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AEC

RESEARCH REPORTS

221. ORNL-3649 .

V. 2

Sec. 2.14

ORNL-3649, Vol. 2  
UC-37 - Instruments  
TID-4500 (37th ed.)

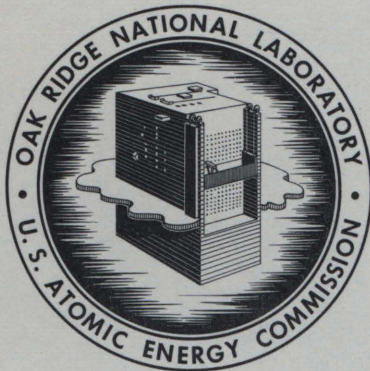
Section 2.14

SMOOTHED THERMOCOUPLE TABLES OF  
EXTENDED SIGNIFICANCE (°C)

Volume 2

Section 2.14 Constantan (YN)-Iron (YP)  
Cryogenic Thermocouples

R. K. Adams  
E. G. Davisson



**OAK RIDGE NATIONAL LABORATORY**

operated by

**UNION CARBIDE CORPORATION**

for the

**U.S. ATOMIC ENERGY COMMISSION**

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ORNL-3649  
Vol. 2, Sect. 2.14

Contract No. W-7405-eng-26

INSTRUMENTATION AND CONTROLS DIVISION

SMOOTHED THERMOCOUPLE TABLES OF EXTENDED SIGNIFICANCE (°C)

R. K. Adams and E. G. Davisson

Volume 2

SECTION 2.14 CONSTANTAN (YN)-IRON (YP) CRYOGENIC THERMOCOUPLES

MARCH 1965

OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, Tennessee  
operated by  
UNION CARBIDE CORPORATION  
for the  
U. S. ATOMIC ENERGY COMMISSION



# SMOOTHED THERMOCOUPLE TABLES OF EXTENDED SIGNIFICANCE (°C)

R. K. Adams      E. G. Davisson

## Volume 2

### SECTION 2.14 CONSTANTAN (YN)–IRON (YP) CRYOGENIC THERMOCOUPLES

This section contains tables of emf (in absolute millivolts) vs temperature in degrees Kelvin) for constantan (YN)–iron (YP) cryogenic thermocouples. The values in these tables, derived from those given by Powell *et al.*,<sup>1</sup> are computed to more significant digits, that is, to the nearest 0.001  $\mu\text{v}$ . The techniques of computation are described in Vol. 1 of this report.

Figure 1, a plot of the difference in microvolts between the values in the smoothed table and those in the original table vs temperature, illustrates how the values in the smoothed table compare with those in the original table.

In Table 14 a smoothed emf value is tabulated in absolute millivolts for every degree Kelvin in the range of the Table.

In Table 14A the first two columns contain the same information as given in Table 14. To the right of these two columns is a difference table of the millivolt values in column 2. The difference table expressed in thousandths of microvolts and contains orders 0 through 5. This difference table gives a convenient tabulation of differences for those engaged in temperature difference work.

Although these tables are expressed to the nearest 0.001  $\mu\text{v}$ , which is roughly equivalent to 0.0001°K, this in no way implies that temperature measurements to this accuracy are possible. The user of these tables is reminded of the accuracy tolerances on thermocouples published by the American Society for Testing and Materials<sup>2</sup> and the Instrument Society of America.<sup>3</sup> An illustration of the expected accuracy for cryogenic thermocouple materials may be found in an article by Powell *et al.*<sup>4</sup>

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<sup>1</sup>R. L. Powell *et al.*, "Low-Temperature Thermocouples," pp. 65–77 in *Temperature: Its Measurement and Control in Science and Industry*, vol. 6, part 2, *Applied Instruments and Methods*, ed. by A. I. Dahl, Reinhold, New York, 1962; see Table 6, pp. 74–75.

<sup>2</sup>"Temperature Electromotive Force (EMF) Tables for Thermocouples, ASTM E 230–63," *Am. Soc. Testing Mater.*, *ASTM Std. 1964*, Pt. 30, pp. 646–704; see Table XIII, p. 700.

<sup>3</sup>"Thermocouples and Thermocouple Extension Wires – Terminology, Limits of Error, and Wire Sizes," *Recommended Practice RP 1.3*, Instrument Society of America, Pittsburgh, Pa., 1959.

<sup>4</sup>R. L. Powell *et al.*, *Cryogenics* 1, 142 (1961); see Fig. 3.



CONSTANTAN (YN) - IRON (YP) CRYO (SMOOTHED)

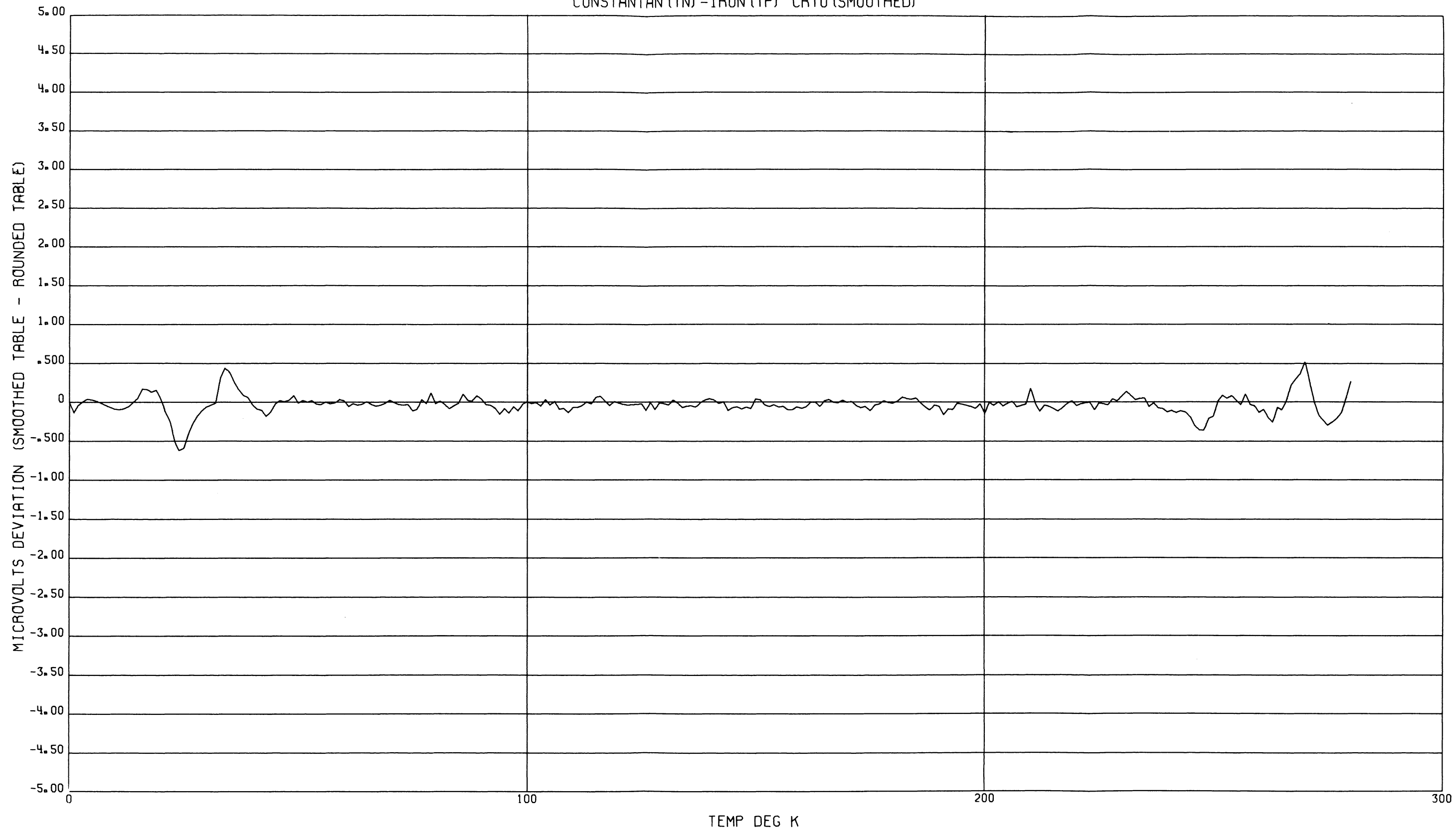


Fig. 1. Deviation of Original Table from Smoothed Table.





CONSTANTAN(YN)-IRON(YP) CRYO(SMOOTHED)  
TABLE NO. 14

TEMP=DEG K  
VOLTAGE=MILLIVOLT ABSOLUTE

TEMP	0	1	2	3	4	5	6	7	8	9
					MILLIVOLTS					
0	0	.000336	.000979	.001927	.003178	.004729	.006579	.008726	.011167	.013900
10	.016924	.020239	.023841	.027729	.031899	.036348	.041071	.046066	.051327	.056850
20	.062631	.068665	.074951	.081485	.088268	.095300	.102584	.110124	.117925	.125994
30	.134338	.142967	.151888	.161109	.170640	.180487	.190657	.201156	.211987	.223154
40	.234659	.246504	.258688	.271212	.284076	.297279	.310822	.324703	.338924	.353483
50	.368382	.383620	.399197	.415114	.431371	.447967	.464902	.482176	.499787	.517735
60	.536017	.554633	.573581	.592860	.612468	.632403	.652663	.673247	.694153	.715380
70	.736925	.758788	.780967	.803459	.826264	.849380	.872805	.896537	.920577	.944921
80	.969568	.994516	1.019764	1.045310	1.071150	1.097284	1.123707	1.150416	1.177410	1.204684
90	1.232236	1.260060	1.288154	1.316514	1.345137	1.374019	1.403156	1.432546	1.462186	1.492073
100	1.522205	1.552579	1.583193	1.614045	1.645133	1.676456	1.708012	1.739799	1.771816	1.804062
110	1.836535	1.869233	1.902157	1.935304	1.968674	2.002265	2.036075	2.070104	2.104350	2.138810
120	2.173484	2.208368	2.243462	2.278763	2.314269	2.349977	2.385886	2.421993	2.458296	2.494793
130	2.531482	2.568362	2.605429	2.642684	2.680123	2.717746	2.755550	2.793533	2.831695	2.870032
140	2.900543	2.947225	2.986078	3.025098	3.064283	3.103632	3.143141	3.182809	3.222634	3.262613
150	3.302745	3.343028	3.383460	3.424039	3.464764	3.505633	3.546646	3.587802	3.629100	3.670538
160	3.712118	3.753838	3.795698	3.837699	3.879839	3.922118	3.964537	4.007095	4.049791	4.092625
170	4.135597	4.178704	4.221948	4.265327	4.308840	4.352487	4.396266	4.440177	4.484218	4.528388
180	4.572687	4.617113	4.661664	4.706339	4.751135	4.796051	4.841084	4.886233	4.931494	4.976865
190	5.022344	5.067928	5.113615	5.159403	5.205291	5.251277	5.297360	5.343539	5.389813	5.436182
200	5.482646	5.529203	5.575856	5.622603	5.669444	5.716381	5.763412	5.810537	5.857757	5.905071
210	5.952480	5.999982	6.047577	6.095265	6.143045	6.190917	6.238881	6.286937	6.335083	6.383322
220	6.431652	6.480074	6.528589	6.577196	6.625897	6.674692	6.723581	6.772565	6.821643	6.870815
230	6.920081	6.969439	7.018887	7.068424	7.118046	7.167750	7.217533	7.267390	7.317319	7.367314
240	7.417371	7.467488	7.517662	7.567890	7.618171	7.668505	7.718892	7.769335	7.819834	7.870395
250	7.921021	7.971717	8.022489	8.073343	8.124286	8.175322	8.226460	8.277705	8.329066	8.380548
260	8.432160	8.483907	8.535797	8.587837	8.640033	8.692393	8.744920	8.797621	8.850501	8.903565
270	8.956816	9.010259	9.063895	9.117727	9.171760	9.225996	9.280440	9.335095	9.389965	9.445053
280	9.500363									

TABLE 14A  
 CONSTANTAN(YN)\*IR5N(YP) CRYO(SMOOTHED)

TEMP	MV	DIFFERENCE ORDER					
		0 TH	1 ST	2 ND	3 RD	4 TH	5 TH
0	0	0					
1	.000336	336	335	307			
2	.000979	979	643	305	=2	0	
3	.001927	1927	948	303	=2	=1	=-1
4	.003178	3178	1251	300	=3		3
5	.004729	4729	1551	299	=1	=1	=-3
6	.006579	6579	1850	297	=2	=1	0
7	.008726	8726	2147	294	=3		2
8	.011167	11167	2441	292	=2	1	0
9	.013900	13900	2733	291	=1	1	0
10	.016924	16924	3024	291	0		=-5
11	.020239	20239	3315	287	=4	3	7
12	.023841	23841	3602	286	=1	=3	=-6
13	.027729	27729	3888	282	=4		4
14	.031899	31899	4170	279	=3	1	=-3
15	.036348	36348	4449	274	=5	3	5
16	.041071	41071	4723	272	=2		=-7
17	.046066	46066	4995	266	=6	2	6
18	.051327	51327	5261	262	=4	0	=-2
19	.056850	56850	5523	258	=4		=-1
20	.062631	62631	5781	253	=5	4	5
21	.068665	68665	6034	252	=1	=3	=-7
22	.074951	74951	6285	248	=4	5	8
23	.081485	81485	6534	249	1	=1	=-6
24	.088268	88268	6783	249	0	3	4
25	.095300	95300	7032	252	3		=-2
26	.102584	102584	7284	256	4	1	0
27	.110124	110124	7540	261	5		1
28	.117925	117925	7801	258	7	2	=-2
29	.125994	125994	8069	258	7	0	3
30	.134338	134338	8344	275	10	3	=-6
31	.142967	142967	8629	292	7	=3	4
32	.151888	151888	8921	292	8	1	1
33	.161109	161109	9221	300	10	2	=-6
34	.170640	170640	9531	310	6	=4	5
35	.180487	180487	9847	316	7	1	=-2
36	.190657	190657	10170	323	6	=1	=-2
			10499	329	5	=3	4
					3		

37	.201156	201156		332		1	
38	.211987	211987	10831	336	4	=2	=3
39	.223154	223154	11167	338	2	0	2
40	.234659	234659	11505	340	2	=3	=3
41	.246504	246504	11845	339	=1	2	5
42	.258688	258688	12184	340	1	=1	=3
43	.271212	271212	12524	340	0	=1	0
44	.284076	284076	12864	339	=1	2	3
45	.297279	297279	13203	340	1	=3	=5
46	.310822	310822	13543	338	=2	4	7
47	.324703	324703	13881	340	2	=4	=8
48	.338924	338924	14221	338	=2	4	8
49	.353483	353483	14559	340	2		=7
50	.368382	368382	14899	339	=1	=3	4
51	.383620	383620	15238	339	0	1	0
52	.399197	399197	15577	340	1		=2
53	.415114	415114	15917	340	0	=1	0
54	.431371	431371	16257	339	=1	1	2
55	.447967	447967	16596	339	0		=1
56	.464902	464902	16935	339	0	0	=2
57	.482176	482176	17274	337	=2	=2	4
58	.499787	499787	17611	337	0	2	=5
59	.517735	517735	17948	337	=3	=3	6
60	.536017	536017	18282	334	0	3	=5
61	.554633	554633	18616	332	=2	=2	3
62	.573581	573581	18948	331	=1	1	=2
63	.592860	592860	19279	329	=2	0	1
64	.612468	612468	19609	327	=2	0	0
65	.632403	632403	19935	325	=2	0	1
66	.652663	652663	20260	324	=1	=1	=2
67	.673247	673247	20584	322	=2		2
68	.694153	694153	20905	322	=1	1	=3
69	.715380	715380	21227	321	=3	=2	5
70	.736925	736925	21545	318	0	3	=5
71	.758788	758788	21863	318	=2	=2	1
72	.780967	780967	22179	316	=3	=1	4
73	.803459	803459	22492	313	0	3	=5
74	.826264	826264	22805	313	=2	=2	2
75	.849380	849380	23115	311	=2	0	0
76	.872805	872805	23425	309	=2	0	3
77	.896537	896537	23732	307	1	3	=8
			24040	308	=4	=5	8

78	.920577	920577		304		3	
79	.944921	944921	24344	303	=1	=1	=4
80	.969568	969568	24647	301	=2	1	2
81	.994516	994516	24948	300	=1	=1	=2
82	1.019764	1019764	25248	298	=2	=2	=1
83	1.045310	1045310	25546	294	=4	4	6
84	1.071150	1071150	25840	294	0		=9
85	1.097284	1097284	26134	289	=5	2	7
86	1.123707	1123707	26423	286	=3	2	0
87	1.150416	1150416	26709	285	=1	=4	=6
88	1.177410	1177410	26994	280	=5	3	7
89	1.204684	1204684	27274	278	=2	=4	=7
90	1.232236	1232236	27552	272	=6	4	8
91	1.260060	1260060	27824	270	=2	=2	=6
92	1.288154	1288154	28094	266	=4	1	3
93	1.316514	1316514	28360	263	=3	=1	=2
94	1.345137	1345137	28623	259	=4	0	1
95	1.374019	1374019	28882	255	=4	2	2
96	1.403156	1403156	29137	255	=2		=3
97	1.432546	1432546	29390	253	=3	=1	1
98	1.462186	1462186	29640	250	=3	0	1
99	1.492073	1492073	29887	247	=2	1	=2
100	1.522205	1522205	30132	245	=3	=1	2
101	1.552579	1552579	30374	242	=3	1	
102	1.583193	1583193	30614	240	=2	0	=1
103	1.614045	1614045	30852	238	=2	0	0
104	1.645133	1645133	31088	236	=2	1	1
105	1.676456	1676456	31323	235	=1	=1	=2
106	1.708012	1708012	31555	233	=2	0	1
107	1.739799	1739799	31787	233	=2	0	1
108	1.771816	1771816	32017	231	=1	1	=1
109	1.804062	1804062	32245	230	=1	0	=1
110	1.836535	1836535	32473	229	=2	=1	1
111	1.869233	1869233	32699	227	=2	0	3
112	1.902157	1902157	32924	225	=2	3	3
113	1.935304	1935304	33147	225	1		=7
114	1.968674	1968674	33370	226	=3	=4	7
115	2.002265	2002265	33591	223	=3	3	7
116	2.036075	2036075	33810	223	0		=5
117	2.070104	2070104	34029	223	=2	=2	2
118	2.104350	2104350	34246	221	=2	0	2
119	2.138810	2138810	34460	219	=2	2	=4
			34674	219	0	=2	=4
				217	=2	=1	1
				214	=3	=1	4
				214	0	3	=7
				214	=4	=4	8

120	2.173484	2173484		210		4	
121	2.208368	2208368	34884	210	0	=3	=7
122	2.243462	2243462	35094	207	=3	1	4
123	2.278763	2278763	35301	205	=2	=1	=2
124	2.314269	2314269	35506	202	=3	2	3
125	2.349977	2349977	35708	201	=1	=2	=4
126	2.385886	2385886	35909	198	=3	1	3
127	2.421993	2421993	36107	196	=2	0	=1
128	2.458296	2458296	36303	194	=2	0	0
129	2.494793	2494793	36497	192	=2	1	1
130	2.531482	2531482	36689	191	=1	=3	=4
131	2.568362	2568362	36880	187	=4	5	8
132	2.605429	2605429	37067	188	1	=5	=10
133	2.642684	2642684	37255	184	=4	4	9
134	2.680123	2680123	37439	184	0	=3	=7
135	2.717746	2717746	37623	181	=3	1	4
136	2.755550	2755550	37804	179	=2	2	1
137	2.793533	2793533	37983	179	0	=4	=6
138	2.831695	2831695	38162	175	=4	3	7
139	2.870032	2870032	38337	174	=1	=2	=5
140	2.908543	2908543	38511	171	=3	3	5
141	2.947225	2947225	38682	171	0	=4	=7
142	2.986078	2986078	38853	167	=4	2	6
143	3.025098	3025098	39020	165	=2	1	=1
144	3.064283	3064283	39185	164	=1	=3	=4
145	3.103632	3103632	39349	160	=4	3	6
146	3.143141	3143141	39509	159	=1	=1	=4
147	3.182809	3182809	39668	157	=2	=1	0
148	3.222634	3222634	39825	154	=3	=1	3
149	3.262613	3262613	39979	153	=1	2	=3
150	3.302745	3302745	40132	151	=2	0	1
151	3.343028	3343028	40283	149	=2	0	0
152	3.383460	3383460	40432	147	=2	1	1
153	3.424039	3424039	40579	146	=1	=1	=2
154	3.464764	3464764	40725	144	=2	2	3
155	3.505633	3505633	40869	144	0	=1	=3
156	3.546646	3546646	41013	143	=1	0	1
157	3.587802	3587802	41155	142	=1	=1	=1
158	3.629100	3629100	41298	140	=2	4	5
159	3.670538	3670538	41438	142	2	=4	=8
160	3.712118	3712118	41580	140	=2	2	6
161	3.753838	3753838	41720	140	0	1	=1
			41860	140	1		=4



162	3.795698	3795698		141		-3	
163	3.837699	3837699	42001	139	-2	2	5
164	3.879839	3879839	42140	139	0	1	-1
165	3.922118	3922118	42279	140	1	-2	-3
166	3.964537	3964537	42419	139	-1	0	2
167	4.007095	4007095	42558	138	-1	1	1
168	4.049791	4049791	42695	138	0	0	-1
169	4.092625	4092625	42834	138	0	-3	-3
170	4.135597	4135597	42972	135	-3	5	8
171	4.178704	4178704	43107	137	2	-4	-9
172	4.221948	4221948	43244	135	-2	1	5
173	4.265327	4265327	43379	134	-1	1	0
174	4.308840	4308840	43513	134	0	-2	-3
175	4.352487	4352487	43647	132	-2	2	4
176	4.396266	4396266	43779	132	0	-2	-4
177	4.440177	4440177	43911	130	-2	1	3
178	4.484218	4484218	44041	129	-1	1	0
179	4.528388	4528388	44170	129	0	-2	-3
180	4.572687	4572687	44299	127	-2	0	2
181	4.617113	4617113	44425	125	-2	1	1
182	4.661664	4661664	44551	124	-1	-2	-3
183	4.706339	4706339	44675	121	-3	2	4
184	4.751135	4751135	44795	120	-1	-2	-4
185	4.796051	4796051	44915	117	-3	2	4
186	4.841084	4841084	45033	116	-1	-3	-5
187	4.886233	4886233	45149	112	-4	2	5
188	4.931494	4931494	45261	110	-2	0	-2
189	4.976865	4976865	45371	108	-2	-1	-1
190	5.022344	5022344	45479	105	-3	1	2
191	5.067928	5067928	45584	103	-2	0	-1
192	5.113615	5113615	45687	101	-2	1	1
193	5.159403	5159403	45789	100	-1	1	-2
194	5.205291	5205291	45888	98	-2	1	2
195	5.251277	5251277	45985	97	-1	0	-1
196	5.297360	5297360	46083	96	-1	0	0
197	5.343539	5343539	46179	95	-1	1	1
198	5.389813	5389813	46274	95	0	0	-1
199	5.436182	5436182	46369	95	0	-2	-2
200	5.482646	5482646	46464	95	-2	5	7
201	5.529203	5529203	46557	96	3	-5	-10
202	5.575856	5575856	46653	94	-2	2	7
203	5.622603	5622603	46747	94	0	2	0
			46841		2		-6

204	5.669444	5669444		96		=4	
205	5.716381	5716381	45937	94	=2	2	6
206	5.763412	5763412	47031	94	0		=1
207	5.810537	5810537	47125	95	1		=3
208	5.857757	5857757	47220	94	=1	2	4
209	5.905071	5905071	47314	95	1		=5
210	5.952480	5952480	47409	93	-2	2	5
211	5.999982	5999982	47502	93	0	0	=2
212	6.047577	6047577	47595	93	0		=1
213	6.095265	6095265	47688	92	=1	=1	2
214	6.143045	6143045	47780	92	0	0	=1
215	6.190917	6190917	47872	92	0	0	0
216	6.238881	6238881	47964	92	0	0	=2
217	6.286937	6286937	48056	92	=2	-2	7
218	6.335083	6335083	48146	90	3	5	=10
219	6.383322	6383322	48239	93	=2	=5	8
220	6.431652	6431652	48330	91	=2	3	
221	6.480074	6480074	48422	92	1	0	=3
222	6.528589	6528589	48515	92	1	-2	=2
223	6.577196	6577196	48607	92	-1	3	5
224	6.625897	6625897	48701	94	2	-2	=5
225	6.674692	6674692	48795	94	0	0	2
226	6.723581	6723581	48889	94	0	0	1
227	6.772565	6772565	48984	94	0	1	=3
228	6.821643	6821643	49078	95	1	=2	3
229	6.870815	6870815	49172	94	=1		
230	6.920081	6920081	49266	94	0	0	=1
231	6.969439	6969439	49359	94	0	-2	=2
232	7.018887	7018887	49449	92	-2	0	2
233	7.068424	7068424	49537	90	-2	1	1
234	7.118046	7118046	49622	89	=1	=3	=4
235	7.167750	7167750	49704	85	=4	1	4
236	7.217533	7217533	49783	82	=3	0	=1
237	7.267390	7267390	49857	79	=3	0	-2
238	7.317319	7317319	49929	74	=5	-2	5
239	7.367314	7367314	49995	72	=2	3	=7
240	7.417371	7417371	50057	66	=6	-4	6
241	7.467488	7467488	50117	62	-4	2	0
242	7.517662	7517662	50174	60	=2	2	=3
243	7.567890	7567890	50229	57	-2	=1	
244	7.618171	7618171	50281	54	-3	0	1
245	7.668505	7668505	50334	53	-3	2	2
			50387	53	-1	1	=1
				53	0	0	=1
				53	0	0	3
				53	3	3	=6

246	7.718892	7718892		56		"3	
247	7.769335	7769335	50443	56	0	6	9
248	7.819834	7819834	50499	62	6	"3	-9
249	7.870395	7870395	50561	65	3	2	5
250	7.921021	7921021	50626	70	5	1	-1
251	7.971717	7971717	50696	76	6	0	-1
252	8.022489	8022489	50772	82	6	1	1
253	8.073343	8073343	50854	89	7	"3	-4
254	8.124286	8124286	50943	93	4	5	8
255	8.175322	8175322	51036	102	9	"4	-9
256	8.226460	8226460	51138	107	5	4	8
257	8.277705	8277705	51245	116	9	"4	-8
258	8.329066	8329066	51361	121	5	4	8
259	8.380548	8380548	51482	130	9	"4	-8
260	8.432160	8432160	51612	135	5	3	7
261	8.483907	8483907	51747	143	8	"1	-4
262	8.535797	8535797	51890	150	7	"1	0
263	8.587837	8587837	52040	156	6	2	3
264	8.640033	8640033	52196	164	8	"5	-7
265	8.692393	8692393	52360	167	3	4	9
266	8.744920	8744920	52527	174	7	"2	-6
267	8.797621	8797621	52701	179	5	0	2
268	8.850501	8850501	52880	184	5	"2	-2
269	8.903565	8903565	53064	187	3	2	4
270	8.956816	8956816	53251	192	5	"4	-6
271	9.010259	9010259	53443	193	1	2	6
272	9.063895	9063895	53635	196	3	2	0
273	9.117727	9117727	53832	201	5	"3	-5
274	9.171760	9171760	54033	203	2	5	6
275	9.225996	9225996	54236	208	5	"2	-5
276	9.280440	9280440	54444	211	3	1	3
277	9.335095	9335095	54655	215	4	"1	-2
278	9.389965	9389965	54870	218	3	1	2
279	9.445053	9445053	55089	222	4		
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