CLASSIFICATION OF COLOUR GAMUTS OF PRINTING PROCESSES

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Abstract: The colour gamut of a printing process (for a given combination of ink strength and substrate) is primarily determined by the chroma values of the primary and secondary colours. In a simplified approach the chroma values can be used to describe the colour gamut of a printing process by one single number. Based on colour measurements of a large selection of different process/substrate combinations a classification is proposed comprising 7 gamuts ranging from extra-large to very small. The gamuts are defined by chroma and hue angle values. It is proposed to use these gamut categories for describing the colour rendering quality of a printing process and for standardising different process/ substrate variations in printing specifications or standards.

Introduction

The colour gamut is one of the most important criterion to describe the rendering quality of a printing process. In contrast to this significance, the colour gamut is not a numerically defined characteristic. Usually, the gamut is described by a set of colour values making it difficult to compare gamuts of different printing processes.
With the increasing importance of non-impact printing processes, such a comparison becomes more and more important. Moreover, there is also a need to quantify the gamut of special reproduction processes, such as the utilisation of more than 4 primary colours, where the main purpose is to increase the colour gamut. The effort to enlarge the colour gamut is only meaningful, if the gamut gain obtained with these processes can be quantified.

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Once the colour gamut is measurable, it is also desirable to define categories of colour gamuts in order to classify printing processes. The ultimate goal is to define generic colour gamuts being applicable to international standards in order to replace the nowadays used individual specifications.

Quantifying colour gamuts

A printing process based on the primary colours Cyan, Magenta and Yellow creates a colour gamut whose volume is determined by a solid with 8 vertices and 12 faces, i.e. a dodecahedron. The vertices represent the following colours:
- Paper white (W)
- Cyan (C)
- Magenta (M)
- Yellow (Y)
- Red (R)
- Green (G)
- Blue (B)
- Black (K).

Black may be either a combination of C+M+Y (e.g. in silver halide systems) or a separate primary colour or an overprint of all four primaries.

If the volume of this colour solid is calculated, it can be shown that the result of the calculation strongly depends on the choice of both the white point and the Black.
This, however, is not the perception in everyday live where most people consider that the colour gamut is primarily determined by the chroma values of the primary and secondary colours. An example for the significance of high chroma values is the so-called HiFi printing process. The basic idea behind this concept is to expand the chroma range to higher chromas rather than to choose a high substrate whiteness or a high-density Black. Based on this consideration, it is proposed to quantify the colour gamut by means of the chroma values of the primary and secondary colours.
The area generated by the primary and secondary colours is a hexagon whose exact calculation requires both the chroma values and the hue angles. If, the hue angles between adjacent colours do not strongly deviate from 60°, the hue angle is less important and an approximate assessment of the hexagon area is possible by solely using the chroma values. The error of this simplified approach is – for typical hue angles found in printing processes – less than 2.5 % compared with the exact calculation (see Appendix 1). Hence the sum of the chroma values of the primary and secondary colours may be regarded a measure for the hexagon area and therefore for the colour gamut.

Colour gamuts of conventional and non-impact printing processes

Based on the concept developed in the preceding chapter, the colour gamut of different processes is described in terms of CIELAB chroma and the CIELAB hue angle (see table 1 and 2). Strictly speaking, the CIELAB colour space is not the best suited system to quantify colour gamuts. However, as the ISO Standard 12647 specifying the colour gamut of the major printing processes is based on CIELAB, these coordinates have also been chosen for this study.

For the conventional printing processes such as offset, gravure and newspaper printing, the CIELAB values specified in ISO 12647 were used to describe the colour gamut. As additional values for offset printing those specified for the European process inks and measured values from wet-on-dry printed samples were included.

The colour values for non-impact printing processes were all measured form printed samples. As the colour values depend on the printing substrate, the given values are just examples for these printing systems.

Altogether 30 examples of process/paper combinations were collected. The most interesting values are the sums of the chroma values shown in table 1. As could be expected, the sum of the 6 chroma values varies within a wide range. The maximum value is 525 and was obtained for the Küppers 7-colour process. The minimum value is 252, found for newspaper printing. Two thirds of the examples are situated between sum values of 350 and 450.

Apart from the overall sum of the chroma values, the fractional sums of the primary and secondary colours are also of interest. The difference between these sums (see table 1) varies between –5 and 55. Under ideal conditions, this difference tends to be zero. This, for instance, is the case when inks based on soluble dyes are printed on a transparent substrate. Therefore, if the primary colours produce a larger chroma sum than the secondary colours, this may be attributed to factors such as an incomplete ink transfer (untertrapping) or a non-ideal transparency of the ink film.

It is interesting to note that the difference of the chroma sums between the primary and the secondary colours is larger for offset prints than for gravure prints (see table 1). This may be explained by the fact that ink undertrapping is not possible in gravure printing but is very common in offset printing.

	C	M	Y	R M+Y	G C+Y	B C+M	Sum CMY	Sum RGB	Total	Difference CMY/RGB
Offset ISO 12647-2										
Paper 1	62	75	95	79	72	51	232	202	434	30
Paper 2	59	72	90	76	65	49	221	190	411	31
Paper 3	56	71	86	74	68	46	213	188	401	25
Paper 4	45	56	68	57	42	30	169	129	298	40
Paper 5	43	55	70	56	42	31	168	129	297	39
Gravure ISO 12647-4										
Paper 1	62	77	99	94	75	46	238	215	453	23
Paper 2	57	71	90	85	64	47	218	196	414	22
Paper 3	51	68	86	82	55	43	205	180	385	25
Newspaper printing ISO 12647-3	35	48	60	48	38	23	143	109	252	34
Küppers 7-Colour Process	66	83	111	93	83	89	260	265	525	-5
European offset ink standard CEI 30-89	62	79	91	91	77	56	232	224	456	8
Ink jet										
Tektronix Phaser 380	60	80	76	72	72	74	216	218	434	-2
HP DesignJet (dye)	58	72	86	84	80	53	216	217	433	-1
HP DesignJet (pigment)	60	66	87	67	60	44	213	171	384	42
Epson Stylus 5000	67	80	92	93	67	64	239	224	463	15
Encad NovaJet	62	75	103	89	79	63	240	231	471	9
Raster Graphics	39	52	76	65	51	32	167	148	315	19
Electrophotography										
Canon CLC 800	60	74	88	74	74	63	222	211	433	11
Canon CLC 1000	53	64	84	69	63	49	201	181	382	20
Xerox DocuColor 40	62	73	91	86	72	43	226	201	427	25
Agfa Chromapress	59	64	87	75	65	41	210	181	391	29
Xeikon	58	71	87	81	66	47	216	194	410	22
Indigo coated paper	61	75	94	89	77	49	230	215	445	15
Indigo uncoated paper	55	67	79	74	63	40	201	177	378	24
Thermal transfer										
3M Rainbow	62	79	102	98	71	58	243	227	470	16
Océ 5241	60	72	94	88	78	43	226	209	435	17
Tektronix Phaser 440	52	67	76	75	59	38	195	172	367	23
Silver halide										
Ektacolor	56	72	85	69	54	58	213	181	394	32
AgfaColor	56	69	90	66	60	59	215	185	400	30
Offset on APCO wet-on-dry	58	74	102	92	77	54	234	223	457	11

Table 1 **CIELAB chroma values (D50/2°) for 30 process/paper combinations**

	C	M	Y	M+Y	C+Y	C+M
Offset ISO 12647-2						
Paper 1	233	355	94	35	155	297
Paper 2	236	358	93	34	157	299
Paper 3	229	358	94	35	155	296
Paper 4	239	358	93	23	156	293
Paper 5	234	1	92	27	156	297
Gravure ISO 12647-4						
Paper 1	241	9	91	39	159	299
Paper 2	242	3	91	38	157	298
Paper 3	243	3	89	38	154	298
Newspaper printing ISO 12647-3	230	0	95	31	152	288
Küppers 7-Colour Process	235	350	91	36	160	297
European offset ink standard CEI 30-89	236	0	93	34	163	296
Ink jet						
Tektronix Phaser 380	227	335	93	28	168	296
HP DesignJet (dye)	231	355	92	35	150	300
HP DesignJet (pigment)	240	352	96	31	163	293
Epson Stylus 5000	241	356	88	38	165	295
Encad NovaJet	235	353	90	36	151	300
Raster Graphics	227	354	96	30	156	277
Electrophotography						
Canon CLC 800	237	338	97	36	164	291
Canon CLC 1000	234	352	95	40	149	296
Xerox DocuColor 40	246	1	95	36	166	292
Agfa Chromapress	243	356	96	37	161	284
Xeikon	235	358	96	36	153	301
Indigo coated paper	232	3	94	36	158	299
Indigo uncoated paper	234	358	95	31	161	294
Thermal transfer						
3M Rainbow	253	6	95	42	165	304
Océ 5241	242	4	95	36	163	293
Tektronix Phaser 440	235	352	93	32	156	293
Silver halide						
Ektacolor	221	336	69	37	148	297
AgfaColor	219	338	81	36	146	298
Offset on APCO wet-on-dry	233	359	92	41	149	298

Table 2 **CIELAB hue angle values (D50/2°) for 30 process/paper combinations**

Although the colour gamut is primarily determined by the level of the chroma values, the hue angles belonging to the chroma values are necessary to visualise the gamut categories.
Looking at table 2, it can be seen, that the hue angle is variable in a range which is dependent on the particular primary or secondary colour. The smallest variation has Yellow with only 8° difference between the minimum and maximum values. The largest variation is found for Magenta which may be explained by the fact that both bluish and reddish Magentas are being used for process colour printing. Almost the same situation holds for Cyan where bluish and greenish shades are used (see table 3).

As the purpose of this paper is not to stipulate ideal hue angle values for the primary and secondary colours, the values chosen for illustrating the gamut categories solely claim to be typical. For that purpose, rounded average values from the statistics in table 3 have been chosen.

	CIELAB hue angle				
	Min.	**Max.**	**Range**	**Average**	**Rounded average**
M	335	9	34	357	355
M+Y	23	42	19	34	35
Y	89	97	8	93	95
C+Y	149	168	19	159	155
C	227	253	26	237	235
C+M	277	304	27	295	300

Table 3 **Statistics of the hue angle values of 28 process/paper combinations (listed in table 2)**

The hue values found for the silver halide process are not included in these statistics.

Proposal for colour gamut categories

As can be seen from table 1, the chroma sum of the primary and secondary colours varies between 525 (for the 7-colour printing process) and 252 (for newspaper printing). These values determine the range between a small and a very large colour gamut. As the maximum value of 525 was obtained with a process using more than three chromatic primaries, a sum exceeding 500 can be regarded more than very large and may be referred to as an extra-large gamut. At the other end, chroma sums below 250 may represent the category of very small gamuts. The question is now how many gamut categories should be defined between extra-large and very low. A logical classification results if the chroma sum is scaled in steps of 50 leading to the following categories:

Chroma sum	**Gamut category**	
above 500	A	extra-large
450 – 500	B	very large
400 – 450	C	large
350 – 400	D	enhanced
300 – 350	E	medium
250 – 300	F	small
below 250	G	very small

This scaling corresponds to an average chroma difference of about 8 units between the proposed categories.

To visualise these categories in a chroma/hue diagram, the chroma sums have to be broken down into individual chroma values for each primary and secondary colour. Moreover, hue values have to be attributed to each chroma value. A proposal for such a graphical representation of the 7 gamut categories is shown in figure 1. The corresponding chroma and hue values are listed in table 4. A closer look to table 4 shows that the chroma sum was chosen in such a way that the difference between the primary and the secondary colours increases when going to smaller gamuts. This is in line with the experimental observation that smaller gamuts are characterised by lower chroma values of the secondary colours.

				R	**G**	**B**	**Sum**			**Difference**
	C	**M**	**Y**	**M+Y**	**C+Y**	**C+M**	**CMY**	**RGB**	**Total**	**CMY/RGB**
Chroma values										
A Extra-large	65	80	110	90	80	75	255	245	500	10
B Very large	59	73	100	81	72	65	232	218	450	14
C Large	53	66	90	72	64	55	209	191	400	18
D Enhanced	47	59	80	63	56	45	186	164	350	22
E Medium	41	52	70	54	48	35	163	137	300	26
F Small	35	45	60	45	40	25	140	110	250	30
Hue angle values	235	355	95	35	155	300				

Table 4 **CIELAB chroma and hue angle values (D50/2°) for the proposed colour gamut categories**

How the process/substrate combinations listed in table 1 and 2 are distributed in the above defined gamut categories is shown in table 5.

Printing process	Gamut category						
	A	B	C	D	E	F	G
Offset printing ISO 12647-2			x			x	
Gravure printing ISO 12647-4		x	x	x			
Screen printing ISO 12647-5			x				
Newspaper printing ISO 12647-3						x	
Küppers 7-colour printing	x						
Electrophotography			x	x			
Ink jet printing		x	x	x	x		
Thermal transfer direct			x				
Dye sublimation printing		x		x			
Silver halide photography on paper			x	x			

Table 5 **Characterisation of 28 process/substrate combinations by gamut categories**

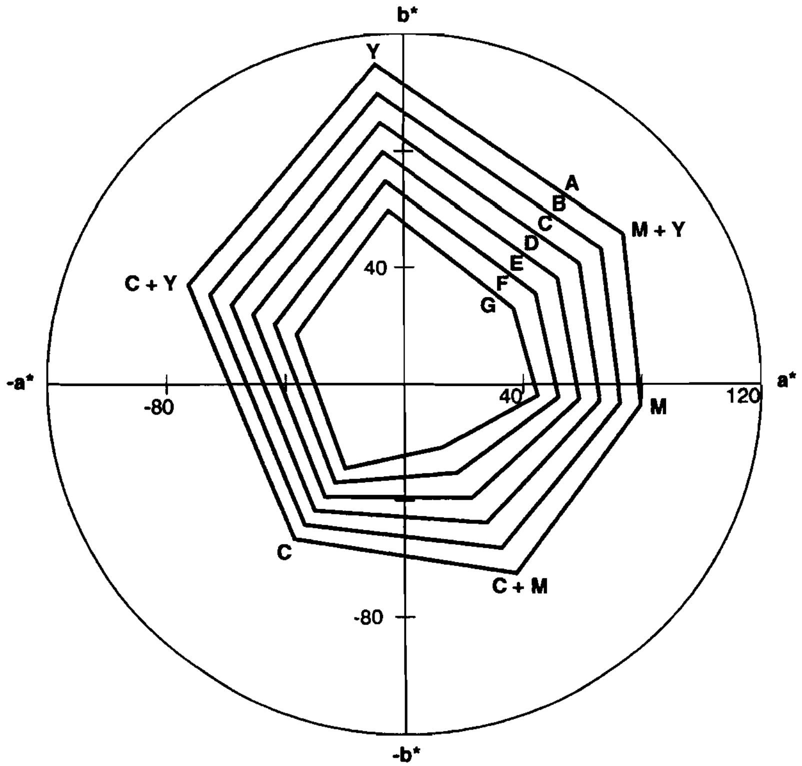


Figure 1 **Proposed gamut categories for printing processes plotted in an a*b* diagram (D50/2°)**

In the above proposed classification based on chroma values a definition of Black and the substrate white is not included. While both colours are necessary to describe the colour gamut in terms of a volume, the paper white has little to do with a gamut classification, because the chroma values of a certain category can be achieved on different substrate whites.
The only prominent exception where the paper white is linked with the colour gamut is newspaper printing. But the same colour gamut may also be obtained with offset printing on machine-finished stocks showing a much higher lightness.

This is shown in table 6 where the lightness values of 30 process/paper combinations are listed for the substrate white, Black and the chromatic inks. As can be seen, the lightness values of the substrate (except newsprint) vary between 87 and 97 and are almost independent of the colour gamut.

For Black, however, it is necessary to adjust the ink strength to those of the chromatic primaries. While the ink strength of the chromatic primaries is determined by the chroma value, the relevant value for Black is lightness.

To derive target values for the lightness of Black, the measured values of the 30 process/substrate combinations shown in table 6 may again serve as reference. The proposed values for Black are given in table 7. This table also presents lightness values for the Cyan, Magenta and Yellow and gives a specification of all CIELAB coordinates for the proposed gamut categories.

Gloss and its influence on colour gamut

As the colorimetric values used to classify colour gamuts refer to a measurement geometry of 45/0 (or 0/45), they are strongly dependent on the gloss of the measured ink film. This would not be the case, if the measurement were performed by an integrating sphere with inclusion of the specular component of the reflected light. Using the 45/0 geometry, glossy ink films have a higher measured chroma than matt ink films.
The contribution of gloss to the measured chroma depends on the hue and lightness of the measured sample. In a fundamental study published by Dalal and Natale-Hoffmann (1) it is shown that the gloss creates an additive component to the tristimulus values of a colour sample measured without gloss. As this component is equal, irrespective of the tristimulus values of the measured colour, colours having low XYZ values are more affected by gloss than colours with high XYZ values.
Based on a model derived by Dalal and Natale-Hoffmann, the influence of gloss has been calculated for the colour values of gamut E. As can be seen from figure 2, an increase from 0 % to 70 % gloss expands the colour gamut from category E to category C. In view of the substantial influence of gloss on chroma it should

	C	M	Y	M+Y	C+Y	C+M	K	Paper
Offset ISO 12647-2								
Paper 1	54	47	88	48	49	26	18	93
Paper 2	54	47	88	47	47	26	18	92
Paper 3	54	45	82	46	50	26	20	87
Paper 4	62	53	86	51	52	38	35	92
Paper 5	58	53	84	50	52	38	35	88
Gravure ISO 12647-4								
Paper 1	47	46	87	46	41	14	11	92
Paper 2	47	46	83	45	40	15	13	87
Paper 3	46	46	80	44	38	16	16	87
Newspaper printing ISO 12647-3	57	53	79	52	53	41	40	80
Küppers 7-Colour Process	49	53	91	55	66	25		
European offset ink standard CEI 30-89	52	50	91	49	47	18	18	95
Ink jet								
Tektronix Phaser 380	51	53	85	50	47	21	15	91
HP DesignJet (dye)	63	49	89	46	56	22	19	94
HP DesignJet (pigment)	54	51	90	50	48	29	20	93
Epson Stylus 5000	40	51	90	51	35	19	21	97
Encad NovaJet	54	45	88	41	43	14	10	93
Raster Graphics	62	58	89	57	60	43	26	92
Electrophotography								
Canon CLC 800	49	51	86	47	43	22	21	91
Canon CLC 1000	55	47	83	48	53	27	19	89
Xerox DocuColor 40	44	44	86	43	38	15	14	90
Agfa Chromapress	51	49	89	47	44	25	24	92
Xeikon	54	43	87	42	49	19	16	91
Indigo coated paper	54	48	89	47	49	17	15	93
Indigo uncoated paper	57	52	88	51	52	27	28	91
Thermal transfer								
3M Rainbow	43	45	90	44	37	10	4	94
Océ 5241	46	41	85	39	40	12	8	90
Tektronix Phaser 440	55	55	85	51	55	33	19	92
Silver halide								
Ektacolor	44	39	64	33	38	12	4	91
AgfaColor	45	37	74	34	39	12	5	90
Offset on APCO wet-on-dry	57	51	90	50	50	23		94

Table 6 **CIELAB lightness values (D50/2°) for 30 process/paper combinations**

Gamut	Colour	L*	C_{ab}	h_{ab}	a*	b*
A	C	50	65	235	-37.3	-53.2
A	M	45	80	355	79.7	-7.0
A	Y	90	110	95	-9.6	109.6
A	M+Y	50	90	35	73.7	51.6
A	C+Y	50	80	155	-72.5	33.8
A	C+M	20	75	300	37.5	-65.0
A	K	5			0.0	0.0
B	C	55	59	235	-33.8	-48.3
B	M	45	73	355	72.7	-6.4
B	Y	90	100	95	-8.7	99.6
B	M+Y	45	81	35	66.4	46.5
B	C+Y	45	72	155	-65.3	30.4
B	C+M	20	65	300	32.5	-56.3
B	K	10			0.0	0.0
C	C	55	53	235	-30.4	-43.4
C	M	45	66	355	65.7	-5.8
C	Y	85	90	95	-7.8	89.7
C	M+Y	45	72	35	59.0	41.3
C	C+Y	45	64	155	-58.0	27.0
C	C+M	25	55	300	27.5	-47.6
C	K	15			0.0	0.0
D	C	55	47	235	-27.0	-38.5
D	M	50	59	355	58.8	-5.1
D	Y	85	80	95	-7.0	79.7
D	M+Y	45	63	35	51.6	36.1
D	C+Y	45	56	155	-50.8	23.7
D	C+M	30	45	300	22.5	-39.0
D	K	20			0.0	0.0
E	C	60	41	235	-23.5	-33.6
E	M	55	52	355	51.8	-4.5
E	Y	85	70	95	-6.1	69.7
E	M+Y	50	54	35	44.2	31.0
E	C+Y	50	48	155	-43.5	20.3
E	C+M	40	35	300	17.5	-30.3
E	K	25			0.0	0.0
F	C	60	35	235	-20.1	-28.7
F	M	55	45	355	44.8	-3.9
F	Y	85	60	95	-5.2	59.8
F	M+Y	50	45	35	36.9	25.8
F	C+Y	50	40	155	-36.3	16.9
F	C+M	40	25	300	12.5	-21.7
F	K	35			0.0	0.0

Table 7 **CIELAB values (D50/2°) of the 6 proposed colour gamut categories**

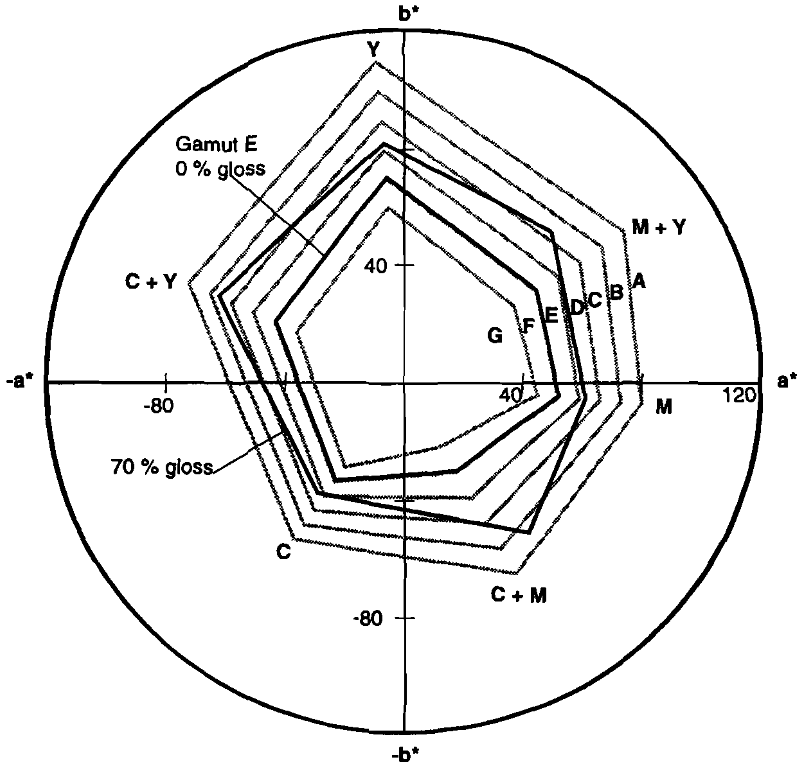


Figure 2 **Difference between 0 % and 70 % gloss calculated for colour gamut E**

be discussed whether colour gamuts should be defined for different gloss levels. The understanding of the present classification of colour gamuts is that gloss is one of many factors influencing the colour gamut, meaning that a set of process colours printed as glossy ink film may fall in a higher gamut category than the same set printed with a matt appearance.

Ink film thickness and its influence on colour gamut

It is a well known fact that the chroma value of a process ink increases with higher ink film thickness. However, it is important to know that the ink film thickness also affects the hue value. Figure 3 illustrates the curves resulting in an a*b* diagram, if the ink film thickness of a given set of process inks conforming to gamut C is varied. As can be seen, the hue dependence of the ink film thickness is different for the three primary colours and most distinct for Magenta. At low ink film thicknesses Magenta tends to be more bluish and turns to reddish the more the thickness is increased.

For the gamut classification concept proposed in this paper, the hue dependence of the ink film thickness means that different gamuts having the same hue values are not achievable with the same set of process inks. In other words: Each gamut category specified in figure 1 needs its own process ink formulation to make sure that both the chroma and the hue specification are met. However, if a hue angle tolerance of ±5 is admitted, a Yellow matching the specification for gamut C is also suitable for all other gamuts. If a Cyan matches gamut C, it may also be used for the gamuts E, D and B, but it does not qualify for A and F. For Magenta, the change of the hue angle from one gamut to the next is in most cases larger than $\Delta h_{ab} = 5$, thus not permitting the same formulation for more than one gamut.

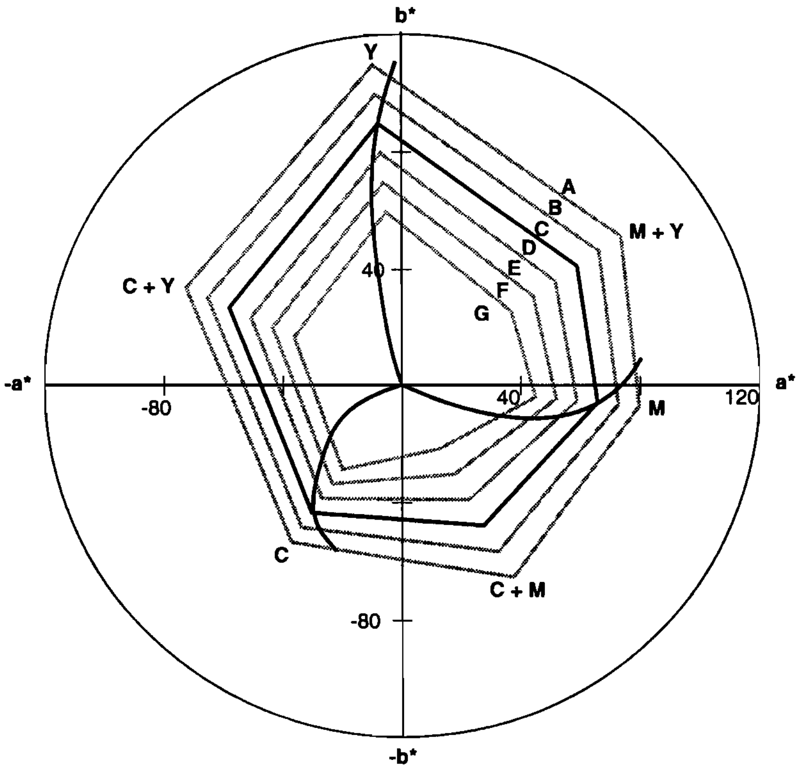


Figure 3 **Ink film thickness curves of process inks matching gamut C**

Possibilities to expand the colour gamut

There are basically four methods to expand the colour gamut of the conventional four-colour process.

- printing with a higher ink film thickness
- printing the CMY inks twice
- using high-chroma primaries
- adding extra primaries.

The chroma values of CMY as they are specified for standard offset and gravure printing on a premium gloss coated paper can be increased by applying higher ink film thicknesses. In gravure printing this is possible by increasing the cell volume. In offset printing the ink film thickness cannot be substantially increased, unless it is done by applying a second ink film in a subsequent print run.

The chroma increase resulting from printing the CMY inks twice is only significant in the primary colours, whereas the secondary colours become darker due to its 400 % dot area coverage. In the total chroma sum the increase is not sufficient to attain the extra-large gamut A. Using high-chroma inks means to replace the conventional primaries with inks consisting of other pigments. An example for this are the PANTONE inks. However, a higher chroma is not always possible for the hue angles which are typical for process inks. So, the process Cyan can hardly be replaced by a high-chroma pigment. But a certain chroma increase may be achieved in case of Yellow and Magenta.

Adding extra primaries means to use a Green, a Red and a Blue instead of generating these colours by overprints of Cyan, Magenta and Yellow. There are three practical approaches of this concept:

- the PANTONE Hexachrome process: This concept is based on 5 chromatic primaries, the extra primaries being a Green and an Orange. The Blue is conventionally printed using Cyan and Magenta. Figure 4 shows that the gamut increase is mainly obtained by generating additional overprints with the extra primaries. In this way the resulting colour gamut is a decagon rather than a hexagon.

- the Küppers seven-colour process (2): In this concept 6 chromatic primaries are used, meaning that all 3 secondary colours are replaced by extra primary colours. However, the Küppers process does not admit overprints between the primary colours. Therefore, the colour gamut is still determined by a hexagon, but using high-chroma inks for all primaries.

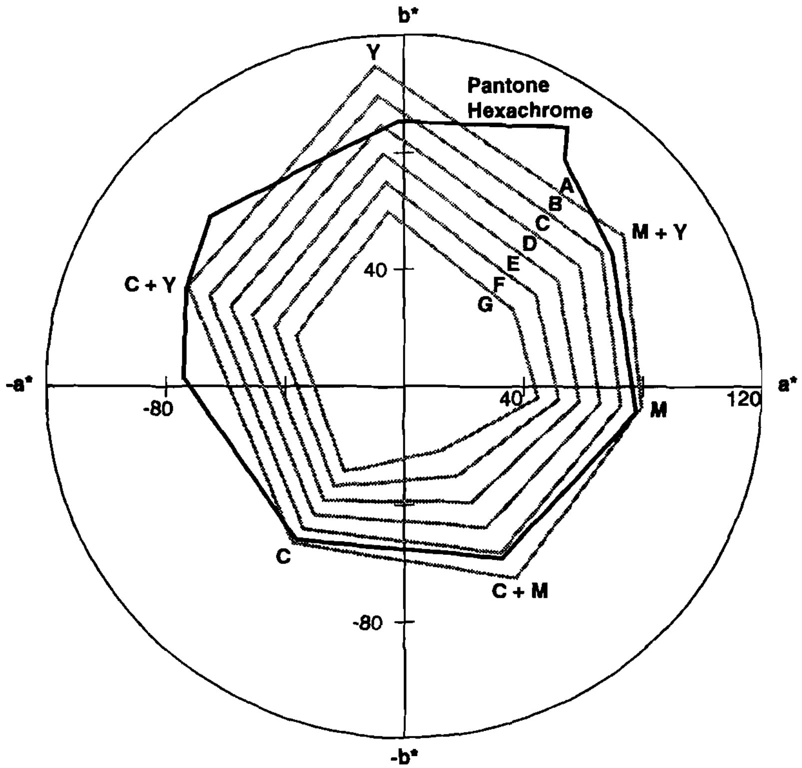
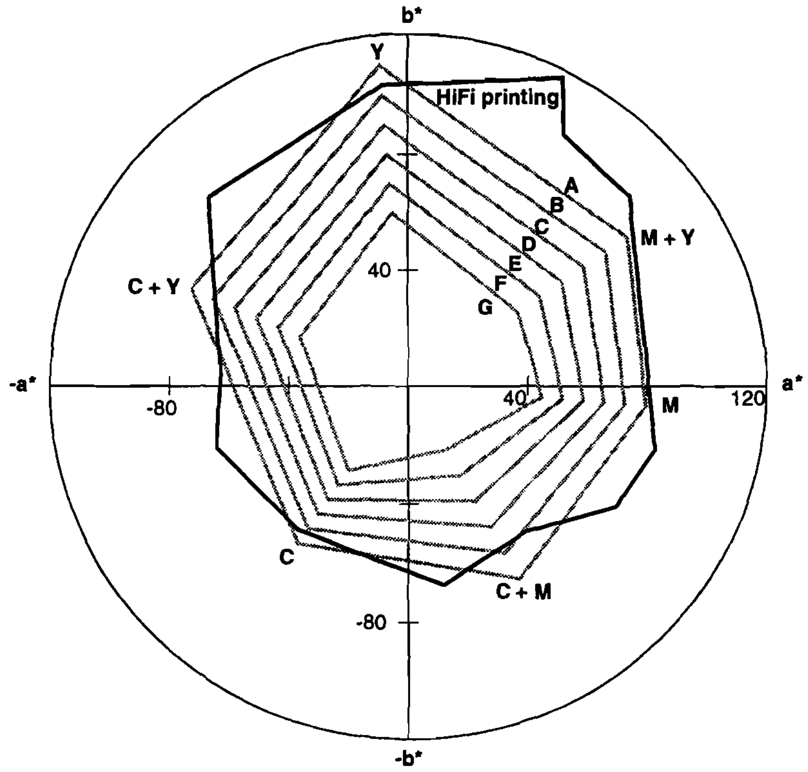


Figure 4 **The Pantone Hexachrome gamut based on 5 chromatic primaries (Yellow, Orange, Magenta, Cyan, Green)**

- the HiFi printing process (3): This concept is similar to the Küppers process concerning the number of primaries, but it allows overprints between all primaries. The resulting colour gamut is therefore characterised by a dodecagon (see figure 5).

The before mentioned processes contribute differently to a higher colour gamut. The Pantone Hexachrome process is not able to expand the colour gamut significantly. A chroma increase is only obtained from Orange and Green, while Blue and Yellow have a «normal» chroma. Nevertheless, the Hexachrome process attains a gamut area which is slightly larger than gamut A (extra-large).

In case of the Küppers 7-colour process a large gamut is achieved due to the use of high-chroma inks. The gain is especially noticeable for Blue which has a chroma value of 89 compared to a value of 51 which is achieved in offset printing on gloss coated paper.



Source (3): FOGRA Report No. 50.026, table 6 (D65/2° values converted to D50/2°)

Figure 5 **Gamut obtained with HiFi printing (6 chromatic primaries and 6 two-colour overlaps)**

The largest colour gamut is obtainable with a true HiFi printing process based on 6 chromatic primaries and 6 additional two-colour overprints. The gamut shown in figure 5 is an example described by Paul (3). The area of this dodecagon is 16% larger than the area of gamut A.

Benefits of gamut categories

One important feature of the concept of gamut categories is that a defined ratio between the colour strength of the primary colours is proposed. When measuring the chroma values of certain sets of process colours, the values of the primary colours are often found to be in a poor balance, i.e. that one primary has a chroma typical for a very large gamut, while the chroma of another primary only qualifies for a medium gamut. To avoid this, the present classification provides a numerical recommendation for the ratio of the chroma values of the primaries. This ratio is proposed to be C:M:Y = 1:1.25:1.7 (for illuminant D50).

In the same way, also the hue angles proposed in this concept define a certain balance between «warm» and «cold» ink shades. In earlier days it was an often discussed question as to whether the Magenta should be more bluish or reddish for an optimum colour gamut, and likewise whether Cyan should be greenish or bluish and Yellow greenish or reddish. The gamut categories described in this paper propose «neutral» hue angles which, for a given chroma level of the primaries, assure an optimum hue rendering over the entire colour space.

The here proposed gamut categories could play the role of reference values for almost all printing applications and processes. Table 8 shows a proposal how the gamut categories could be applied to define reference conditions for different printing processes.

The most obvious advantage of the present classification is that any parameter influencing the colour gamut can be judged in numerical terms. This may concern gloss, ink film thickness, pigment concentration or paper quality. In the same way, all concepts to expand the colour gamut, such as HiFi printing, may be assessed quantitatively.

	Gamut category					
	A	**B**	**C**	**D**	**E**	**F**
Offset/gravure printing						
HiFi x						
premium		x				
commercial			x	x	x	
publication			x			
newspaper						x
Screen printing			x			
Flexography			x	x		
Non-impact printing						
publication			x	x		
commercial			x	x	x	
large-format		x	x			
proofing		x	x	x	x	x

Table 8 **Colour gamut categories used as reference printing conditions for printing processes**

References

(1) Dalal E.N., Natale-Hoffman K.M.
1999 «The effect of gloss on color», Col. Res. Appl., Vol. 24 pp. 369–376

(2) K. Schläpfer
1997 «The colour gamut of the seven-colour printing process» J. Prepress Printing Tech., Volume 1, pp. 22–25

(3) A. Paul
1994 «Steigerung der Druckqualität durch Variation des Offsetfarbraums» FOGRA-Bericht Nr. 50.026, 42 pages

Appendix

Calculation of the area of the colour gamut hexagon

Gamut category	$\sum C^*_{ab}$	Calculated area Exact	Simplified*	Difference in %
A Extra-large	500	17 895	18 042	0.8
B Very large	450	14 299	14 614	2.2
C Large	400	11 306	11 547	2.1
D Enhanced	350	8659	8841	2.1
E Medium	300	6360	6495	2.1
F Small	250	4406	4511	2.4

* calculated from the sum of the chroma values according to the formula

$$A = \frac{(\sum C^*_{ab})^2 \sqrt{3}}{24}$$

where

A area of the hexagon

$\sum C^*_{ab}$ sum of the chroma values of C, M, Y, (C+M), (C+Y), (M+Y)