SMPTE STANDARD

for Television — Color Reference Pattern

1 Scope

This standard defines the electrical and physical representation of a television color reference pattern. It also specifies colorimetry, geometry, and related parameters.

2 Colorimetry

2.1 Colorimetric data in tables 1, 2, and 3 represent the color reference pattern using white-point definitions for television (D_{65}), studio lighting (3100 K), and film (D_{55}). The data are based on a 2° standard observer (CIE S002).

2.2 The CIE tristimulus data specified in tables 1, 2, and 3 are aim-point specifications for each color reference pattern sample.

2.3 Common television practice is to set up the camera for the desired appearance on a D65 monitor, regardless of the original scene illumination. Therefore, tables 4, 5, 6, and 7 are based on D65, and values for 3100 K studio lighting are not included. The values in table 8, based on D55, should not be used for television.

3 Geometry

3.1 The color reference pattern is made up of 24 sample colors whose colorimetric designations are distributed throughout the color television gamut. These samples are square and arranged in four rows of six samples per row. The first two rows consist of colors that are designed to simulate the color appearance of natural objects. The third row consists of colors that represent subtractive primaries (cyan, magenta, and yellow) as well as the binary combinations of these colors (red, green, and blue). The last row consists of a six-step neutral gray scale; the neutral numbers are Munsell values.

3.2 Each color sample is represented as a square 18% of picture height.

3.3 The rows and columns of color samples are separated by black spaces around the color samples. The black spaces are 3% of picture height.

3.4 The six columns of color samples are surrounded by a black border on the left and right. The left and right borders are 5% of picture height at 4:3 aspect ratio and 27.5% of picture height at 16:9 aspect ratio.

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The four rows of color samples are surrounded by a black border at the top and bottom of the chart. The top and bottom borders are defined to be 9.5% of picture height for both 4:3 and 16:9 aspect ratios. Some existing charts have a 5% border and do not provide 4:3 aspect ratio. These older charts should be framed to fill a 4:3 raster horizontally, giving overscan at the top and bottom of the chart. They should be overscanned both vertically and horizontally in 16:9 applications to match best the geometric specifications of this standard (see figure 1).

4 Video color representations

4.1 All video signal levels are calculated using SMPTE RP 177, the standard television system D_{65} white point, and each of the following standard television primary colorimetry definitions: ITU-R BT.709, SMPTE 170M / SMPTE 240M, PAL (EBU), and original NTSC (1953 FCC) (see table 9). In addition, a set of video color representations is calculated using illuminant D_{55} for only the ITU-R BT.709 primaries.

4.2 The linear video signal levels in tables 4 through 8 are video voltages ranging between 0.0 V (black) and 1.0 V (white). The user must apply the appropriate gamma or transfer characteristic. Because of the number of possible gamma or transfer curves which could be used, no gamma correction is applied to any of the video representations listed in this standard.

4.3 Any color sample having any video levels outside the 0.0 V to 1.0 V range cannot be reproduced using the reference primaries for that system. For example, the cyan sample 18 results in a negative red value with ITU-R BT.709, PAL, and SMPTE 240M primaries and a D_{65} white point. Both yellow sample 16 and cyan sample 18 result in negative values with illuminant D_{55} and ITU-R BT.709 primaries (see figure 2).

4.4 The video signal levels in tables 4 through 8 assume that 1.0 V corresponds to a perfect 100% white reflector.

5 Considerations in using the color reference pattern

5.1 The color reference pattern should be illuminated and the camera positioned as shown in figure 3. The illuminator, camera, and reference pattern should be in the same horizontal plane. The illuminator should be positioned to the side at 45° off camera axis. Two illuminators, one on each side, may make it easier to achieve uniform illumination.

5.2 The camera should be properly set up using other appropriate test patterns. The gray samples on this reference pattern are not intended to be used for setting camera color balance, white levels, or black levels. The preferred white reference is a 100% reflecting white sample, such as halon or barium sulfate. Alternately, gain may be set to match the white levels shown in tables 4-8. The preferred black level reference is a capped lens or light trap.

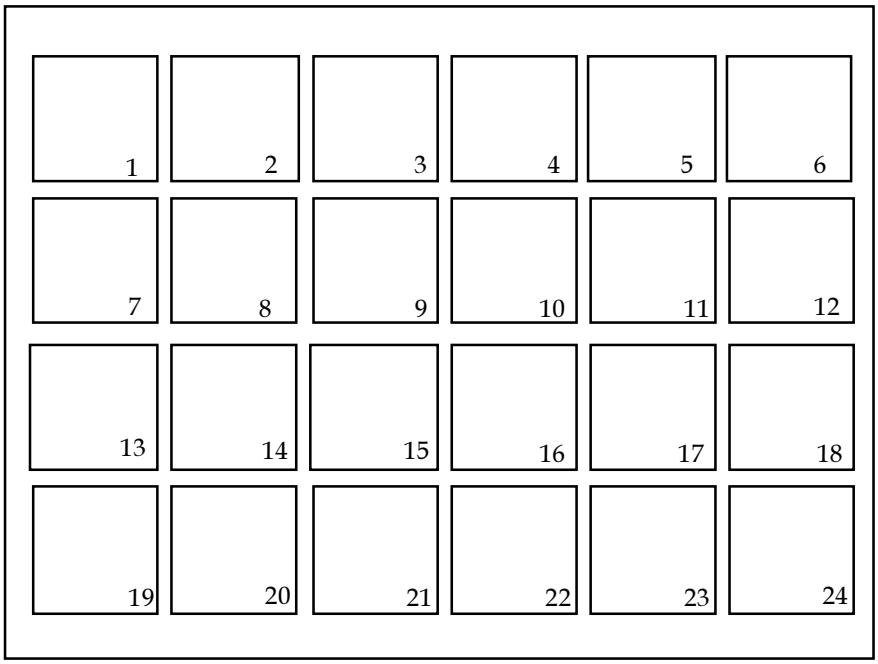

Figure 1 – Color reference pattern sample numbers

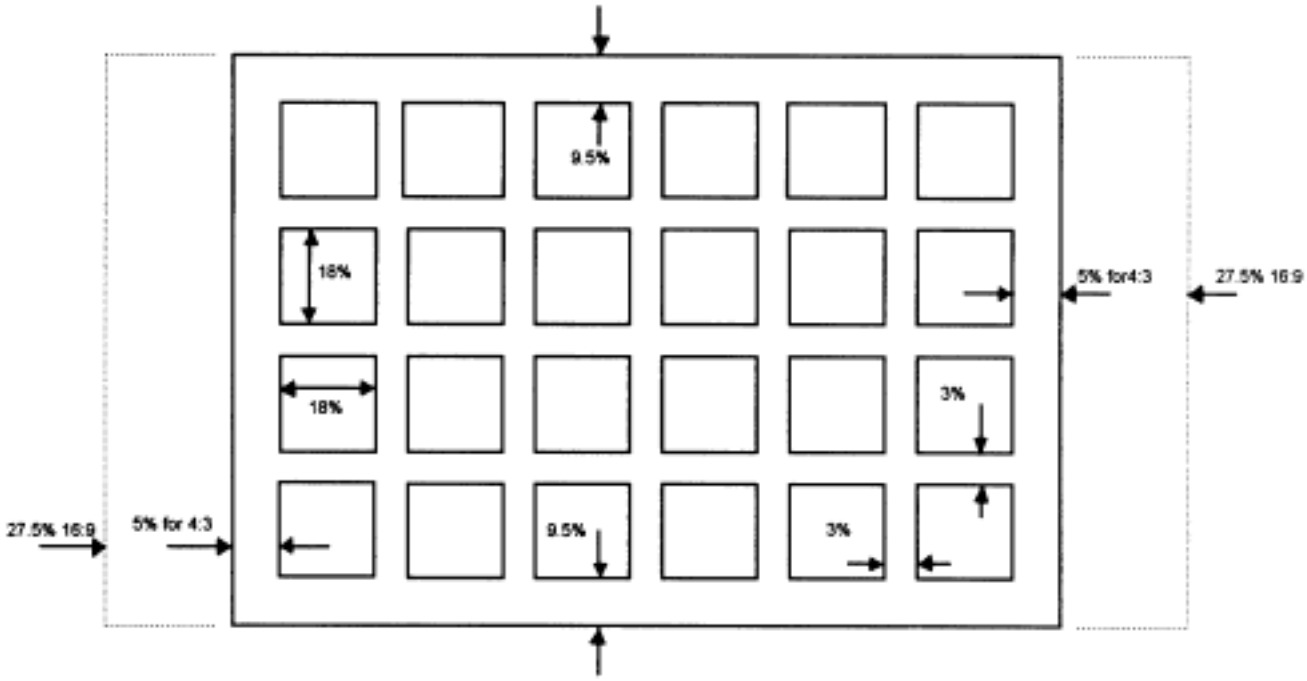

Figure 2 – Color reference pattern geometry expressed in percentage of picture height

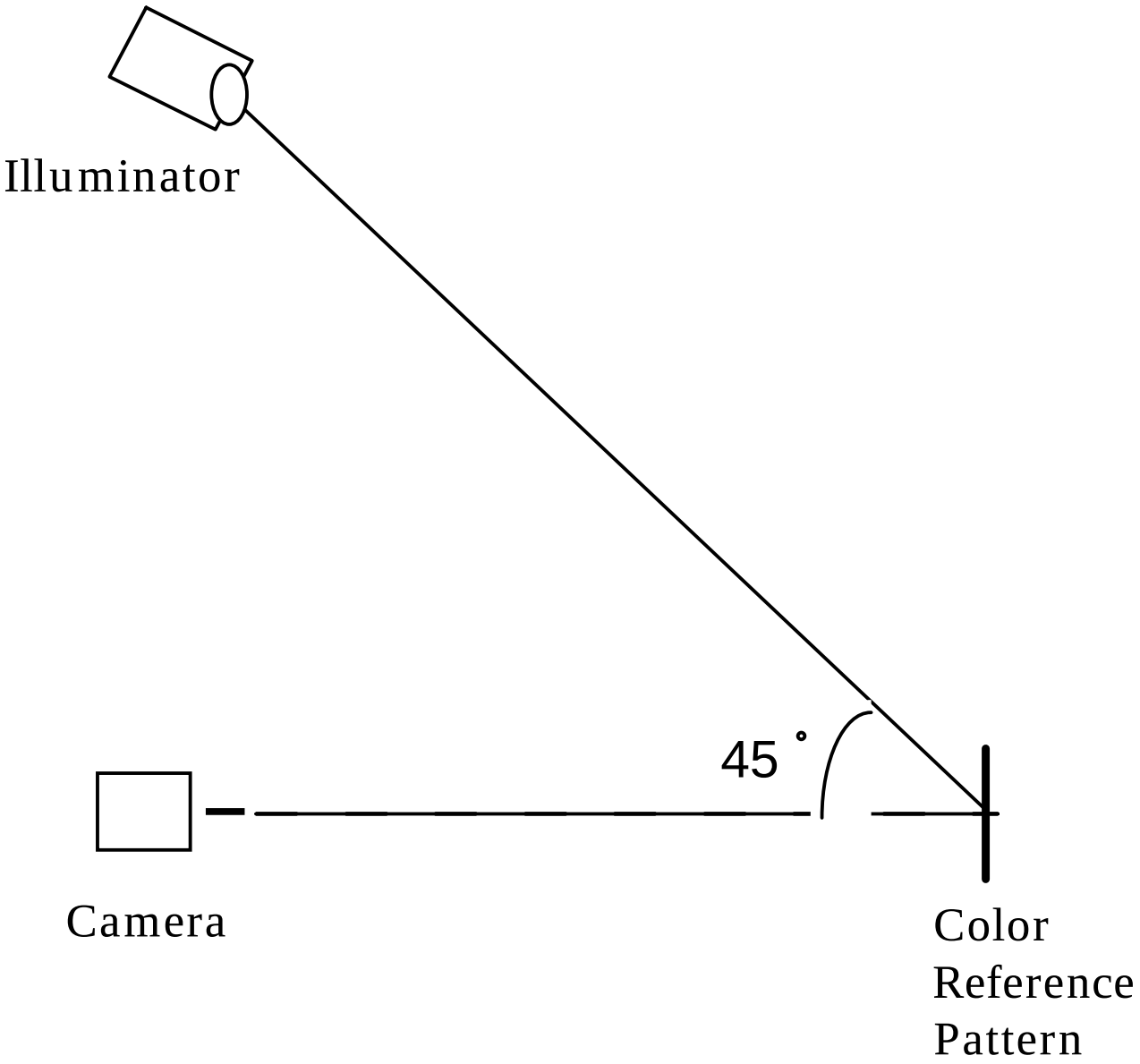

Figure 3 – Measurement configuration

Table 1 – Colorimetric specifications with illuminant D_{65}

Sample number	Color name	CIE X	CIE Y	CIE Z
1	Dark skin	10.97	9.70	6.06
2	Light skin	38.12	35.58	25.92
3	Blue sky	17.86	19.08	34.52
4	Foliage	10.10	12.98	6.69
5	Blue flower	25.83	24.38	45.32
6	Bluish green	31.27	42.73	44.69
7	Orange	36.46	29.32	5.89
8	Purplish blue	13.42	11.76	37.23
9	Moderate red	28.45	19.22	13.75
10	Purple	8.68	6.52	14.69
11	Yellow green	33.20	43.66	11.19
12	Orange yellow	46.17	43.12	8.40
13	Blue	8.40	6.22	30.00
14	Green	14.50	23.58	9.51
15	Red	20.17	11.82	5.20
16	Yellow	56.05	59.64	9.56
17	Magenta	29.42	19.27	30.29
18	Cyan	14.47	19.87	39.52
19	White	83.98	88.76	92.35
20	Neutral 8	55.88	58.87	62.87
21	Neutral 6.5	33.67	35.51	38.11
22	Neutral 5	18.30	19.30	20.83
23	Neutral 3.5	7.96	8.40	9.06
24	Black	2.83	2.95	3.22

NOTE – Assuming CIE illuminant D_{65} relative to CIE 1931 (2°) standard observer:

CIE D_{65} white point: x = 0.3127; y = 0.3290

Table 2 – Colorimetric specifications with illuminant 3100 K

Sample number	Color name	CIE X	CIE Y	CIE Z
1	Dark skin	14.18	10.80	2.35
2	Light skin	48.32	38.29	10.28
3	Blue sky	17.23	17.77	13.07
4	Foliage	11.82	12.74	2.70
5	Blue flower	27.21	23.81	17.12
6	Bluish green	32.16	39.10	17.90
7	Orange	49.53	35.09	2.35
8	Purplish blue	11.44	10.55	13.89
9	Moderate red	39.18	23.72	5.21
10	Purple	9.62	6.88	5.32
11	Yellow green	40.39	43.56	4.99
12	Orange yellow	60.94	48.69	3.51
13	Blue	6.01	5.23	11.17
14	Green	15.83	21.84	4.07
15	Red	30.23	15.92	1.99
16	Yellow	73.31	64.24	4.45
17	Magenta	37.96	22.79	11.14
18	Cyan	12.05	16.42	15.59
19	White	95.41	88.97	35.79
20	Neutral 8	63.16	58.94	24.28
21	Neutral 6.5	37.98	35.53	14.70
22	Neutral 5	20.61	19.30	8.03
23	Neutral 3.5	8.95	8.40	3.49
24	Black	3.20	2.96	1.24

NOTE – Assuming 3100 K illumination relative to CIE 1931 (2°) standard observer:

3100 K (Planckian) white point: x = 0.4299; y = 0.4016

Table 3 – Colorimetric specifications with illuminant D_{55}

Sample number	Color name	CIE X	CIE Y	CIE Z
1	Dark skin	11.38	9.87	5.13
2	Light skin	39.39	35.98	22.08
3	Blue sky	17.37	18.86	29.12
4	Foliage	10.30	12.97	5.71
5	Blue flower	25.51	24.24	38.21
6	Bluish green	31.00	42.19	38.16
7	Orange	38.36	30.22	5.01
8	Purplish blue	12.69	11.52	31.37
9	Moderate red	29.89	19.88	11.59
10	Purple	8.62	6.56	12.24
11	Yellow green	34.23	43.76	9.73
12	Orange yellow	48.33	44.04	7.21
13	Blue	7.71	6.02	25.33
14	Green	14.65	23.38	8.21
15	Red	21.60	12.43	4.39
16	Yellow	58.61	60.47	8.37
17	Magenta	30.29	19.75	25.37
18	Cyan	13.72	19.29	33.71
19	White	84.73	88.79	78.30
20	Neutral 8	56.30	58.87	53.26
21	Neutral 6.5	33.91	35.52	32.27
22	Neutral 5	18.42	19.30	17.64
23	Neutral 3.5	8.01	8.40	7.67
24	Black	2.85	2.95	2.73

NOTE – Assuming CIE illuminant D_{55} relative to CIE 1931 (2°) standard observer:

CIE D_{55} white point: x = 0.3324; y = 0.3474

Table 4 – RGB values before gamma correction based on D_{65} and ITU-R BT.709 primaries

Sample number	Color name	R	G	B
1	Dark skin	0.176192	0.078161	0.050369
2	Light skin	0.559217	0.308765	0.222598
3	Blue sky	0.113384	0.199172	0.335883
4	Foliage	0.094429	0.148387	0.049854
5	Blue flower	0.236358	0.225838	0.443659
6	Bluish green	0.133698	0.517089	0.402597
7	Orange	0.701529	0.199095	0.022732
8	Purplish blue	0.069851	0.106012	0.376989
9	Moderate red	0.558012	0.090525	0.121956
10	Purple	0.107833	0.044287	0.146799
11	Yellow green	0.348986	0.501909	0.047688
12	Orange yellow	0.791553	0.364908	0.026515
13	Blue	0.027033	0.047735	0.309077
14	Green	0.060008	0.305765	0.060487
15	Red	0.446057	0.028404	0.042073
16	Yellow	0.852001	0.579539	0.010575
17	Magenta	0.506210	0.088935	0.297217
18	Cyan	–0.033561	0.248928	0.385235
19	White	0.896718	0.889514	0.841782
20	Neutral 8	0.592520	0.588894	0.575523
21	Neutral 6.5	0.355289	0.355648	0.349110
22	Neutral 5	0.192522	0.193346	0.190980
23	Neutral 3.5	0.083667	0.084194	0.083056
24	Black	0.030311	0.029250	0.029592

NOTE – The following conversion matrices are assumed:

$$[A] = \begin{bmatrix} 0.412391 & 0.357584 & 0.180481 \\ 0.212639 & 0.715169 & 0.072192 \\ 0.019331 & 0.119195 & 0.950532 \end{bmatrix}$$

$$[A]^{-1} = \begin{bmatrix} 3.240970 & -1.537383 & -0.49861 \\ -0.969244 & 1.875968 & 0.041555 \\ 0.055630 & -0.203977 & 1.056972 \end{bmatrix}$$

Table 5 – RGB values before gamma correction based on D_{65} and ANSI/SMPTE 240M primaries

Sample number	Color name	R	G	B
1	Dark skin	0.182879	0.076701	0.050697
2	Light skin	0.576451	0.305289	0.223528
3	Blue sky	0.106411	0.198569	0.334917
4	Foliage	0.091884	0.151095	0.050361
5	Blue flower	0.234872	0.221987	0.442360
6	Bluish green	0.109775	0.526532	0.402663
7	Orange	0.736137	0.192181	0.024618
8	Purplish blue	0.063353	0.102215	0.375289
9	Moderate red	0.588262	0.080821	0.122529
10	Purple	0.110965	0.041324	0.146283
11	Yellow green	0.343520	0.512510	0.050184
12	Orange yellow	0.822823	0.362193	0.029257
13	Blue	0.023072	0.043769	0.307464
14	Green	0.046388	0.314693	0.061568
15	Red	0.473226	0.019975	0.042672
16	Yellow	0.875491	0.583708	0.014459
17	Magenta	0.531413	0.077257	0.296639
18	Cyan	–0.053390	0.252193	0.383950
19	White	0.897665	0.890171	0.842081
20	Neutral 8	0.592890	0.589047	0.575609
21	Neutral 6.5	0.355331	0.355765	0.349149
22	Neutral 5	0.192492	0.193402	0.190993
23	Neutral 3.5	0.083644	0.084224	0.083062
24	Black	0.030377	0.029223	0.029591

NOTE – The following conversion matrices are assumed:

$$[A] = \begin{bmatrix} 0.393521 & 0.365258 & 0.191677 \\ 0.212376 & 0.701060 & 0.086564 \\ 0.018739 & 0.111934 & 0.958385 \end{bmatrix}$$

$$[A]^{-1} = \begin{bmatrix} 3.506003 & -1.739791 & -0.544058 \\ -1.069048 & 1.977779 & 0.035171 \\ 0.056307 & -0.196976 & 1.049952 \end{bmatrix}$$

Table 6– RGB values before gamma correction based on D_{65} and PAL primaries

Sample number	Color name	R	G	B
1	Dark skin	0.172057	0.078161	0.050038
2	Light skin	0.548651	0.308765	0.221570
3	Blue sky	0.117003	0.199172	0.337515
4	Foliage	0.096705	0.148387	0.048678
5	Blue flower	0.235914	0.225838	0.446259
6	Bluish green	0.149872	0.517089	0.401231
7	Orange	0.680333	0.199095	0.020628
8	Purplish blue	0.070091	0.106012	0.380222
9	Moderate red	0.538291	0.090525	0.122331
10	Purple	0.105152	0.044287	0.148022
11	Yellow green	0.355437	0.501909	0.042267
12	Orange yellow	0.773555	0.364908	0.022477
13	Blue	0.027906	0.047735	0.312196
14	Green	0.070375	0.305765	0.057560
15	Red	0.428438	0.028404	0.042236
16	Yellow	0.840507	0.579539	0.037854
17	Magenta	0.488607	0.088935	0.299702
18	Cyan	–0.021644	0.248928	0.386862
19	White	0.896414	0.889514	0.841212
20	Neutral 8	0.592367	0.588894	0.575364
21	Neutral 6.5	0.355304	0.355648	0.349032
22	Neutral 5	0.192557	0.193346	0.190952
23	Neutral 3.5	0.083689	0.084194	0.083042
24	Black	0.030267	0.029250	0.029596

NOTE – The following conversion matrices are assumed:

$$[A] = \begin{bmatrix} 0.430554 & 0.341550 & 0.178352 \\ 0.222004 & 0.706655 & 0.071341 \\ 0.020182 & 0.129553 & 0.939322 \end{bmatrix}$$

$$[A]^{-1} = \begin{bmatrix} 3.063361 & -1.393390 & -0.475824 \\ -0.969244 & 1.875968 & 0.041555 \\ 0.067861 & -0.228799 & 1.069090 \end{bmatrix}$$

Table 7– RGB values before gamma correction based on D_{65} and NTSC 1953 primaries

Sample number	Color name	R	G	B
1	Dark skin	0.144900	0.081539	0.053913
2	Light skin	0.478764	0.318281	0.232637
3	Blue sky	0.144518	0.189652	0.325483
4	Foliage	0.107855	0.153175	0.055296
5	Blue flower	0.240366	0.213305	0.429699
6	Bluish green	0.248636	0.516911	0.403232
7	Orange	0.540014	0.218391	0.043100
8	Purplish blue	0.089166	0.089516	0.358724
9	Moderate red	0.414254	0.097060	0.128208
10	Purple	0.091569	0.039438	0.141268
11	Yellow green	0.381202	0.525697	0.074476
12	Orange yellow	0.648109	0.392310	0.056061
13	Blue	0.042164	0.032102	0.291736
14	Green	0.127950	0.315689	0.072057
15	Red	0.317143	0.035084	0.048594
16	Yellow	0.748624	0.617645	0.052361
17	Magenta	0.383905	0.084242	0.291092
18	Cyan	0.058489	0.235909	0.371371
19	White	0.892894	0.892430	0.845010
20	Neutral 8	0.590951	0.589740	0.576456
21	Neutral 6.5	0.355182	0.356024	0.349529
22	Neutral 5	0.192698	0.193469	0.191119
23	Neutral 3.5	0.083792	0.084251	0.083120
24	Black	0.029994	0.029249	0.029588

NOTE – The following conversion matrices are assumed:

$$[A] = \begin{bmatrix} 0.588099 & 0.179133 & 0.183223 \\ 0.289661 & 0.605640 & 0.104699 \\ 0.000000 & 0.068241 & 1.020817 \end{bmatrix}$$

$$[A]^{-1} = \begin{bmatrix} 1.971026 & -0.549468 & -0.297418 \\ -0.953709 & 1.936318 & -0.027418 \\ 0.063755 & -0.129442 & 0.981441 \end{bmatrix}$$

Table 8 – RGB values before gamma correction based on D_{55} and ITU-R BT.709 primaries (not for television applications)

Sample number	Color name	R	G	B
1	Dark skin	0.1735	0.0780	0.0491
2	Light skin	0.5556	0.3064	0.2209
3	Blue sky	0.1158	0.2002	0.3388
4	Foliage	0.0960	0.1478	0.0481
5	Blue flower	0.2387	0.2263	0.4476
6	Bluish green	0.1502	0.5136	0.4062
7	Orange	0.6826	0.1998	0.0154
8	Purplish blue	0.0704	0.1076	0.3827
9	Moderate red	0.5482	0.0892	0.1197
10	Purple	0.1064	0.0452	0.1467
11	Yellow green	0.3515	0.4998	0.0396
12	Orange yellow	0.7729	0.3655	0.0161
13	Blue	0.0281	0.0494	0.3154
14	Green	0.0674	0.3040	0.0574
15	Red	0.4412	0.0260	0.0402
16	Yellow	0.8407	0.5774	–0.0028
17	Magenta	0.4996	0.0886	0.2972
18	Cyan	–0.0181	0.2461	0.3942
19	White	0.8972	0.8886	0.8423
20	Neutral 8	0.5924	0.5886	0.5758
21	Neutral 6.5	0.3551	0.3558	0.3491
22	Neutral 5	0.1923	0.1934	0.1911
23	Neutral 3.5	0.0835	0.0842	0.0831
24	Black	0.0303	0.0292	0.0297

NOTE – The following conversion matrices are assumed:

$$[A] = \begin{bmatrix} 0.455311 & 0.352891 & 0.14862 \\ 0.23477 & 0.705782 & 0.059448 \\ 0.021343 & 0.11763 & 0.782731 \end{bmatrix}$$

$$[A]^{-1} = \begin{bmatrix} 2.935457 & -1.39246 & -0.451609 \\ -0.982134 & 1.900917 & 0.042108 \\ 0.067556 & -0.247705 & 1.283564 \end{bmatrix}$$

Table 9 – Television primaries

Television standard	Primary	CIE x	CIE y
ITU-R BT.709	Red	0.640	0.330
	Green	0.300	0.600
	Blue	0.150	0.060
SMPTE 170M and SMPTE 240M	Red	0.630	0.340
	Green	0.310	0.595
	Blue	0.155	0.070
PAL (EBU)	Red	0.640	0.330
	Green	0.290	0.600
	Blue	0.150	0.060
Old NTSC (FCC 1953)	Red	0.670	0.330
	Green	0.210	0.710
	Blue	0.140	0.080

Annex A (informative)
Bibliography

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ITU-R BT.709-4 (03/00), Parameter Values for the HDTV Standard for Production and International Programme Exchange