 MEDICAL RESEARCH LABORATORY REPORT NO. 144

MEDICAL RESEARCH LABORATORY

U. S. Naval Submarine Base
New London

TRICHROMATIC SPECIFICATIONS OF THE MUNSELL 100 HUES AT 5/5 FOR ILLUMINANT A

By
Hermann von Schelling and
Dean Farnsworth, Lt. Cdr., H(S), USNR

Report no. 3
BuMed NM 011 019
Miscellaneous Tests and Minor Investigations

15 April 1949

COLOR VISION REPORT NO. 20

APPROVED: T.L. Willmon, Captain, (MC), USN, MO-in-C

TRICHROMATIC SPECIFICATIONS OF THE MUNSELL 100 HUES AT 5/5 FOR ILLUMINANT A

By

Hermann von Schelling and
Dean Farnsworth, Lt. Cdr., H(S), USNR

BuMed NM 011 019
Miscellaneous Tests and Minor Investigations

15 April 1949

COLOR VISION REPORT NO. 20

U.S. Naval Medical Research Laboratory
U.S. Naval Submarine Base, New London, Connecticut

TRICHROMATIC SPECIFICATIONS OF THE MUNSELL 100 HUES AT 5/5 FOR ILLUMINANT A

The series of painted papers known as the Munsell 100-Hues at 5/5, production numbers 101 to 200, were made on the basis of the Atlas system in which the reflectance followed the square of the value. They were originally intended to be used as standards within the Munsell Laboratory and no general sale or distribution was anticipated. The supply of the original papers is now completely exhausted.

However, the series was, and remains, the most exact circuit of closely spaced colors in psychological intervals which has ever been produced. It became invaluable for certain types of visual studies and a number of laboratory researches now in progress are based upon their colorimetric properties. In addition, the series was made the basis (by selection and replacement) of the Farnsworth-Munsell 100 Hue test which has been used for research and examining purposes in several hundred industries. Several journal articles, many industrial reports and the "contiguous match" examining procedure used in this laboratory depend upon exact colorimetric specification of these colors.

Data for Illuminant C was calculated from the original curves which were made at the Interchemical Research Laboratories, February 1939, by Walter Granville. These appear in Table III, page 382, of a paper by Granville, Nickerson and Foss, "Trichromatic Specifications for Intermediate and Special Colors of the Munsell System", J. Opt. Soc. Am., 33, 376 (July 1943).

Use of the papers and of the F-M 100 Hue Test has been extended to the evaluation of the effects of illuminants on a variety of tasks, such as testing with polychromatic plates for color-blindness, color zones of color deficiency, seed-sorting, color-printing inspection, process plate engraving, selection of colored lenses, dye-passing and studies of psycho-physical intervals of the chromaticity diagram. The uses in this laboratory have necessitated the calculation of the tristimulus values for Illuminant A which are here printed and graphed for the benefit of other workers.

The tables for tristimulus values and trilinear coordinates for C Illuminant were calculated by Dr. Herman von Schelling by the thirty ordinate method from the original curves which were supplied by Dorothy Nickerson. The trilinear coordinates x and y are plotted for C Illuminant in Figure 1 and for A Illuminant in Figure 2. These grids are reproduced to the same scale as the "Mixture diagram according to the 1931 I.C.I. Standard Observer and Coordinate System" supplied by the Inter-Society Color Council. If desired, therefore, Figures 1 and 2 can be cut from this report and pasted on standard charts

When we are dealing with such small spacings, the question arises as to the uniformity of the samples and the degree of accuracy of spectrophotometric methods. In other words, how closely does the sample in hand conform to tabular specifications? Therefore, a series of papers was selected whose colorimetric data showed poor agreement with psychophysical observation* and these colors, but not the original samples, were rerun in September 1943 by Walter Granville on the same General Electric recording spectrophotometer and calculated for C Illuminant by the same method. Comparative specifications are given in the following table.

TABLE I

	1939		1943	
Sample	x	y	x	y
149	.254	.333	.256	.331
150	.251	.326	.252	.325
151	.251	.322	.252	.321
152	.250	.321	.242	.317
153	.246	.313	.245	.312

It can be estimated from these values that the mean deviations of the measurements from all causes - variability between papers, errors in the machine curves and in calculating - can be expected to be less than half the average distance between points. In regions in which observation shows good agreement with spectrophotometric data, (op. cit., Fig. 3) it may be expected that colorimetric data will be accurate to less than one-quarter the distance between points.

*Dean Farnsworth, J. Opt. Soc. Am., 33, 568, 1943. Fig. 3, page 570.

A better psychological spacing of the series was worked out in the F-M 100 Hue selection. Since this test provides a semi-permanent form and protection for the papers, it is anticipated that it will be preferred in future research. Numerical equivalents of the two series are given in the following table:

TABLE 2

F-M Test	Munsell Number	F-M Test	Munsell Number	F-M Test	Munsell Number
1	101	-	134	57	167
-	102	30	135	58	168
2	103	31	136	59	169
3	104	32	137	60	170
4	105	33	138	61	171
5	106	34	139	62	172
6	107	35	140	63	173
7	108	36	141	64	174
8	109	37	142	65	175
9	110	38	143	66	176
10	111	39	144	67	177
-	112	40	145	68	178
11	113	41	146	69	179
12	114	42	147	70	180
13	115	43	148	71	181
14	116	44	149	72	182
15	117	45	150	-	183
16	118	46	151	73	184
-	119	47	152	74	185
17	120	48	153	-	186
18	121	-	154	75	187
-	122	49	155	76	188
19	123	50	156	77	189
20	124	51	157	78	190
21	125	52	158	-	191
22	126	-	159	79	192
23	127	53	160	-	193
24	128	-	161	80	194
25	129	54	162	81	195
26	130	-	163	82	196
27	131	55	164	83	197
28	132	56	165	84	198
29	133	-	166	85	199
				-	200

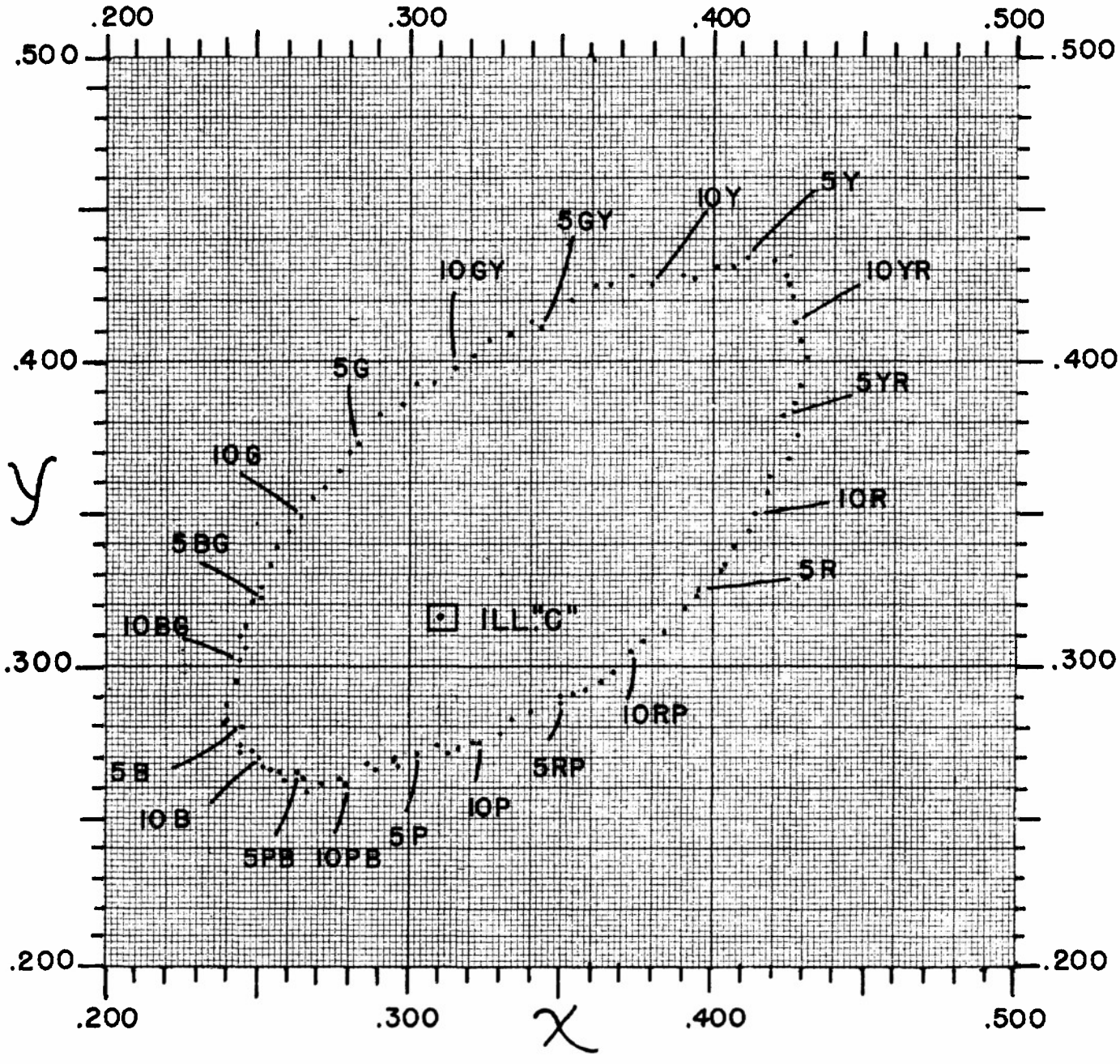

FIGURE I.

I.C.I. Chromaticity diagram showing values for x and y for Illuminant C for 100 hues at 5/5 (old value scale).

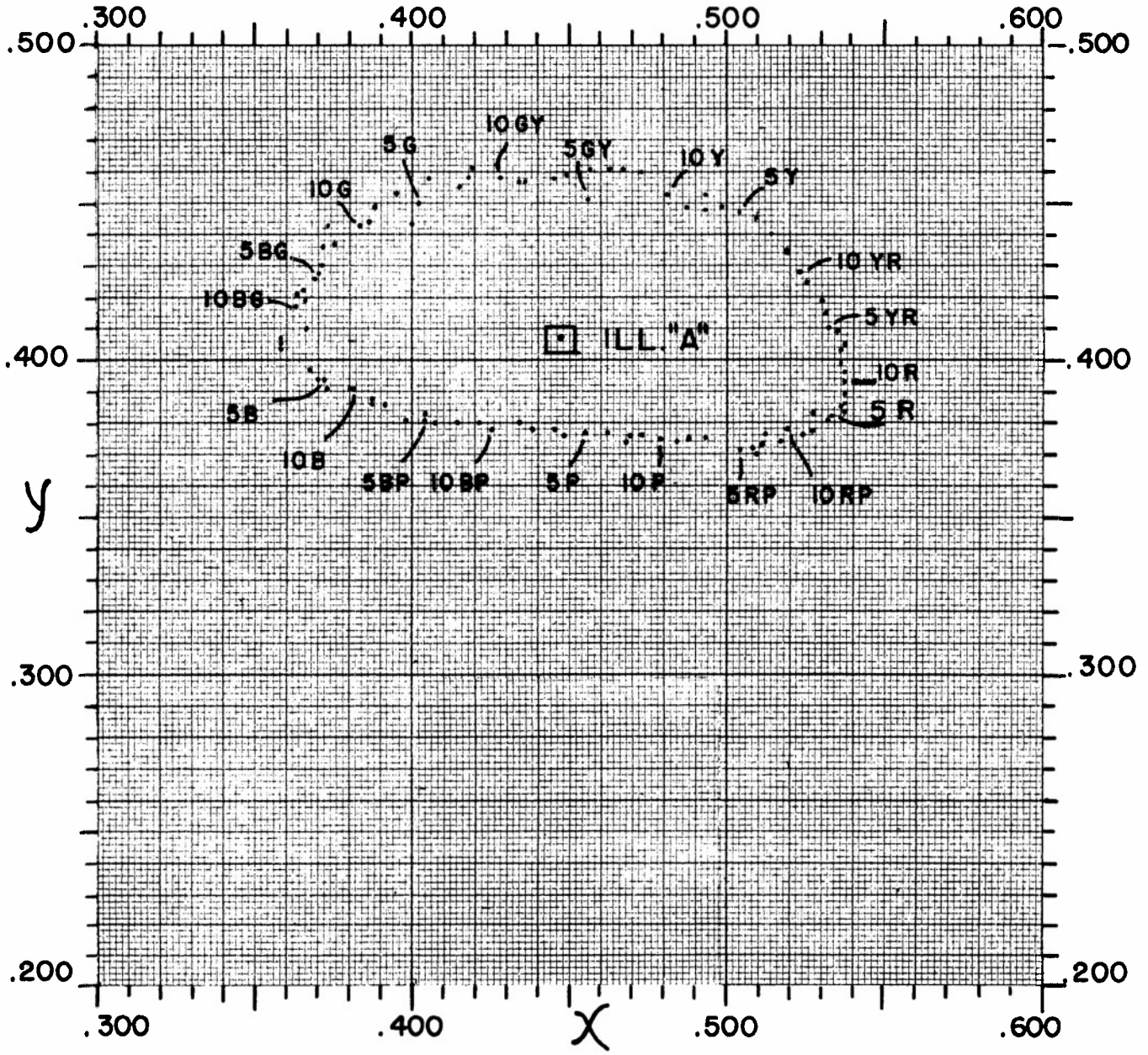

FIGURE 2.

I.C.I. Chromaticity diagram showing values for x and y for Illuminant A for 100 hues at 5/5 (old value scale).

100 HUES

Book Notation	Munsell Production No.	For ICI Illuminant A					
		Tristimulus Values			Trilinear Coordinates		
		X	Y	Z	x	y	z
5R	101	.3647	.2610	.0582	.533	.382	.085
6	102	.3717	.2650	.0559	.537	.383	.080
7	103	.3538	.2539	.0526	.536	.385	.079
8	104	.3496	.2518	.0501	.537	.386	.077
9	105	.3484	.2524	.0479	.537	.389	.074
10	106	.3494	.2559	.0458	.537	.393	.070
1YR	107	.3321	.2452	.0416	.537	.396	.067
2	108	.3311	.2464	.0402	.536	.399	.065
3	109	.3268	.2455	.0372	.536	.403	.061
4	110	.3187	.2403	.0345	.537	.405	.058
5	111	.3229	.2486	.0353	.532	.410	.058
6	112	.3155	.2416	.0331	.535	.409	.056
7	113	.3159	.2470	.0318	.531	.415	.054
8	114	.3120	.2465	.0303	.530	.419	.051
9	115	.3223	.2602	.0303	.526	.425	.049
10	116	.3171	.2597	.0298	.523	.428	.049
1Y	117	.3275	.2735	.0299	.519	.434	.047
2	118	.3233	.2714	.0289	.519	.435	.046
3	119	.3118	.2671	.0278	.514	.440	.046
4	120	.3226	.2816	.0292	.509	.445	.046
5	121	.3160	.2804	.0308	.504	.447	.049
6	122	.3177	.2869	.0337	.498	.449	.053
7	123	.3221	.2953	.0353	.493	.453	.054
8	124	.3075	.2796	.0371	.493	.448	.059
9	125	.3142	.2893	.0412	.487	.449	.064
10	126	.3114	.2934	.0424	.481	.453	.066
1GY	127	.3016	.2931	.0429	.473	.460	.067
2	128	.2804	.2766	.0433	.467	.461	.072
3	129	.2868	.2859	.0468	.463	.461	.076
4	130	.2804	.2830	.0504	.457	.461	.082
5	131	.2748	.2716	.0559	.456	.451	.093
6	132	.2745	.2802	.0565	.449	.459	.092
7	133	.2727	.2808	.0592	.445	.458	.097
8	134	.2662	.2790	.0651	.436	.457	.107
9	135	.2651	.2796	.0666	.434	.457	.109
10	136	.2674	.2867	.0713	.428	.458	.114
1G	137	.2570	.2826	.0740	.419	.461	.120
2	138	.2441	.2673	.0726	.418	.458	.124
3	139	.2569	.2821	.0803	.415	.455	.130
4	140	.2325	.2633	.0786	.405	.458	.137
5	141	.2194	.2457	.0809	.402	.450	.148
6	142	.2168	.2483	.0833	.395	.453	.152
7	143	.2265	.2510	.0893	.400	.443	.157

Book Notation	Munsell Production No.	For ICI Illuminant A					
		Tristimulus Values			Trilinear Coordinates		
		X	Y	Z	x	y	z
8	144	.2180	.2523	.0912	.388	.449	.163
9	145	.2141	.2468	.0942	.386	.444	.170
10	146	.2176	.2521	.0988	.383	.443	.174
1BG	147	.2036	.2423	.1004	.373	.443	.184
2	148	.2041	.2376	.1023	.375	.437	.188
3	149	.2098	.2466	.1089	.371	.436	.193
4	150	.2146	.2488	.1154	.371	.430	.199
5	151	.1985	.2286	.1088	.370	.427	.203
6	152	.2100	.2423	.1165	.369	.426	.205
7	153	.2017	.2330	.1178	.365	.422	.213
8	154	.1970	.2282	.1171	.363	.421	.216
9	155	.2035	.2329	.1197	.366	.419	.215
10	156	.2119	.2429	.1283	.363	.417	.220
1B	157	.2126	.2383	.1307	.366	.410	.224
2	158	.1988	.2257	.1307	.358	.407	.235
3	159	.2002	.2268	.1323	.358	.405	.237
4	160	.1969	.2220	.1310	.358	.404	.238
5	161	.1964	.2082	.1233	.372	.394	.234
6	162	.2081	.2246	.1336	.367	.397	.236
7	163	.2126	.2262	.1352	.370	.394	.236
8	164	.2147	.2256	.1360	.373	.391	.236
9	165	.2276	.2345	.1374	.380	.391	.229
10	166	.2281	.2343	.1368	.381	.391	.228
1PB	167	.2366	.2360	.1386	.387	.386	.227
2	168	.2382	.2379	.1387	.387	.387	.226
3	169	.2450	.2414	.1396	.391	.386	.223
4	170	.2633	.2518	.1466	.398	.381	.221
5	171	.2537	.2395	.1349	.404	.381	.215
6	172	.2513	.2383	.1329	.404	.383	.213
7	173	.2532	.2361	.1324	.407	.380	.213
8	174	.2681	.2463	.1333	.414	.380	.206
9	175	.2733	.2466	.1287	.421	.380	.199
10	176	.2738	.2430	.1270	.425	.378	.197
1P	177	.2869	.2506	.1227	.434	.380	.186
2	178	.2887	.2493	.1213	.438	.378	.184
3	179	.3039	.2585	.1210	.445	.378	.177
4	180	.2883	.2418	.1133	.448	.376	.176
5	181	.3197	.2646	.1180	.455	.377	.168
6	182	.3371	.2753	.1172	.462	.377	.161
7	183	.3283	.2623	.1109	.468	.374	.158
8	184	.3338	.2672	.1105	.469	.376	.155
9	185	.3303	.2623	.1055	.473	.376	.151
10	186	.3353	.2530	.1035	.478	.375	.147

100 HUES

Book Notation	Munsell Production No.	For ICI Illuminant A					
		Tristimulus Values			Trilihear Coordinates		
		X	Y	Z	x	y	z
1RP	187	.3405	.2631	.0999	.484	.374	.142
2	188	.3541	.2715	.0995	.488	.375	.137
3	189	.3698	.2808	.0988	.493	.375	.132
4	190	.3694	.2682	.0879	.509	.370	.121
5	191	.3485	.2565	.0869	.504	.371	.125
6	192	.3684	.2699	.0866	.508	.372	.120
7	193	.3747	.2738	.0850	.511	.373	.116
8	194	.3797	.2789	.0833	.512	.376	.112
9	195	.3800	.2746	.0803	.517	.374	.109
10	196	.3649	.2660	.0723	.519	.378	.103
1R	197	.3788	.2720	.0726	.524	.376	.100
2	198	.3661	.2617	.0666	.527	.377	.096
3	199	.3642	.2645	.0626	.527	.383	.090
4	200	.3727	.2670	.0610	.532	.381	.087