	-9.321 405 866 7 x 10^{-9}	-1.919 749 550 4 x 10^{-13}
c_7 =	-1.028 760 553 4 x 10^{-10}	-1.253 660 049 7 x 10^{-15}
c_8 =	-8.037 012 362 1 x 10^{-13}	2.148 921 756 9 x 10^{-18}
c_9 =	-4.397 949 739 1 x 10^{-15}	-1.438 804 178 2 x 10^{-21}
c_{10} =	-1.641 477 635 5 x 10^{-17}	3.596 089 948 1 x 10^{-25}
c_{11} =	-3.967 361 951 6 x 10^{-20}	
c_{12} =	-5.582 732 872 1 x 10^{-23}	
c_{13} =	-3.465 784 201 3 x 10^{-26}	

Type E Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1E + c_2E^2 + \ldots c_iE^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-200 to 0°C	0 to 1,000°C
Voltage Range:	-8,825 to 0 μV	0 to 76,373 μV
c_0 =	0.000 000 0	0.000 000 0 ....
c_1 =	1.697 728 8 x 10^{-2}	1.705 703 5 x 10^{-2}
c_2 =	-4.351 497 0 x 10^{-7}	-2.330 175 9 x 10^{-7}
c_3 =	-1.585 969 7 x 10^{-10}	6.543 558 5 x 10^{-12}
c_4 =	-9.250 287 1 x 10^{-14}	-7.356 274 9 x 10^{-17}
c_5 =	-2.608 431 4 x 10^{-17}	-1.789 600 1 x 10^{-21}
c_6 =	-4.136 019 9 x 10^{-21}	8.403 616 5 x 10^{-26}
c_7 =	-3.403 403 0 x 10^{-25}	-1.373 587 9 x 10^{-30}
c_8 =	-1.156 489 0 x 10^{-29}	1.062 982 3 x 10^{-35}
c_9 =		-3.244 708 7 x 10^{-41}
Error Range:	0.03 to -0.01°C	0.02 to -0.02°C

Type N Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90}, for the indicated temperature ranges. The equations are of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-270 to 0°C	0 to 1,300°C
c_0 =	0.000 000 000 0....	0.000 000 000 0....
c_1 =	$2.615\ 910\ 596\ 2 \times 10^{1}$	$2.592\ 939\ 460\ 1 \times 10^{1}$
c_2 =	$1.095\ 748\ 422\ 8 \times 10^{-2}$	$1.571\ 014\ 188\ 0 \times 10^{-2}$
c_3 =	$-9.384\ 111\ 155\ 4 \times 10^{-5}$	$4.382\ 562\ 723\ 7 \times 10^{-5}$
c_4 =	$-4.641\ 203\ 975\ 9 \times 10^{-8}$	$-2.526\ 116\ 979\ 4 \times 10^{-7}$
c_5 =	$-2.630\ 335\ 771\ 6 \times 10^{-9}$	$6.431\ 181\ 933\ 9 \times 10^{-10}$
c_6 =	$-2.265\ 343\ 800\ 3 \times 10^{-11}$	$-1.006\ 347\ 151\ 9 \times 10^{-12}$
c_7 =	$-7.608\ 930\ 079\ 1 \times 10^{-14}$	$9.974\ 533\ 899\ 2 \times 10^{-16}$
c_8 =	$-9.341\ 966\ 783\ 5 \times 10^{-17}$	$-6.086\ 324\ 560\ 7 \times 10^{-19}$
c_9 =		$2.084\ 922\ 933\ 9 \times 10^{-22}$
c_{10} =		$-3.068\ 219\ 615\ 1 \times 10^{-26}$

Type N Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1 E + c_2 E^2 + \ldots c_i E^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-200 to 0°C	0 to 600°C	600 to 1,300°C	0 to 1,300°C
Voltage Range:	-3,990 to 0 µV	0 to 20,613 µV	20,613 to 47,513 µV	0 47,513 µV
c_0 =	0.000 000 0	0.000 00	$1.972\ 485 \times 10^{1}$	0.000 000 0 ....
c_1 =	$3.843\ 684\ 7 \times 10^{-2}$	$3.868\ 96 \times 10^{-2}$	$3.300\ 943 \times 10^{-2}$	$3.878\ 327\ 7 \times 10^{-2}$
c_2 =	$1.101\ 048\ 5 \times 10^{-6}$	$-1.082\ 67 \times 10^{-6}$	$-3.915\ 159 \times 10^{-7}$	$-1.161\ 234\ 4 \times 10^{-6}$
c_3 =	$5.222\ 931\ 2 \times 10^{-9}$	$4.702\ 05 \times 10^{-11}$	$9.855\ 391 \times 10^{-12}$	$6.952\ 565\ 5 \times 10^{-11}$
c_4 =	$7.206\ 052\ 5 \times 10^{-12}$	$-2.121\ 69 \times 10^{-18}$	$-1.274\ 371 \times 10^{-16}$	$-3.009\ 007\ 7 \times 10^{-15}$
c_5 =	$5.848\ 858\ 6 \times 10^{-15}$	$-1.172\ 72 \times 10^{-19}$	$7.767\ 022 \times 10^{-22}$	$8.831\ 158\ 4 \times 10^{-20}$
c_6 =	$2.775\ 491\ 6 \times 10^{-18}$	$5.392\ 80 \times 10^{-24}$		$-1.621\ 383\ 9 \times 10^{-24}$
c_7 =	$7.707.516\ 6 \times 10^{-22}$	$-7.981\ 56 \times 10^{-29}$		$1.669\ 336\ 2 \times 10^{-29}$
c_8 =	$1.158\ 266\ 5 \times 10^{-25}$			$-7.311\ 754\ 0 \times 10^{-35}$
c_9 =	$7.313\ 886\ 8 \times 10^{-30}$			
Error Range:	0.03 to -0.02°C	0.03 to -0.02°C	0.02 to -0.04°C	0.06 to -0.06°C

Type B Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90}, for the indicated temperature ranges. The equations are of the form:

$$E = \sum_{i=0}^{n} c_i (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	0 to 630.615°C	630.615 to 1,820°C
c_0 =	0.000 000 000 0	$-3.893\ 816\ 862\ 1 \times 10^{3}$
c_1 =	$-2.465\ 081\ 834\ 6 \times 10^{-1}$	$2.857\ 174\ 747\ 0 \times 10^{1}$
c_2 =	$5.904\ 042\ 117\ 1 \times 10^{-3}$	$-8.488\ 510\ 478\ 5 \times 10^{-2}$
c_3 =	$-1.325\ 793\ 163\ 6 \times 10^{-6}$	$1.578\ 528\ 016\ 4 \times 10^{-4}$
c_4 =	$1.566\ 829\ 190\ 1 \times 10^{-9}$	$-1.683\ 534\ 486\ 4 \times 10^{-7}$
c_5 =	$-1.694\ 452\ 924\ 0 \times 10^{-12}$	$1.110\ 979\ 401\ 3 \times 10^{-10}$
c_6 =	$6.229\ 034\ 709\ 4 \times 10^{-16}$	$-4.451\ 543\ 103\ 3 \times 10^{-14}$
c_7 =		$9.897\ 564\ 082\ 1 \times 10^{-18}$
c_8 =		$-9.379\ 133\ 028\ 9 \times 10^{-22}$

Type B Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1 E + c_2 E^2 + \ldots c_i E^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	250 to 700°C	700 to 1,820°C
Voltage Range:	291 to 2,431 µV	2,431 to 13,820 µV
c_0 =	$9.842\ 332\ 1 \times 10^{1}$	$2.131\ 507\ 1 \times 10^{2}$
c_1 =	$6.997\ 150\ 0 \times 10^{-1}$	$2.851\ 050\ 4 \times 10^{-1}$
c_2 =	$-8.476\ 530\ 4 \times 10^{-4}$	$-5.274\ 288\ 7 \times 10^{-5}$
c_3 =	$1.005\ 264\ 4 \times 10^{-6}$	$9.916\ 080\ 4 \times 10^{-9}$
c_4 =	$-8.334\ 595\ 2 \times 10^{-10}$	$-1.296\ 530\ 3 \times 10^{-12}$
c_5 =	$4.550\ 854\ 2 \times 10^{-13}$	$1.119\ 587\ 0 \times 10^{-16}$
c_6 =	$-1.552\ 303\ 7 \times 10^{-16}$	$-6.062\ 519\ 9 \times 10^{-21}$
c_7 =	$2.988\ 675\ 0 \times 10^{-20}$	$1.866\ 169\ 6 \times 10^{-25}$
c_8 =	$-2.474\ 286\ 0 \times 10^{-24}$	$-2.487\ 858\ 5 \times 10^{-30}$
Error Range:	0.03 to -0.02°C	0.02 to -0.01°C

ITS-90 Thermocouple Direct & Inverse Polynomials Cont'd

Type R Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90}, for the indicated temperature ranges. The equations are of the for:

$$E = \sum_{i=0}^{n} c_i \, (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-50 to 1,064.18°C	1,064.18 to 1,664.5°C	1,664.5 to 1,768.1°C
c_0 =	0.000 000 000 0	2.951 579 253 16 x 103	1.522 321 182 09 x 10^{5}
c_1 =	5.289 617 297 65	-2.520 612 513 32	-2.688 198 885 45 x 10^{2}
c_2 =	1.391 665 897 82 x 10^{-2}	1.595 645 018 65 x 10^{-2}	1.712 802 804 71 x 10^{-1}
c_3 =	-2.388 556 930 17 x 10^{-5}	-7.640 859 475 76 x 10^{-6}	-3.458 957 064 53 x 10^{-5}
c_4 =	3.569 160 010 63 x 10^{-8}	2.053 052 910 24 x 10^{-9}	-9.346 339 710 46 x 10^{-12}
c_5 =	-4.623 476 662 98 x 10^{-11}	-2.933 596 681 73 x 10^{-13}	
c_6 =	5.007 774 410 34 x 10^{-14}		
c_7 =	-3.731 058 861 91 x 10^{-17}		
c_8 =	1.577 164 823 67 x 10^{-20}		
c_9 =	-2.810 386 252 51 x 10^{-24}		

Type R Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1E + c_2E^2 + \ldots c_iE^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-50°C to 250°C	250 to 1,200°C	1,064 to 1,664.5°C	1,664.5 to 1,768.1°C
Voltage Range:	**-226 to 1,923 µV**	**1,923 to 13,228 µV**	**11,361 to 19,739 µV**	**19,739 to 21,103 µV**
c_0 =	0.000 000 0	1.334 584 505 x 10^{1}	-8.199 599 416 x 10^{1}	3.406 177 836 x 10^{4}
c_1 =	1.889 138 0 x 10^{-1}	1.472 644 573 x 10^{-1}	1.553 962 042 x 10^{-1}	-7.023 729 171 ....
c_2 =	-9.383 529 0 x 10^{-5}	-1.844 024 844 x 10^{-5}	-8.342 197 663 x 10^{-6}	5.582 903 813 x 10^{-4}
c_3 =	1.306 861 9 x 10^{-7}	4.031 129 x 726 10^{-9}	4.279 433 549 x 10^{-10}	-1.952 394 635 x 10^{-8}
c_4 =	-2.270 358 0 x 10^{-10}	-6.249 428 360 x 10^{-13}	-1.191 577 910 x 10^{-14}	2.560 740 231 x 10^{-13}
c_5 =	3.514 565 9 x 10^{-13}	6.468 412 046 x 10^{-17}	1.492 290 091 x 10^{-19}	
c_6 =	-3.895 390 0 x 10^{-16}	-4.458 750 426 x 10^{-21}		
c_7 =	2.823.947 1 x 10^{-19}	1.994 710 146 x 10^{-25}		
c_8 =	-1.260 728 1 x 10^{-22}	-5.313 401 790 x 10^{-30}		
c_9 =	3.135 361 1 x 10^{-26}	6.481 976 217 x 10^{-35}		
c_{10} =	-3.318 776 9 x 10^{-30}			
Error Range:	0.02 to -0.02°C	0.005 to -0.005°C	0.001 to -0.0005°C	0.002 to -0.001°C

Type S Thermocouples - coefficients, c_i, of reference equations giving the thermoelectric voltage, E, as a function of temperature, t_{90}, for the indicated temperature ranges. The equations are of the for:

$$E = \sum_{i=0}^{n} c_i \, (t_{90})^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-50 to 1,064.18°C	1,064.18 to 1,664.5°C	1,664.5 to 1,768.1°C
c_0 =	0.000 000 000 0	1.329 004 450 85 x 10^{3}	1.466 282 326 36 x 10^{5}
c_1 =	5.403 133 086 31....	3.345 093 113 44	-2.584 305 167 52 x 10^{2}
c_2 =	1.259 342 897 40 x 10^{-2}	6.548 051 928 18 x 10^{-3}	1.636 935 746 41 x 10^{-1}
c_3 =	-2.324 779 686 89 x 10^{-5}	-1.648 562 592 09 x 10^{-6}	-3.304 390 469 87 x 10^{-5}
c_4 =	3.220 288 230 36 x 10^{-8}	1.299 896 051 74 x 10^{-11}	-9.432 236 906 12 x 10^{-12}
c_5 =	-3.314 651 963 89 x 10^{-11}		
c_6 =	2.557 442 517 86 x 10^{-14}		
c_7 =	-1.250 688 713 93 x 10^{-17}		
c_8 =	2.714 431 761 45 x 10^{-21}		

Type S Thermocouples - coefficients of approximate inverse functions giving temperature, t_{90}, as a function of the thermoelectric voltage, E, in selected temperature and voltage ranges. The functions are of the form:

$$t_{90} = c_0 + c_1E + c_2E^2 + \ldots c_iE^i$$

where E is in microvolts and t_{90} is in degrees Celsius.

Temperature Range:	-50 to 250°C	250 to 1,200°C	1,064 to 1,664.5°C	1,664.5 to 1,768.1°C
Voltage Range:	**-235 to 1,874 µV**	**1,874 to 11,950 µV**	**10,332 to 17,536 µV**	**17,536 to 18,693 µV**
c_0 =	0.000 000 0	1.291 507 177 x 10^{1}	-8.087 801 117 x 10^{1}	5.333 875 126 x 10^{4}
c_1 =	1.849 494 60 x 10^{-1}	1.466 298 863 x 10^{-1}	1.621 573 104 x 10^{-1}	-1.235 892 298 x 10^{1}
c_2 =	-8.005 040 62 x 10^{-5}	-1.534 713 402 x 10^{-5}	-8.536 869 453 x 10^{-6}	1.092 657 613 x 10^{-3}
c_3 =	1.022 374 30 x 10^{-7}	3.145 945 973 x 10^{-9}	4.719 686 976 x 10^{-10}	-4.265 693 686 x 10^{-8}
c_4 =	-1.522 485 92 x 10^{-10}	-4.163 257 839 x 10^{-13}	-1.441 693 666 x 10^{-14}	6.247 205 420 x 10^{-13}
c_5 =	1.888 213 43 x 10^{-13}	3.187 963 771 x 10^{-17}	2.081 618 890 x 10^{-19}	
c_6 =	-1.590 859 41 x 10^{-16}	-1.291 637 500 x 10^{-21}		
c_7 =	8.230 278 80 x 10^{-20}	2.183 475 087 x 10^{-26}		
c_8 =	-2.341 819 44 x 10^{-23}	-1.447 379 511 x 10^{-31}		
c_9 =	2.797 862 60 x 10^{-27}	8.211 272 125 x 10^{-36}		
Error Range:	0.02 to -0.02°C	0.01 to -0.01°C	0.0002 to -0.0002°C	0.002 to -0.002°C

Reference Temperatures

We cannot build a temperature divider as we can a voltage divider, nor can we add temperatures as we would add lengths to measure distance. We must rely upon temperatures established by physical phenomena which are easily observed and consistent in nature. The International Practical Temperature Scale (IPTS) is based on such phenomena. Revised in 1968, it establishes eleven reference temperatures.

Since we have only these fixed temperatures to use as a reference, we must use instruments to interpolate between them. But accurately interpolating between these temperatures can require some fairly exotic transducers, many of which are too complicated or expensive to use in a practical situation. We shall limit our discussion to the four most common temperature transducers: thermocouples, resistance-temperature detector's (RTD's), thermistors, and integrated circuit sensors.

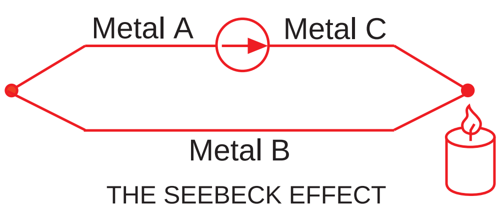
IPTS-68 REFERENCE TEMPERATURES

EQUILIBRIUM POINT	K	°C
Triple Point of Hydrogen	13.81	-259.34
Liquid/Vapor Phase of Hydrogen at 25/76 Std. Atmosphere	17.042	-256.108
Boiling Point of Hydrogen	20.28	-252.87
Boiling Point of Neon	27.102	-246.048
Triple Point of Oxygen	54.361	-218.789
Boiling Point of Oxygen	90.188	-182.962
Triple Point of Water	273.16	.01
Boiling Point of Water	373.15	100
Freezing Point of Zinc	692.73	419.58
Freezing Point of Silver	1235.08	961.93
Freezing Point of Gold	1337.58	1064.43

Table 1

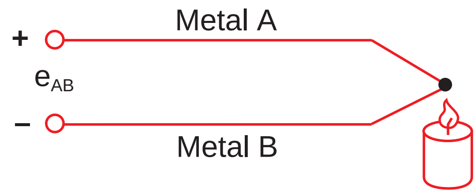
THE THERMOCOUPLE

When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, there is a continuous current which flows in the *thermoelectric* circuit. Thomas Seebeck made this discovery in 1821.



THE SEEBECK EFFECT
Figure 2

If this circuit is broken at the center, the net open circuit voltage (the Seebeck voltage) is a function of the junction temperature and the composition of the two metals.



e_{AB} = SEEBECK VOLTAGE
Figure 3

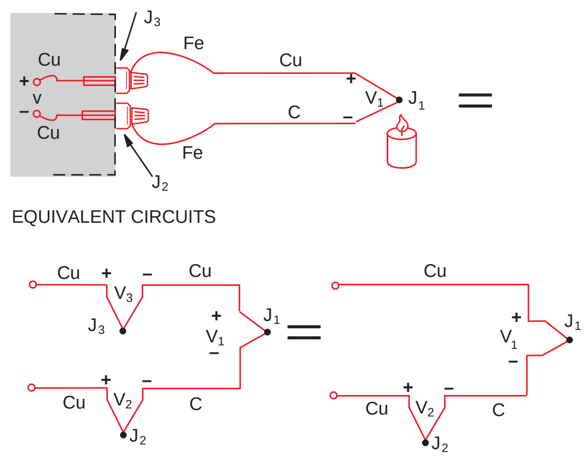
All dissimilar metals exhibit this effect. The most common combinations of two metals are listed in **Appendix B** of this application note, along with their important characteristics. For small changes in temperature the Seebeck voltage is linearly proportional to temperature:

$$\Delta e_{AB} = \alpha \Delta T$$

Where α, the Seebeck coefficient, is the constant of proportionality.

Measuring Thermocouple Voltage - We can't measure the Seebeck voltage directly because we must first connect a voltmeter to the thermocouple, and the voltmeter leads themselves create a new thermoelectric circuit.

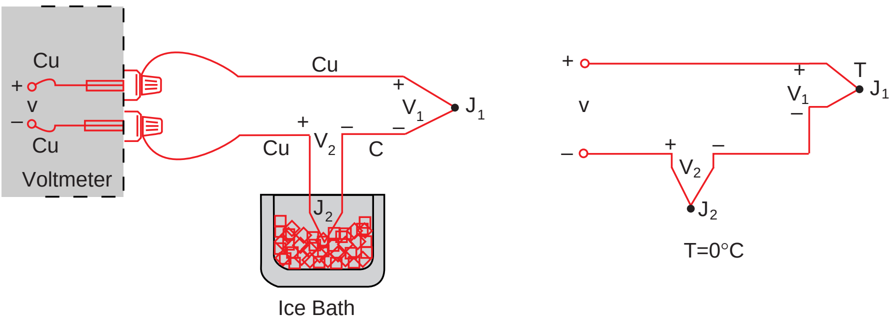
Let's connect a voltmeter across a copper-constantan (Type T) thermocouple and look at the voltage output:



MEASURING JUNCTION VOLTAGE WITH A DVM
Figure 4

We would like the voltmeter to read only V_1, but by connecting the voltmeter in an attempt to measure the output of Junction J_1, we have created two more metallic junctions: J_2 and J_3. Since J_3 is a copper-to-copper junction, it creates no thermal EMF ($V_3 = 0$), but J_2 is a copper-to-constantan junction which will add an EMF (V_2) in opposition to V_1. The resultant voltmeter reading V will be proportional to the temperature difference between J_1 and J_2. This says that we can't find the temperature at J_1 unless we first find the temperature of J_2.

The Reference Junction



EXTERNAL REFERENCE JUNCTION
Figure 5

One way to determine the temperature of J_2 is to physically put the junction into an ice bath, forcing its temperature to be 0ºC and establishing J_2 as the *Reference Junction*. Since both voltmeter terminal junctions are now copper-copper, they create no thermal emf and the reading *V* on the voltmeter is proportional to the temperature difference between J_1 and J_2.

Now the voltmeter reading is (see Figure 5):

$V = (V_1 - V_2) \cong \alpha(t_{J_1} - t_{J_2})$

If we specify T_{J_1} in degrees Celsius:

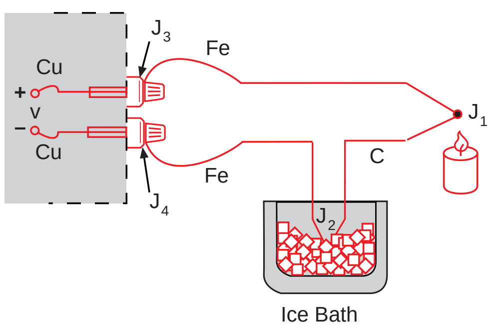
T_{J_1} (ºC) + 273.15 = t_{J_1}

then V becomes:

$$V = V_1 - V_2 = \alpha\,[(T_{J_1} + 273.15) - (T_{J_2} + 273.15)]$$
$$= \alpha\,(T_{J_1} - T_{J_2}) = \alpha\,(T_{J_1} - 0)$$
$$V = \alpha T_{J_1}$$

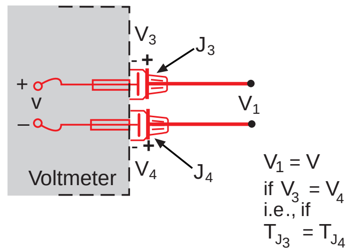
We use this protracted derivation to emphasize that the ice bath junction output, V_2, is *not* zero volts. It is a function of absolute temperature.

By adding the voltage of the ice point reference junction, we have now referenced the reading V to 0ºC. This method is very accurate because the ice point temperature can be precisely controlled. The ice point is used by the National Bureau of Standards (NBS) as the fundamental reference point for their thermocouple tables, so we can now look at the NBS tables and directly convert from voltage V to Temperature T_{J_1}.



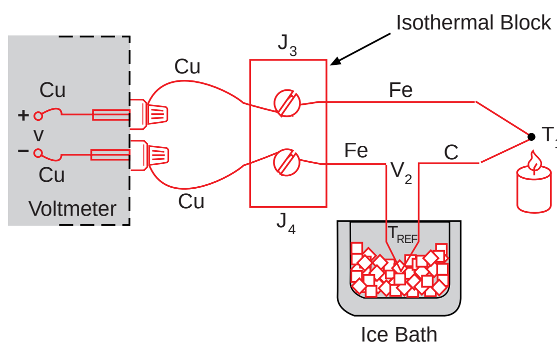
IRON-CONSTANTAN COUPLE
Figure 6

The copper-constantan thermocouple shown in Figure 5 is a unique example because the copper wire is the same metal as the voltmeter terminals. Let's use an iron-constantan (Type J) thermocouple instead of the copper-constantan. The iron wire (Figure 6) increases the number of dissimilar metal junctions in the circuit, as both voltmeter terminals become Cu-Fe thermocouple junctions.



JUNCTION VOLTAGE CANCELLATION
Figure 7

If both front panel terminals are not at the same temperature, there will be an error. For a more precise measurement, the copper voltmeter leads should be extended so the copper-to-iron junctions are made on an *isothermal* (same temperature) block:



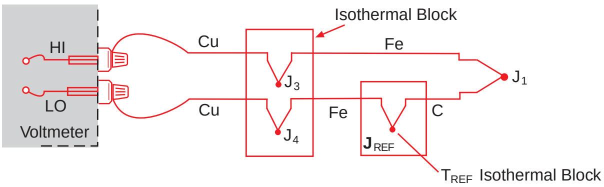
REMOVING JUNCTIONS FROM DVM TERMINALS
Figure 8

The isothermal block is an electrical insulator but a good heat conductor, and it serves to hold J_3 and J_4 at the same temperature. The absolute block temperature is unimportant because the two Cu-Fe junctions act in opposition. We still have

$$V = \alpha\,(T_1 - T_{REF})$$

Reference Circuit

Let's replace the ice bath with another isothermal block



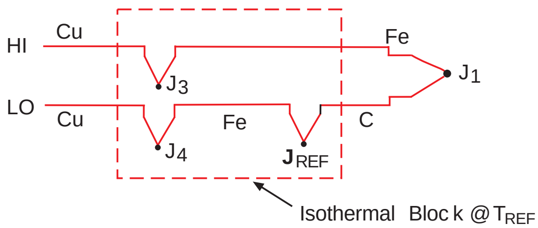
ELIMINATING THE ICE BATH
Figure 9a

The new block is at Reference Temperature T_{REF}, and because J_3 and J_4 are still at the same temperature, we can again show that

$$V = \alpha\,(T_1 - T_{REF})$$

This is still a rather inconvenient circuit because we have to connect two thermocouples. Let's eliminate the extra Fe wire in the negative (LO) lead by combining the Cu-Fe junction (J_4) and the Fe-C junction (J_{REF}).

We can do this by first joining the two isothermal blocks (Figure 9b).

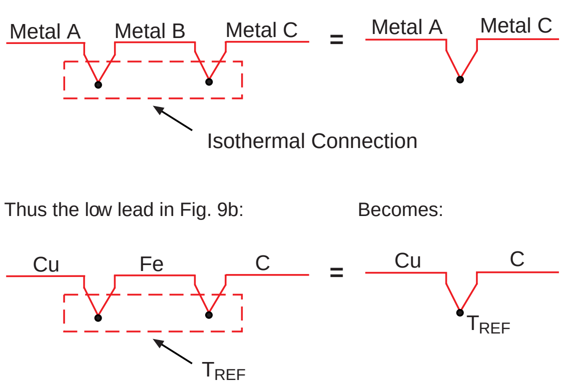


JOINING THE ISOTHERMAL BLOCKS
Figure 9b

We haven't changed the output voltage V. It is still

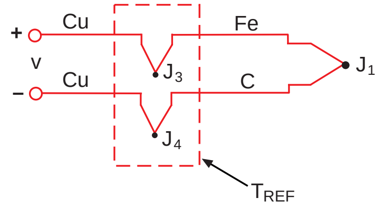
$$V = \alpha\,(T_{J_1} - T_{J_{REF}})$$

Now we call upon the law of intermediate metals (see Appendix A) to eliminate the extra junction. This empirical "law" states that a third metal (in this case, iron) inserted between the two dissimilar metals of a thermocouple junction will have no effect upon the output voltage as long as the two junctions formed by the additional metal are at the same temperature:



LAW OF INTERMEDIATE METALS
Figure 10

This is a useful conclusion, as it completely eliminates the need for the iron (Fe) wire in the LO lead:

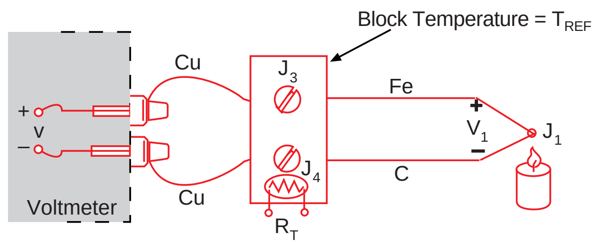


EQUIVALENT CIRCUIT
Figure 11

Again, $V = \alpha\,(T_{J_1} - T_{REF})$, where α is the Seebeck coefficient for an Fe-C thermocouple.|

Junctions J_3 and J_4, take the place of the ice bath. These two junctions now become the *Reference Junction.*

Now we can proceed to the next logical step: Directly measure the temperature of the isothermal block (the *Reference Junction*) and use that information to compute the unknown temperature, T_{J_1}.



EXTERNAL REFERENCE JUNCTION-NO ICE BATH
Figure 12

A thermistor, whose resistance R_T is a function of temperature, provides us with a way to measure the absolute temperature of the reference junction. Junctions J_3 and J_4 and the thermistor are all assumed to be at the same temperature, due to the design of the isothermal block. Using a digital multimeter under computer control, we simply:

1) Measure R_T to find T_{REF} and convert T_{REF} to its equivalent reference junction voltage, V_{REF}, then
2) Measure V and subtract V_{REF} to find V_1, and convert V_1 to temperature T_{J_1}.

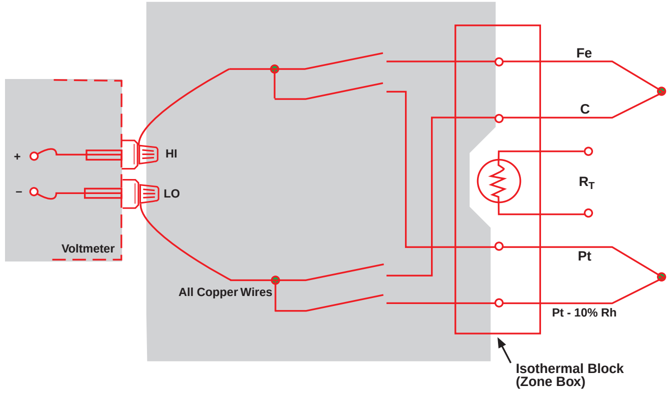
This procedure is known as *Software Compensation* because it relies upon the software of a computer to compensate for the effect of the reference junction. The isothermal terminal block temperature sensor can be any device which has a characteristic proportional to absolute temperature: an RTD, a thermistor, or an integrated circuit sensor.

It seems logical to ask: If we already have a device that will measure absolute temperature (like an RTD or thermistor), why do we even bother with a thermocouple that requires reference junction compensation? The single most important answer to this question is that the thermistor, the RTD, and the integrated circuit transducer are only useful over a certain temperature range. Thermocouples, on the other hand, can be used over a range of temperatures, and optimized for various atmospheres. They are much more rugged than thermistors, as evidenced by the fact that thermocouples are often welded to a metal part or clamped under a screw. They can be manufactured on the spot, either by soldering or welding. In short, thermocouples are the most versatile temperature transducers available and, since the measurement system performs the entire task of reference compensation and software voltage to-temperature conversion, using a thermocouple becomes as easy as connecting a pair of wires.

Thermocouple measurement becomes especially convenient when we are required to monitor a large number of data points. This is accomplished by using the isothermal reference junction for more than one thermocouple element (see Figure 13).

A reed relay scanner connects the voltmeter to the various thermocouples in sequence. All of the voltmeter and scanner wires are copper, independent of the type of thermocouple chosen. In fact, as long as we know what each thermocouple is, we can mix thermocouple types on the same isothermal junction block (often called a *zone box*) and make the appropriate modifications in software. The junction block temperature sensor R_T is located at the center of the block to minimize errors due to thermal gradients.

Software compensation is the most versatile technique we have for measuring thermocouples. Many thermocouples are connected on the same block, copper leads are used throughout the scanner, and the technique is independent of the types of thermocouples chosen. In addition, when using a data acquisition system with a built-in zone box, we simply connect the thermocouple as we would a pair of test leads. All of the conversions are performed by the computer. The one disadvantage is that the computer requires a small amount of additional time to calculate the reference junction temperature. For maximum speed we can use hardware compensation.



ZONE BOX SWITCHING
Figure 13

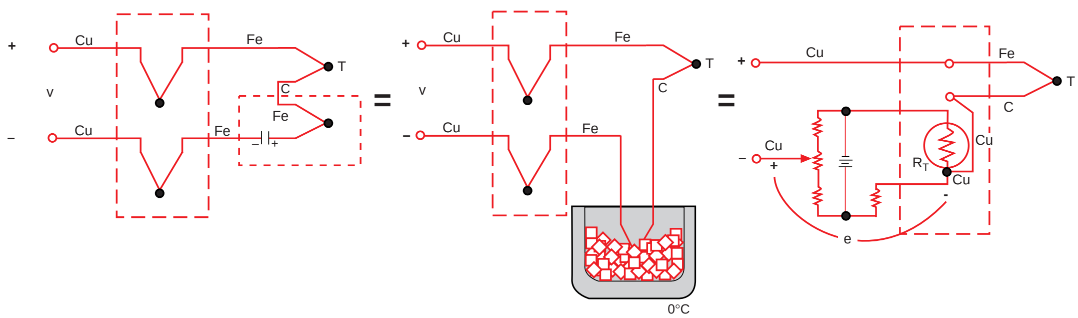
Hardware Compensation

Rather than measuring the temperature of the reference junction and computing its equivalent voltage as we did with software compensation, we could insert a battery to cancel the offset voltage of the reference junction. The combination of this *hardware compensation* voltage and the reference junction voltage is equal to that of a 0°C junction.

The compensation voltage, *e*, is a function of the temperature sensing resistor, R_T. The voltage V is now referenced to 0°C, and may be read directly and converted to temperature by using the NBS tables.

Another name for this circuit is the *electronic ice point reference*.[2] These circuits are commercially available for use with any voltmeter and with a wide variety of thermocouples. The major drawback is that a unique ice point reference circuit is usually needed for each individual thermocouple type.

Figure 15 shows a practical ice point reference circuit that can be used in conjunction with a reed relay scanner to compensate an entire block of thermocouple inputs. All the thermocouples in the block must be of the same type, but each block of inputs can accommodate a different thermocouple type by simply changing gain resistors.



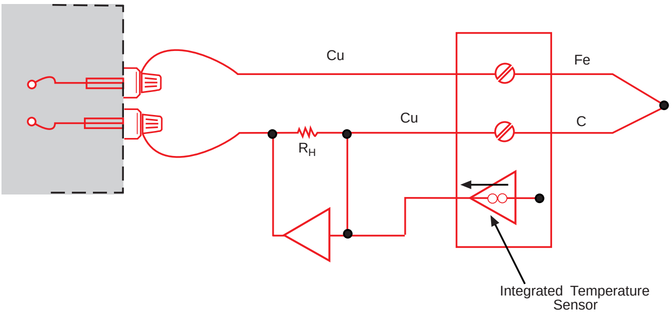
HARDWARE COMPENSATION CIRCUIT
Figure 14

[2] *Refer to Bibliography 6.*

OMEGA TAC-Electronic Ice Point and Thermocouple Preamplifier/Linearizer Plugs into Standard Connector

OMEGA Electronic Ice Point Built into Thermocouple Connector -"MCJ"

OMEGA Ice Point Reference Chamber. Electronic Refigeration Eliminates Ice Bath



PRACTICAL HARDWARE COMPENSATION

Figure 15

The advantage of the hardware compensation circuit or *electronic ice point reference* is that we eliminate the need to compute the reference temperature. This saves us two computation steps and makes a hardware compensation temperature measurement somewhat faster than a software compensation measurement.

HARDWARE COMPENSATION	SOFTWARE COMPENSATION
Fast Restricted to one thermocouple type per card	Requires more computer manipulation time Versatile - accepts any thermocouple

TABLE 2

Voltage-To-Temperature Conversion

We have used hardware and software compensation to synthesize an ice-point reference. Now all we have to do is to read the digital voltmeter and convert the voltage reading to a temperature. Unfortunately, the temperature-versus-voltage relationship of a thermocouple is not linear. Output voltages for the more common thermocouples are plotted as a function of temperature in Figure 16. If the slope of the curve (the Seebeck coefficient) is plotted vs. temperature, as in Figure 17, it becomes quite obvious that the thermocouple is a non-linear device.

A horizontal line in Figure 17 would indicate a constant α, in other words, a linear device. We notice that the slope of the type K thermocouple approaches a constant over a temperature range from 0ºC to 1000ºC. Consequently, the type K can be used with a multiplying voltmeter and an external ice point reference to obtain a moderately accurate direct readout of temperature. That is, the temperature display involves only a scale factor. This procedure works with voltmeters.

By examining the variations in Seebeck coefficient, we can easily see that using one constant scale factor would limit the temperature range of the system and restrict the system accuracy. Better conversion accuracy can be obtained by reading the voltmeter and consulting the National Bureau of Standards Thermocouple Tables[3] in Section T of the *OMEGA TEMPERATURE MEASUREMENT HANDBOOK* - see Table 3.

$T = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \; ... + a_n x^n$

where

T = Temperature

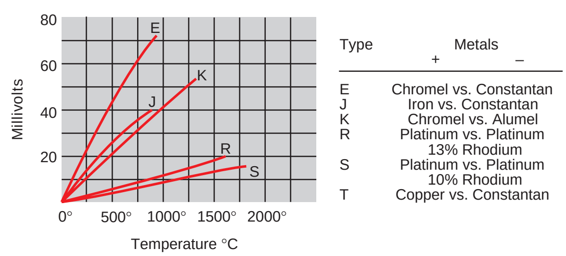
x = Thermocouple EMF in Volts

a = Polynomial coefficients unique to each thermocouple

n = Maximum order of the polynomial

As n increases, the accuracy of the polynomial improves. A representative number is n = 9 for ± 1ºC accuracy. Lower order polynomials may be used over a narrow temperature range to obtain higher system speed.

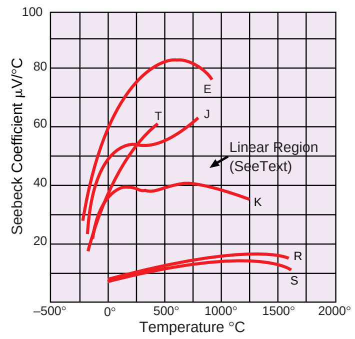
Table 4 is an example of the polynomials used to convert voltage to temperature. Data may be utilized in packages for a data acquisition system. Rather than directly calculating the exponentials, the computer is programmed to use the *nested polynomial* form to save execution time. The polynomial *fit* rapidly degrades outside the temperature range shown in Table 4 and should not be extrapolated outside those limits.



THERMOCOUPLE TEMPERATURE
vs.
VOLTAGE GRAPH

Figure 16

[3] *Refer to Bibliography 4.*



SEEBECK COEFFICIENT vs. TEMPERATURE
Figure 17

mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV
	TEMPERATURES IN DEGREES C (IPTS 1968)											
0.00	0.00	0.17	0.34	0.51	0.68	0.85	1.02	1.19	1.36	1.53	1.70	0.00
0.10	1.70	1.87	2.04	2.21	2.38	2.55	2.72	2.89	3.06	3.23	3.40	0.10
0.20	3.40	3.57	3.74	3.91	4.08	4.25	4.42	4.58	4.75	4.92	5.09	0.20
0.30	5.09	5.26	5.43	5.60	5.77	5.94	6.11	6.27	6.44	6.61	6.78	0.30
0.40	6.78	6.95	7.12	7.29	7.46	7.62	7.79	7.96	8.13	8.30	8.47	0.40
0.50	8.47	8.63	8.80	8.97	9.14	9.31	9.47	9.64	9.81	9.98	10.15	0.50
0.60	10.15	10.31	10.48	10.65	10.82	10.98	11.15	11.32	11.49	11.65	11.82	0.60
0.70	11.82	11.99	12.16	12.32	12.49	12.66	12.83	12.99	13.16	13.33	13.49	0.70
0.80	13.49	13.66	13.83	13.99	14.16	14.33	14.49	14.66	14.83	14.99	15.16	0.80
0.90	15.16	15.33	15.49	15.66	15.83	15.99	16.16	16.33	16.49	16.66	16.83	0.90
1.00	16.83	16.99	17.16	17.32	17.49	17.66	17.82	17.99	18.15	18.32	18.48	1.00
1.10	18.48	18.65	18.82	18.98	19.15	19.31	19.48	19.64	19.81	19.97	20.14	1.10
1.20	20.14	20.31	20.47	20.64	20.80	20.97	21.13	21.30	21.46	21.63	21.79	1.20
1.30	21.79	21.96	22.12	22.29	22.45	22.62	22.78	22.94	23.11	23.27	23.44	1.30
1.40	23.44	23.60	23.77	23.93	24.10	24.26	24.42	24.59	24.75	24.92	25.08	1.40

TYPE E THERMOCOUPLE
Table 3

Z

	TYPE E	TYPE J	TYPE K	TYPE R	TYPE S	TYPE T
	Nickel-10% Chromium(+) Versus Constantan(-)	**Iron(+) Versus Constantan(-)**	**Nickel-10% Chromium(+) Versus Nickel-5%(-) (Aluminum Silicon)**	**Platinum-13% Rhodium(+) Versus Platinum(-)**	**Platinum-10% Rhodium(+) Versus Platinum(-)**	**Copper(+) Versus Constantan(-)**
a_0	-100℃ to 1000℃ ± 0.5℃ 9th order	0℃ to 760℃ ± 0.1℃ 5th order	0℃ to 1370℃ ± 0.7℃ 8th order	0℃ to 1000℃ ± 0.5℃ 8th order	0℃ to 1750℃ ± 1℃ 9th order	-160℃ to 400℃ ±0.5℃ 7th order
a_1	0.104967248	-0.048868252	0.226584602	0.263632917	0.927763167	0.100860910
a_2	17189.45282	19873.14503	24152.10900	179075.491	169526.5150	25727.94369
a_3	-282639. 0850	-218614.5353	67233.4248	-48840341.37	-31568363.94	-767345.8295
a_4	12695339.5	11569199.78	2210340.682	1.90002E + 10	8990730663	78025595.81
a_5	-448703084.6	-264917531.4	-860963914.9	-4.82704E + 12	-1.63565E + 12	-9247486589
a_6	1.10866E + 10	2018441314	4.83506E + 10	7.62091E + 14	1.88027E + 14	6.97688E + 11
a_7	-1. 76807E + 11		-1. 18452E + 12	-7.20026E + 16	-1.37241E + 16	-2.66192E + 13
a_8	1.71842E + 12		1.38690E + 13	3.71496E + 18	6.17501E + 17	3.94078E + 14
a_9	-9.19278E + 12		-6.33708E + 13	-8.03104E + 19	-1.56105E + 19	
	2.06132E + 13				1.69535E + 20	

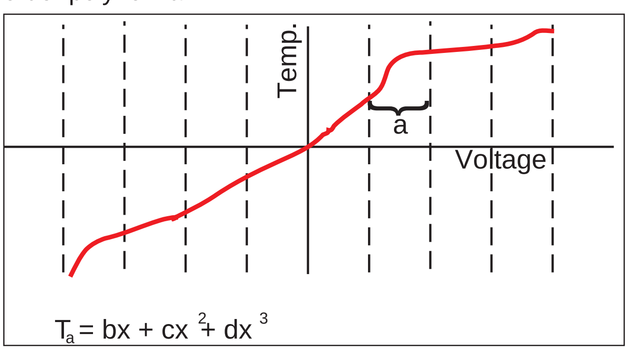
TEMPERATURE CONVERSION EQUATION: $T = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n$

NESTED POLYNOMIAL FORM: $T = a_0 + x(a_1 + x(a_2 + x(a_3 + x(a_4 + a_5 x))))$ (5th order)

where x is in Volts, T is in °C

NBS POLYNOMIAL COEFFICIENTS
Table 4

The calculation of high-order polynomials is a time-consuming task for a computer. As we mentioned before, we can save time by using a lower order polynomial for a smaller temperature range. In the software for one data acquisition system, the thermocouple characteristic curve is divided into eight sectors, and each sector is approximated by a third-order polynomial.*



CURVE DIVIDED INTO SECTORS
Figure 18

** HEWLETT PACKARD 3054A.*

All the foregoing procedures assume the thermocouple voltage can be measured accurately and easily; however, a quick glance at Table 3 shows us that thermocouple output voltages are very small indeed. Examine the requirements of the system voltmeter:

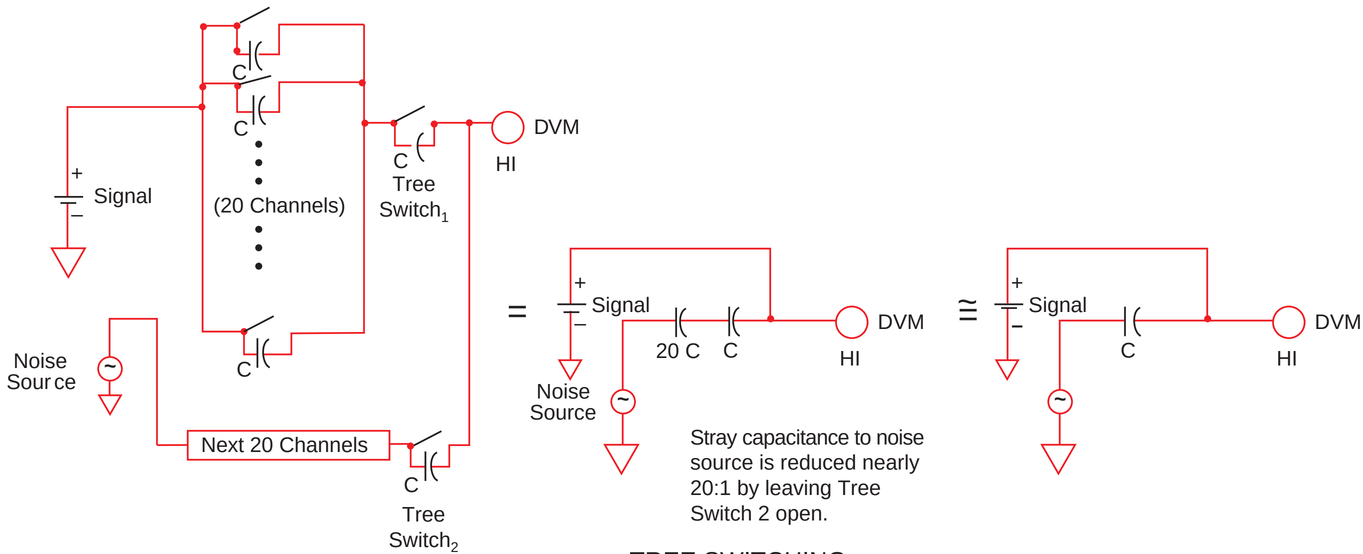
THERMOCOUPLE TYPE	SEEBECK COEFFICIENT (µV/°C) @ 20°C	DVM SENSITIVITY FOR 0.1°C (µV)
E	62	6.2
J	51	5.1
K	40	4.0
R	7	0.7
S	7	0.7
T	40	4.0

REQUIRED DVM SENSITIVITY

Table 5

Even for the common type K thermocouple, the voltmeter must be able to resolve 4 µV to detect a 0. 1°C change. The magnitude of this signal is an open invitation for noise to creep into any system. For this reason, instrument designers utilize several fundamental noise rejection techniques, including tree switching, normal mode filtering, integration and guarding.

Noise Rejection



TREE SWITCHING

Figure 19

Tree Switching - Tree switching is a method of organizing the channels of a scanner into groups, each with its own main switch.

Without tree switching, every channel can contribute noise directly through its *stray* capacitance. With tree switching, groups of parallel channel capacitances are in series with a single *tree switch* capacitance. The result is greatly reduced crosstalk in a large data acquisition system, due to the reduced interchannel capacitance.

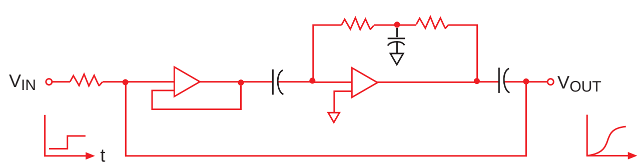
Analog Filter - A filter may be used directly at the input of a voltmeter to reduce noise. It reduces interference dramatically, but causes the voltmeter to respond more slowly to step inputs.

Integration - Integration is an A/D technique which essentially averages noise over a full line cycle; thus, power line related noise and its harmonics are virtually eliminated. If the integration period is chosen to be less than an integer line cycle, its noise rejection properties are essentially negated.

Since thermocouple circuits that cover long distances are especially susceptible to power line related noise, it is advisable to use an integrating analog-to-digital converter to measure the thermocouple voltage. Integration is an especially attractive A/D technique in light of recent innovations which allow reading rates of 48 samples per second with full cycle integration.

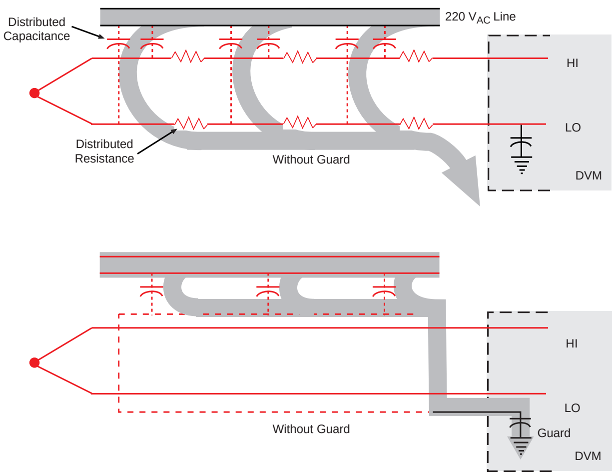
Guarding - Guarding is a technique used to reduce interference from any noise source that is common to both high and low measurement leads, i.e., from *common mode* noise sources.

Let's assume a thermocouple wire has been pulled through the same conduit as a 220 Vac supply line. The capacitance between the power lines and the thermocouple lines will create an AC signal of approximately equal magnitude on both thermocouple wires. This *common mode* signal is not a problem in an ideal circuit, but the voltmeter is not ideal. It has some capacitance between its low terminal and safety ground (chassis). Current flows through this capacitance and through the thermocouple lead resistance, creating a normal mode noise signal. The guard, physically a floating metal box surrounding the entire voltmeter circuit, is connected to a shield surrounding the thermocouple wire, and serves to shunt the interfering current.



ANALOG FILTER

Figure 20



GUARD SHUNTS INTERFERING WITH CURRENT

Figure 21

Each shielded thermocouple junction can directly contact an interfering source with no adverse effects, since provision is made on the scanner to switch the guard terminal separately for each thermocouple channel. This method of connecting the shield to guard serves to eliminate *ground loops* often created when the shields are connected to earth ground.

The dvm guard is especially useful in eliminating noise voltages created when the thermocouple junction comes into direct contact with a common mode noise source.

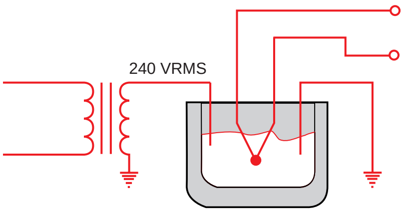


Figure 22

In Figure 22 we want to measure the temperature at the center of a molten metal bath that is being heated by electric current. The potential at the center of the bath is 120 V RMS. The equivalent circuit is:

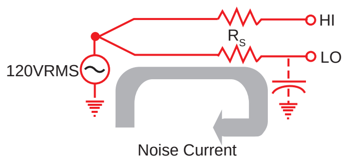


Figure 23

The stray capacitance from the dvm Lo terminal to chassis causes a current to flow in the low lead, which in turn causes a noise voltage to be dropped across the series resistance of the thermocouple, R_S. This voltage appears directly across the dvm Hi to Lo terminals and causes a noisy measurement. If we use a guard lead connected directly to the thermocouple, we drastically reduce the current flowing in the Lo lead. The noise current now flows in the guard lead where it cannot affect the reading:

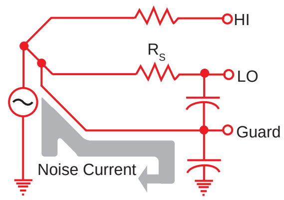


Figure 24

Notice that we can also minimize the noise by minimizing R_S. We do this by using larger thermocouple wire that has a smaller series resistance.

To reduce the possibility of magnetically induced noise, the thermocouple should be twisted in a uniform manner. Thermocouple *extension wires* are available commercially in a *twisted pair* configuration.

Practical Precautions - We have discussed the concepts of the reference junction, how to use a polynomial to extract absolute temperature data, and what to look for in a data acquisition system, to minimize the effects of noise. Now let's look at the thermocouple wire itself. The polynomial curve fit relies upon the thermocouple wire's being perfect; that is, it must not become *decalibrated* during the act of making a temperature measurement. We shall now discuss some of the pitfalls of thermocouple thermometry.

Aside from the specified accuracies of the data acquisition system and its zone box, most measurement errors may be traced to one of these primary sources:

1. Poor junction connection
2. Decalibration of thermocouple wire
3. Shunt impedance and galvanic action
4. Thermal shunting
5. Noise and leakage currents
6. Thermocouple specifications
7. Documentation

Poor Junction Connection

There are a number of acceptable ways to connect two thermocouple wires: soldering, silver-soldering, welding, etc. When the thermocouple wires are soldered together, we introduce a third metal into the thermocouple circuit, but as long as the temperatures on both sides of the thermocouple are the same, the solder should not introduce any error. The solder does limit the maximum temperature to which we can subject this junction. To reach a higher measurement temperature, the joint must be welded. But welding is not a process to be taken lightly.[3] Overheating can degrade the wire, and the welding gas and the atmosphere in which the wire is welded can both diffuse into the thermocouple metal, changing its characteristics. The difficulty is compounded by the very different nature of the two metals being joined. Commercial thermocouples are welded on expensive machinery using a capacitive-discharge technique to insure uniformity.

SOLDERING A THERMOCOUPLE
Figure 25

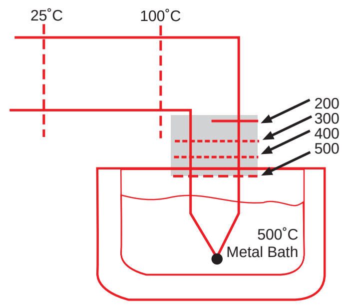
A poor weld can, of course, result in an open connection, which can be detected in a measurement situation by performing an *open thermocouple check.* This is a common test function available with dataloggers. While the open thermocouple is the easiest malfunction to detect, it is not necessarily the most common mode of failure.

Decalibration

Decalibration is a far more serious fault condition than the open thermocouple because it can result in a temperature reading that *appears* to be correct. Decalibration describes the process of unintentionally altering the physical makeup of the thermocouple wire so that it no longer conforms to the NBS polynomial within specified limits. Decalibration can result from diffusion of atmospheric particles into the metal caused by temperature extremes. It can be caused by high temperature annealing or by *cold-working* the metal, an effect that can occur when the wire is drawn through a conduit or strained by rough handling or vibration. Annealing can occur within the section of wire that undergoes a temperature gradient.

Robert Moffat in his *Gradient Approach to Thermocouple Thermometry* explains that the thermocouple voltage is actually generated by the section of wire that contains the temperature gradient, and not necessarily by the junction.[4] For example, if we have a thermal probe located in a molten metal bath, there will be two regions that are virtually isothermal and one that has a large gradient.

In Figure 26, the thermocouple junction will not produce *any* part of the output voltage. The shaded section will be the one producing virtually the entire thermocouple output voltage. If, due to aging or annealing, the output of this thermocouple were found



GRADIENT PRODUCES VOLTAGE
Figure 26

to be drifting, then replacing the thermocouple junction alone would not solve the problem. We would have to replace the entire shaded section, since it is the source of the thermocouple voltage.

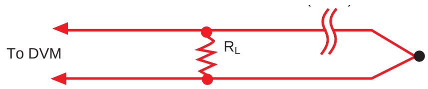
Thermocouple wire obviously can't be manufactured perfectly; there will be some defects which will cause output voltage errors. These *inhomogeneities* can be especially disruptive if they occur in a region of steep temperature gradient. Since we don't know where an imperfection will occur within a wire, the best thing we can do is to avoid creating a steep gradient. Gradients can be reduced by using metallic sleeving or by careful placement of the thermocouple wire.

Shunt Impedance

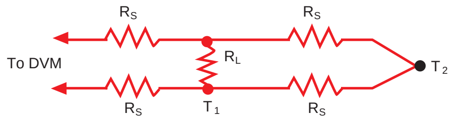
High temperatures can also take their toll on thermocouple wire *insulators*. Insulation resistance decreases exponentially with increasing temperature, even to the point that it creates a *virtual junction.*[5] Assume we have a completely open thermocouple operating at a high temperature.

The leakage Resistance, R_L, can be sufficiently low to complete the circuit path and give us an improper voltage reading. Now let's assume the thermocouple is not open, but we are using a very long section of small diameter wire.

[3] Refer to Bibliography 5
[4] Refer to Bibliography 9
[5] Refer to Bibliography 7



LEAKAGE RESISTANCE
Figure 27



VIRTUAL JUNCTION
Figure 28

If the thermocouple wire is small, its series resistance, R_S, will be quite high and under extreme conditions $R_L << R_S$. This means that the thermocouple *junction* will appear to be at R_L and the output will be proportional to T_1 not T_2.

High temperatures have other detrimental effects on thermocouple wire. The impurities and chemicals within the insulation can actually diffuse into the thermocouple metal causing the temperature-voltage dependence to deviate from published values. When using thermocouples at high temperatures, the insulation should be chosen carefully. Atmospheric effects can be minimized by choosing the proper protective metallic or ceramic sheath

Galvanic Action

The dyes used in some thermocouple insulation will form an electrolyte in the presence of water. This creates a galvanic action, with a resultant output hundreds of times greater than the Seebeck effect. Precautions should be taken to shield thermocouple wires from all harsh atmospheres and liquids.

Thermal Shunting

No thermocouple can be made without mass. Since it takes energy to heat any mass, the thermocouple will slightly alter the temperature it is meant to measure. If the mass to be measured is small, the thermocouple must naturally be small. But a thermocouple made with small wire is far more susceptible to the problems of contamination, annealing, strain, and shunt impedance. To minimize these effects, thermocouple *extension wire* can be used. Extension wire is commercially available wire primarily intended to cover long distances between the measuring thermocouple and the voltmeter.

Extension wire is made of metals having Seebeck coefficients very similar to a particular thermocouple type. It is generally larger in size so that its series resistance does not become a factor when traversing long distances. It can also be pulled more readily through a conduit than can very small thermocouple wire. It generally is specified over a much lower temperature range than premium grade thermocouple wire. In addition to offering a practical size advantage, extension wire is less expensive than standard thermocouple wire. This is especially true in the case of platinum-based thermocouples.

Since the extension wire is specified over a narrower temperature range and it is more likely to receive mechanical stress, the temperature gradient across the extension wire should be kept to a minimum. This, according to the gradient theory, assures that virtually none of the output signal will be affected by the extension wire.

Noise - We have already discussed line-related noise as it pertains to the data acquisition system. The techniques of integration, tree switching and guarding serve to cancel most line-related interference. Broadband noise can be rejected with the analog filter.

The one type of *noise* the data acquisition system cannot reject is a dc offset caused by a dc leakage current in the system. While it is less common to see dc leakage currents of sufficient magnitude to cause appreciable error, the possibility of their presence should be noted and prevented, especially if the thermocouple wire is very small and the related series impedance is high.

Wire Calibration

Thermocouple wire is manufactured to a certain specification, signifying its conformance with the NBS tables. The specification can sometimes be enhanced by *calibrating* the wire (testing it at known temperatures). Consecutive pieces of wire on a continuous spool will generally track each other more closely than the specified tolerance, although their output voltages may be slightly removed from the center of the absolute specification.

If the wire is calibrated in an effort to improve its fundamental specifications, it becomes even more imperative that all of the aforementioned conditions be heeded in order to avoid decalibration.

Documentation - It may seem incongruous to speak of documentation as being a source of voltage measurement error, but the fact is that thermocouple systems, by their very ease of use, invite a large number of data points. The sheer magnitude of the data can become quite unwieldy. When a large amount of data is taken, there is an increased probability of error due to mislabeling of lines, using the wrong NBS curve, etc.

Since channel numbers invariably change, data should be categorized by measureand, not just channel number.[6] Information about any given measureand, such as transducer type, output voltage, typical value and location, can be maintained in a data file. This can be done under computer control or simply by filling out a pre-printed form. No matter how the data is maintained, the importance of a concise system should not be underestimated, especially at the outset of a complex data gathering project.

Diagnostics

Most of the sources of error that we have mentioned are aggravated by using the thermocouple near its temperature limits. These conditions will be encountered infrequently in most applications. But what about the situation where we are using small thermocouples in a harsh atmosphere at high temperatures? How can we tell when the thermocouple is producing erroneous results? We need to develop a reliable set of diagnostic procedures.

Through the use of diagnostic techniques, R.P. Reed has developed an excellent system for detecting faulty thermocouples and data channels.[6] Three components of this system are the event record, the zone box test, and the thermocouple resistance history.

Event Record - The first diagnostic is not a test at all, but a recording of all pertinent events that could even remotely affect the measurements. An example would be:

MARCH 18 EVENT RECORD

10:43 Power failure
10:47 System power returned
11:05 Changed M821 to type K thermocouple
13:51 New data acquisition program
16:07 M821 appears to be bad reading

Figure 29

We look at our program listing and find that measurand #M821 uses a type J thermocouple and that our new data acquisition program interprets it as a type J. But from the event record, apparently thermocouple M821 was changed to a type K, and the change was not entered into the program. While most anomalies are not discovered this easily, the event record can provide valuable insight into the reason for an unexplained change in a system measurement. This is especially true in a system configured to measure hundreds of data points.

Zone Box Test - A zone box is an isothermal terminal block of known temperature used in place of an ice bath reference. If we temporarily short-circuit the thermocouple directly at the zone box, the system should read a temperature very close to that of the zone box, *i.e.*, close to room temperature.

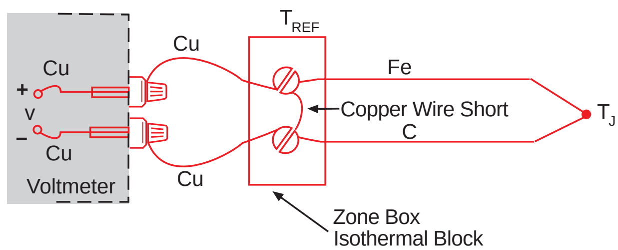
If the thermocouple lead resistance is much greater than the shunting resistance, the copper wire shunt forces V = 0. In the normal *unshorted* case, we want to measure T_J, and the system reads:

$$V \cong \alpha (T_J - T_{REF})$$

But, for the functional test, we have shorted the terminals so that V=0. The indicated temperature T'_J is thus:

$$0 = \alpha (T'_J - T_{REF})$$
$$T'_J = T_{REF}$$

Thus, for a dvm reading of V = 0, the system will indicate the zone box temperature. First we observe the temperature T_J (forced to be different from T_{REF}), then we short the thermocouple with a copper wire and make sure that the system indicates the zone box temperature instead of T_J.



SHORTING THE THERMOCOUPLE AT THE TERMINALS
Figure 30

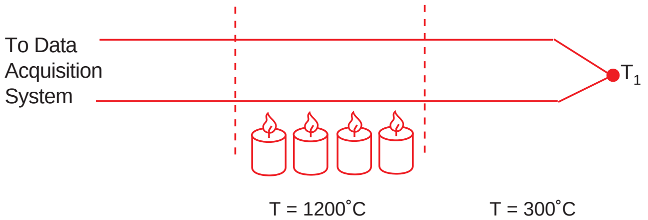
This simple test verifies that the controller, scanner, voltmeter and zone box compensation are all operating correctly. In fact, this simple procedure tests everything but the thermocouple wire itself.

Thermocouple Resistance - A sudden change in the resistance of a thermocouple circuit can act as a warning indicator. If we plot resistance vs. time for each set of thermocouple wires, we can immediately spot a sudden resistance change, which could be an indication of an open wire, a wire shorted due to insulation failure, changes due to vibration fatigue, or one of many failure mechanisms.

For example, assume we have the thermocouple measurement shown in Figure 31.

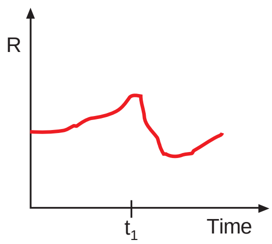
We want to measure the temperature profile of an underground seam of coal that has been ignited. The wire passes through a high temperature region, into a cooler region. Suddenly, the temperature we measure rises from 300°C to 1200°C. Has the burning section of the coal seam migrated to a different location, or has the thermocouple insulation failed, thus causing a short circuit between the two wires at the point of a hot spot?

[6] *Refer to Bibliography 10*



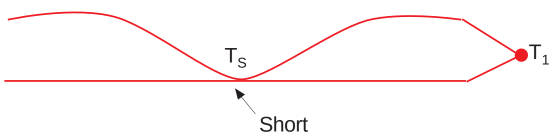
BURNING COAL SEAM
Figure 31

If we have a continuous history of the thermocouple wire resistance, we can deduce what has actually happened.



THERMOCOUPLE RESISTANCE vs. TIME
Figure 32

The resistance of a thermocouple will naturally change with time as the resistivity of the wire changes due to varying temperature. But a sudden change in resistance is an indication that something is wrong. In this case, the resistance has dropped abruptly, indicating that the insulation has failed, effectively shortening the thermocouple loop.



CAUSE OF THE RESISTANCE CHANGE
Figure 33

The new junction will measure temperature T_S, not T_1. The resistance measurement has given us additional information to help interpret the physical phenomenon detected by a standard *open thermocouple* check.

Measuring Resistance - We have casually mentioned checking the resistance of the thermocouple wire as if it were a straightforward measurement. But keep in mind that when the thermocouple is producing a voltage, this voltage can cause a large resistance measurement error. Measuring the resistance of a thermocouple is akin to measuring the internal resistance of a battery. We can attack this problem with a technique known as *offset compensated ohms measurement.*

As the name implies, the voltmeter first measures the thermocouple offset voltage without the ohms current source applied. Then the ohms current source is switched on and the voltage across the resistance is measured again. The voltmeter software compensates for the offset voltage of the thermocouple and calculates the actual thermocouple source resistance.

Special Thermocouples - Under extreme conditions, we can even use diagnostic thermocouple circuit configurations. *Tip-branched* and *leg-branched* thermocouples are four-wire thermocouple circuits that allow redundant measurement of temperature, noise, voltage and resistance for checking wire integrity. Their respective merits are discussed in detail in REF. 8.

Only severe thermocouple applications require such extensive diagnostics, but it is comforting to know that there are procedures that can be used to verify the integrity of an important thermocouple measurement.

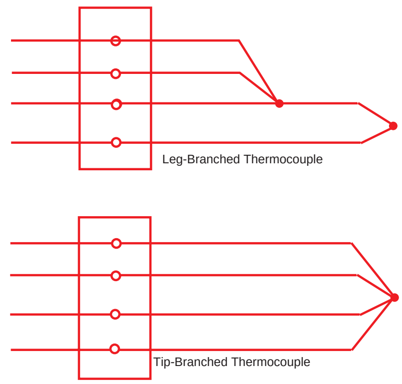


Figure 34

Summary

In summary, the integrity of a thermocouple system can be improved by following these precautions:

- Use the largest wire possible that will not shunt heat away from the measurement area.
- If small wire is required, use it only in the region of the measurement and use extension wire for the region with no temperature gradient.
- Avoid mechanical stress and vibration which could strain the wires.
- When using long thermocouple wires, connect the wire shield to the dvm guard terminal and use twisted pair extension wire.
- Avoid steep temperature gradients.
- Try to use the thermocouple wire well within its temperature rating.
- Use a guarded integrating A/D converter.
- Use the proper sheathing material in hostile environments to protect the thermocouple wire.
- Use extension wire only at low temperatures and only in regions of small gradients.
- Keep an event log and a continuous record of thermocouple resistance.

Nicrosil/Nisil Type N Thermocouples

The Nicrosil/Nisil Type N thermocouple offers better stability than existent base-metal Types E, J, K and T. It is now available and in widespread use worldwide.

DR. NOEL A. BURLEY

The ANSI standard base-metal thermocouples, designated E, J, K and T (Ref. 1), show inherent thermoelectric instability related to time- and/or temperature-dependent instabilities in several of their physical, chemical, nuclear, structural and electronic properties. This paper reviews the major thermoelectric properties of the new nickel-base thermocouple system Nicrosil *versus* Nisil (designated type N), in which very high thermoelectric stability has been achieved by a judicious choice of elemental component concentrations.

INSTABILITY OF CONVENTIONAL BASE-METAL THERMOCOUPLES

There are three principal characteristic types and causes of thermoelectric instability in the standard base-metal thermoelement materials:

1. A gradual and generally cumulative drift in thermal EMF on long exposure at elevated temperatures. This is observed in all base-metal thermoelement materials and is majnly due to compositional changes caused by oxidation, in particular internal oxidation (Figures 1 and 2), and to neutron irradiation which can produce transmutation in nuclear reactor environments.

2. A short-term cyclic change in thermal EMF on heating in the temperature range about 250º to 650ºC, which occurs in types KP (or EP) and JN (or TN and EN). This kind of EMF instability is thought to be due to some form of structural change like magnetic short-range order (Figures 3 and 4).

3. A time-independent perturbation in thermal EMF in specific temperature ranges. This is due to composition-dependent magnetic transformations which perturb the thermal EMF's in type KN in the range of about 25º to 225ºC (Figure 5), and in type JP above about 730ºC.

ULTRA-HIGH STABILITY OF NICROSILINISIL (TYPE N) THERMOCOUPLE

Nicrosil and Nisil thermocouple alloys (Ref. 2) show greatly enhanced thermoelectric stability (Ref. 3) relative to the other standard base-metal thermocouple alloys because their compositions (Table 1) are such as to virtually eliminate or substantially reduce the causes of thermoelectric instability described above. This is achieved primarily by increasing component solute concentrations (chromium and silicon) in a base of nickel above those required to cause a transition from internal to external modes of oxidation, and by selecting solutes (silicon and magnesium) which preferentially oxidize to form a diffusion-barrier, and hence oxidation inhibiting films.

The thermal EMF instabilities of the short-term cyclic kind occurring in KP and JN alloys have virtually been eliminated in nicrosil (NP) by setting the chromium content at 14.2 weight-%.

The increase in the silicon content of nisil (NN) to 4.4 weight-% has suppressed the magnetic transformation of this new alloy to below room temperature.

Virtual freedom from nuclear transmutation effects is achieved by eliminating such elements as manganese, cobalt and iron from the specified compositions of both alloys.

The very high thermoelectric stability of the Nicrosil/Nisil (type N) thermocouple is illustrated in Figures 1 and 2. The influence of thermoelement conductor cross-sectional area upon the thermal-EMF constancy of Nicrosil/Nisil is shown in Figure 6.

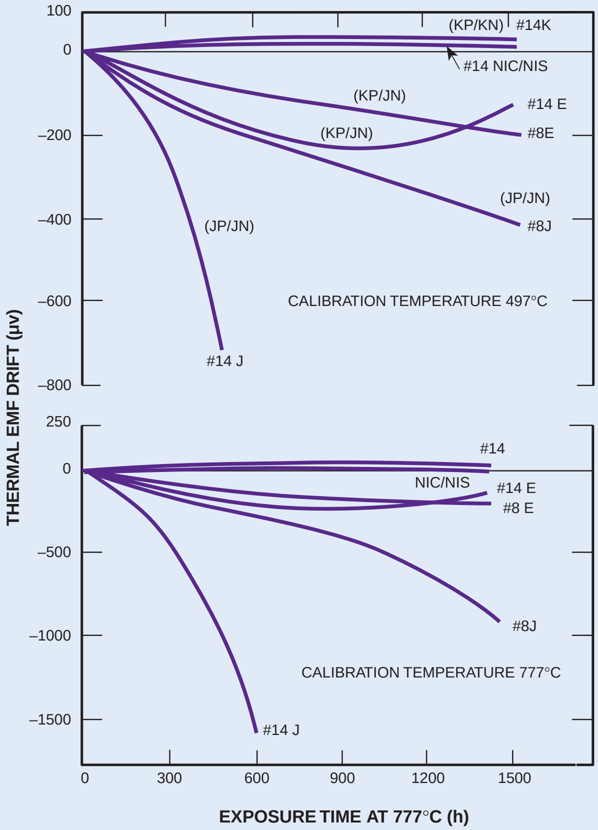


FIGURE 1. Long-term thermal-EMF drifts in air, at two calibration temperatures, for 14 AWG (#14) Nicrosil/Nisil (N) and E, J and K T/Cs. Thermal-EMF drifts for 8 AWG (#8) E and J T/Cs are also given. The drifts are changes from EMF output values existent after 20 hrs of exposure at constant aging temperature of 777°C (Ref. 3).

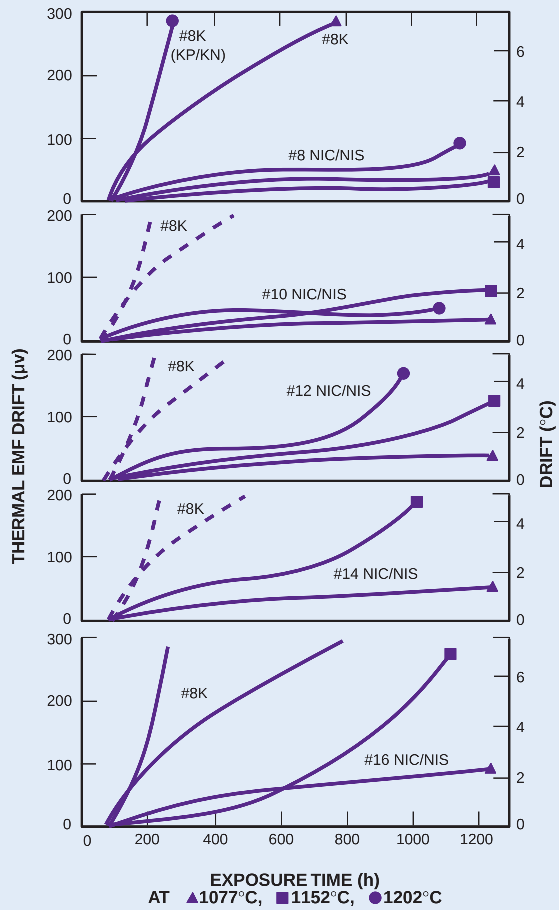


FIGURE 2. Long-term thermal-EMF drifts in air, at three constant aging (and calibration) temperatures for Nicrosil/Nisil T/Cs in five wire gauges (#). Corresponding thermal-EMF drifts for 8 AWG (#8) type K T/Cs at two of these temperatures are also given. The drifts are changes from EMF output values existent after 80 hours of exposure at the constant aging temperature (Ref. 3).

As Figure 2 shows, 8 AWG type K thermocouples appear to be markedly more unstable as temperatures progressively exceed about 1050°C. In contrast, it is clear from Figure 6 that type N thermocouples, in a range of wire sizes finer than 8 AWG, can be used reliably for extended periods of time at temperatures up to at least 1200°C. Indeed, it has recently been demonstrated (Ref. 4) that, in oxidizing atmospheres, the thermoelectric stability of the Nicrosil/Nisil thermocouple, in wire sizes not finer than 10 AWG, is about the same as that of the noble-metal thermocouples of ANSI types R and S up to about 1200°C.

Type N Thermocouples

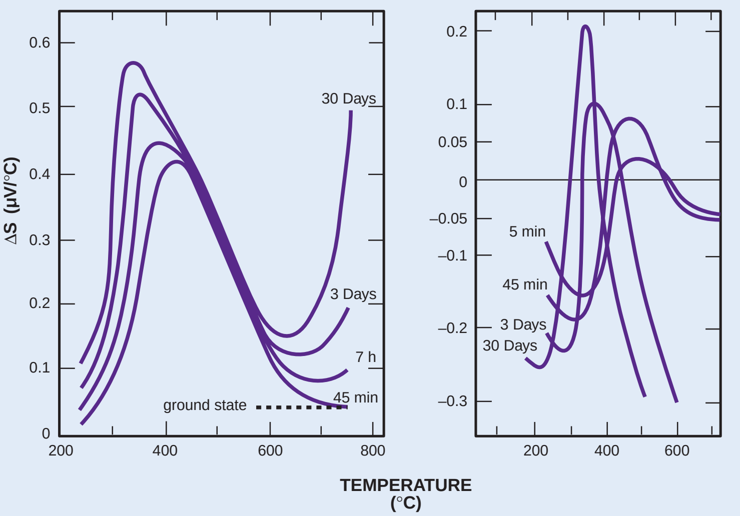


FIGURE 3 (Left). Changes in the Seebeck coefficient (ΔS) of a typical type KP thermoelement vs. platinum on initial heating, as a function of constant aging temperature for the indicated times (Ref. 3).

FIGURE 4 (Right). Similar changes of a type JN thermoelement (Ref. 3).

TABLE.1- NOMINAL COMPOSITIONS OF ANSI STANDARD BASE-METAL THERMOELEMENT ALLOYS, AND NICROSIL AND NISIL ALLOYS

ALLOY ANSI (1) DESIGNATION	CHEMICAL COMPOSITION (WEIGHT-%) Cr	Si	Mn	Al	Co	Mg	Cu	Ni	Fe
(+)KP, EP	9.5	0.4						bal	
(-)KN		1.0	3.0	2.0	0.4	0.015		bal	
(+)JP			0.3						bal
(-)JN, EN, TN			1.0		0.5		54	44	0.5
(+)TP							100		
(+)NP (nicrosil)	14.2	1.4						bal	
(-)NN (nisil)		4.4				0.10		bal	

TABLE 2-VARIANTS OF TYPE KN

ALLOY	CHEMICAL COMPOSITION (WEIGHT-%) Mn	Al	Si	co	Ni
KN1	3.02	1.90	1.19	0.41	balance
KN2	1.67	1.25	1.56	0.72	balance
KN3	-	-	2.50	1.00	balance
KN4	0.43	-	2.39	0.23	balance

PROMULGATION AS A STANDARD

No new thermocouple will survive for universal adoption and use unless it is formally promulgated by national standards authorities around the world. It is fortunate that the Nicrosil/Nisil thermocouple system is in vigorous process of being so promulgated.

The ASTM, through its Committee E-20 on Temperature Measurement, has shown considerable interest in Nicrosil *versus* Nisil, and has kept matters relating to the development, availability and use of the new thermocouple under continual review.

Recently, relevant subcommittees of ASTM E-20 have produced several publications containing information on the properties and characteristics of the Nicrosil *versus* Nisil thermocouple. A document quoting several of the EMF-temperature tables from NBS Monograph 161 (Ref. 2) was published (Ref. 6) for information. A formal ASTM Standard (E1223) is promulgated, while Type N data is now included in ASTM Standard E230. Again, in the recently published third edition of the ASTM Manual on the Use of Thermocouples (Ref. 8), various properties and characteristics of Nicrosil *versus* Nisil are summarized.

Based mainly on the above information, several crucial actions now have been taken by the supreme standardizing bodies in several important countries:

1. The Instrument Society of America (ISA), in October 1983, promulgated the Nicrosil/Nisil system as a U.S. Standard Thermocouple bearing the letter-designation "type N."

2. The British Standards Institute (BSI) has recently promulgated a standard on the type N thermocouple identified as B.S.4937: Part 8.

3. The Japan Society for the Promotion of Science, through its Committee TC19 (Temperature), is nearing the conclusion of its deliberation on type N, leading to the issue of a Japan Industrial Standard (JIS).

These actions have ensured that the type N thermocouple and its allied pyrometric instrumentation and ancillary circuitry elements are now commercially available in a number of major countries around the world.

DISCUSSION

The various types of thermoelectric instability described in this paper can cause substantial changes in thermoelectromotive force and, hence, calibration in ANSI-standard letter-designated base-metal thermocouples types E, J, K and T. In the case of Nicrosil/Nisil, however, thermoelectric instability due to these causes is virtually eliminated or substantially attenuated over the entire temperature range up to 1230˚C. ANSI-standard base-metal thermocouples types E, J, K and T can, therefore, be regarded as obsolescent. Their replacement by Nicrosil/Nisil thermocouples would lead, in most cases, to demonstrable technological and economic advantages for science and industry at large. Indeed, the enhanced calibration stability and longevity of the type N thermocouple, taken into account with its ability to operate at considerably higher upper operating temperatures than conventional base-metal thermocouples, make it ideally suited to scientific, technological and industrial applications where temperature measurements are critical.

Use of type N thermocouples in several countries has already demonstrated a number of advantages: enhanced pyrometric accuracy, improved product quality and performance, lower reject rates, enhanced energy utilization, lower pyrometric maintenance costs, and improved productivity.

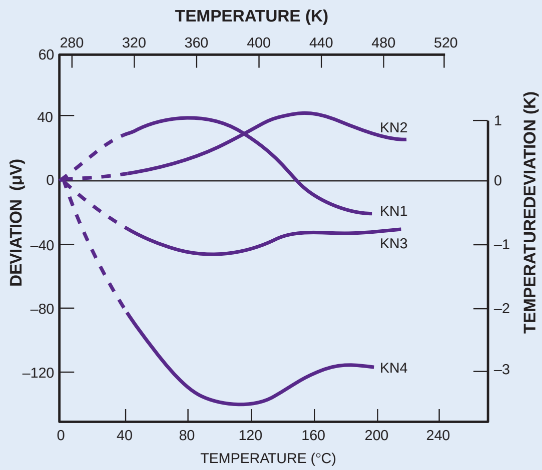


FIGURE 5. Deviations of the measured values of the thermal EMFs of several type KN thermoelements vs. platinum from reference table values (Ref. 5). Variants of type KN are given in Table 2.

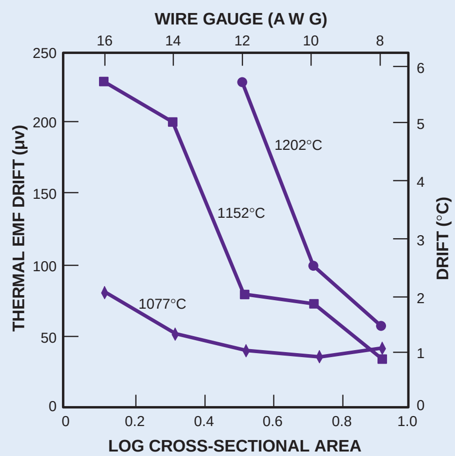


FIGURE 6. Relationship between total thermal-EMF drift (after 1000 hrs of exposure in air at each of three test temperatures) and cross-sectional area of Nicrosil/Nisil T/C wires. The drifts are changes from EMF output values existent after 80 hours of exposure (Ref. 3).

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**The NBS is now NIST (National Institute of Standards and Technology).*

THE AUTHOR

DR. NOEL A. BURLEY, D.App.Sc., C. Eng., F.I.M., F.A.I.M., is General Manager, Research and Development, for Bell-IRH Pty., Ltd., an Australian company specializing in the manufacture of electrical and electronic components, instruments and sensors. It has considerable expertise and established reputation in temperature control. Contact Dr. Burley at Bell-IRH Pty., Ltd., 32 Paramatta Rd., Lidcombe NSW 2141, Sydney, Australia, phone: 02 648 5455.