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The effects on hue resulting from black overprinting in halftone reproductions

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MASTER'S THESIS

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THE EFFECTS ON HUE RESULTING FROM BLACK OVERPRINTING IN HALFTONE REPRODUCTIONS

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing in the College of Graphic Arts and Photography of the Rochester Institute of Technology

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Date May 22, 1985

Brian Philippsen

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ABSTRACT

A type of black printer that only existed in theory is now being applied in the printing industry. The process which makes use of this black printer is known as gray-component replacement.

Developed from the extension of the undercolor removal process, the use of gray-component replacement in printing halftone reproductions is said to result in numerous technical and cost benefits. When used to the maximum, the process eliminates one of the three process color inks in a given unit area and prints black ink from highlight to shadow.

A problem can result from the use of this process as it applies a greater amount of an opaque black ink in combination with selectively transparent colored inks. Where this black ink overprints one or more of the three colored inks there will be an increase in unwanted absorption and a decrease in the wanted absorption. The result of such overprinting will be the alteration of the reflectance curve of the reproduction as compared to the original with the result being a shift in hue.

An experiment was performed to demonstrate the principles. Several tint patches were printed with the

only difference between each patch being the location of black ink overprinting within the tint.

It could be seen by visual analysis that a hue shift did occur. Sample tint patches were analyzed by means of a spectrophotometer to objectively describe the visual results.

CHAPTER ONE

INTRODUCTION

A theoretical concept of the black printer that was developed some time ago is now being put to use within the printing industry. Referred to by several names including Achromatics, Achromatic Color Reproduction, Polychromatic Color Removal and Gray Component Replacement, the process allows the use of a greater amount of black ink in lithographic reproductions.

The response from industry since the introduction of the process has shown that it may become a standard. It has been predicted that by 1987 80% of the printing industry will be using this process.[1]

The developing interest is due to the numerous technical and cost benefits that the process is said to provide. Some of the benefits cited are increased tolerance ranges for process ink balance and register, increased color reproduction stability in gray tones and colors with high neutral components.[2] Other benefits are said to be better detail, reduced ink consumption, improved drying and reduced use of spray powder.

Studies are being conducted to determine the degree to which these stated benefits are valid, however more investigation needs to take place to examine the real implications of putting this theoretical black printer into practice. In order to contribute to that knowledge, this research investigated the effects on hue resulting from the overprinting of one or more of the three subtractive inks with black ink in a halftone reproduction.

SIGNIFICANCE AND BACKGROUND

As the last addition to the three color process, the black printer was to serve four main functions:[3]

(1) To make the control of the other three colors less critical as to color balance.

(2) To produce denser blacks and better shadow detail than the three colors alone can produce.

(3) To substitute a relatively inexpensive black ink for a part of the more costly colored inks.

(4) In high-speed wet printing, to reduce the piling up of several inks which do not print satisfactorily on top of one another.

While the black printer was to assist in these manners its inclusion into the original three color process created two complicating factors. Initially the inclusion of the black printer created the situation where there was no single combination of the four inks that would produce a given color. When using only the three process inks there is only one combination that will yield the same color. With the addition of a fourth element all but the saturated colors can be reproduced with a minimum amount of the three colored inks and a maximum of black; vice versa, or by any combination between these two extremes.

Secondly, the methods of color separation were developed for the three color reproduction process, therefore the addition of a fourth color required a means of reducing the percent coverage of the three colored inks in order to accommodate the black. Failure to do so would result in the trend towards a dark reproduction with degraded colors as the use of black was increased.

During its development there were two concepts of the black printer and how they should be combined with the three colored inks.[4] The first type of black printer would carry the maximum amount of black ink and be combined with not more than two of the three subtractive colors in any one unit area. The second type of black printer would carry only enough black ink to increase the range of neutral grays. Of these two concepts it was the first type of black printer that was considered the "ideal".[5] This black printer would be a record of the "gray-component" of an original with gray-component being defined as the amount of the least predominate printing ink in a unit area of a color corrected, three color reproduction. It was this concept that provided the foundations for what was to develop into the process of gray-component replacement.

Complex filtration and masking procedures would be required to produce the first type of black printer. It was realized at the time that the only simple and effective method of producing the ideal black printer would be by electronic means, using a scanning machine.[6] For these reasons it was the second type of black printer which was developed for industry use. Referred to as a skeleton black printer its function was to supplement the three colored inks in order to cover ink imbalances and to provide the densities required in the darkest areas of the reproduction. This fixed condition on the black printer permitted the continued use of the three color separation method without any modification as to the determination of each separation. Figure 1 illustrates how the skeleton black printer only begins when the overprints of the three colored inks have reached their maximum density.

Nevertheless, interest in achieving the first type of black printer continued but some means had to be devised to handle the increased amount of black ink. Once the black printer became larger than a skeleton image it

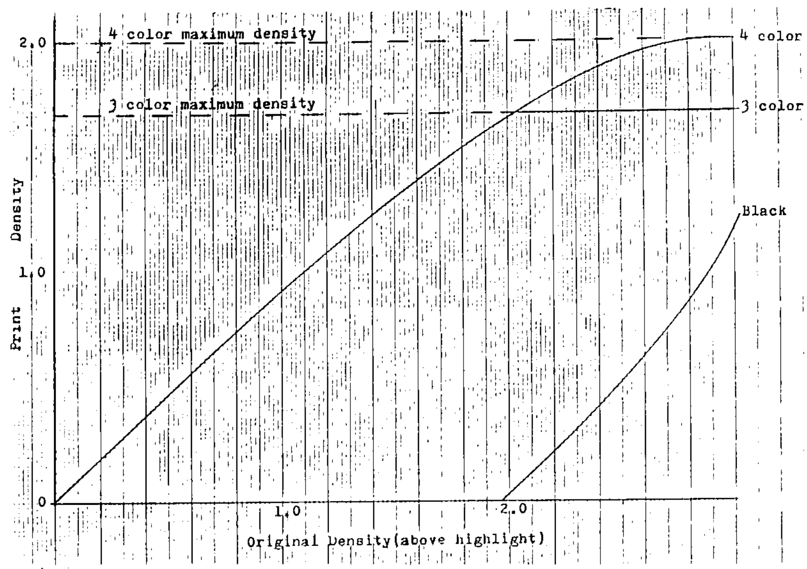


Figure 1

was necessary to decrease the color densities of the other colors where black was to be printed, otherwise the densities of the grays would be too high resulting in a dark reproduction.

Another factor that had to be considered was that in four color overprinting, paper, ink and press conditions will limit the total dot area that can be printed in any one unit area if proper trapping is to be achieved.[7] Therefore if the coverage of the black printer was to be extended a means of accommodating it had to be formulated. The process that accomplished this is known as undercolor removal (UCR).

UCR is the process of reducing by some degree the dot areas of the yellow, magenta, and cyan printing in the darker neutral areas and replacing them with the appropriate amount of black. This is possible as three color gray is reduced in proportional amounts, maintaining the gray balance but producing a lighter gray.[8] The black is increased in these areas to exactly compensate for the yellow, magenta, and cyan removed with the net effect being to extend the gray-component that already exists in a more efficient manner than three color gray.

Figure 2 illustrates the effects of UCR where black ink has begun to print at a lower density and the three color density has been reduced accordingly.

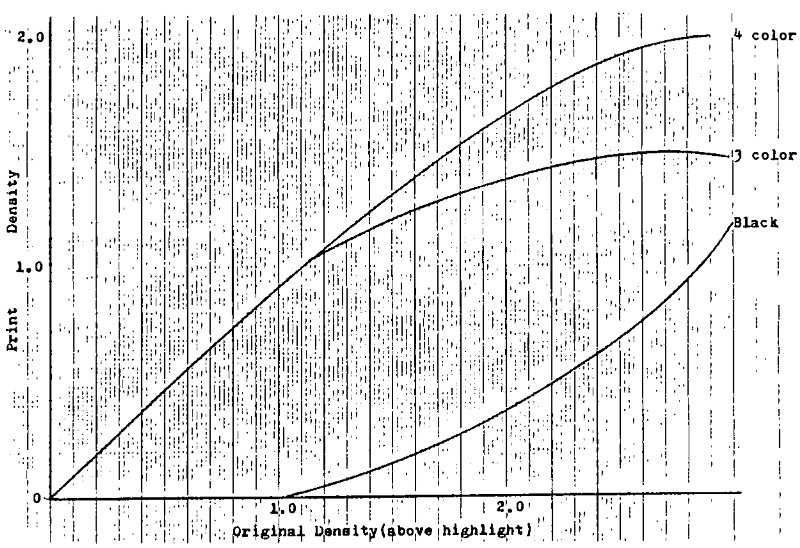


Figure 2

The idea of printing black and no more than two of the colored inks in a unit area as suggested by Yule[9] was further developed by Hardy and Wurzburg[10] and Tobias.[11] Tobias made reference to the fact that within a three printing ink system, such as yellow, magenta and cyan, one can define the entire chromaticity gamut of that system when the inks are taken two at a time, i.e., yellow and magenta, magenta and cyan, yellow and cyan. The addition of a third color to the combination does not alter the chromaticity gamut available from the binary mixture but rather alters the grayness of it.[12] In theory then, gray resulting from the common reflectances of the three colored inks could be entirely derived from the black ink.

Although the theory to make full use of the first type of black printer had developed, the means of implementing it was still under investigation. It was not until the recent developments in electronic scanning equipment that the means of generating the necessary separations was possible. The method that enabled this was an extension of the undercolor removal process. The limitation of UCR to the neutral areas alone was removed permitting undercolor removal to be performed throughout the entire tonal range.

When the process of undercolor removal was developing the defined term was not restricted to mean its application in the shadow areas only.[13] However, due to its limited use in these areas the understood definition also became limited. Thus it was necessary to select a new term for the process of extended undercolor removal. The term that will be used is gray-component replacement (GCR).[14]

Gray-component replacement, as the present state of the art, is the removal of the least predominate colored ink after color correction; the reduction in dot size of the two remaining colors in a proportion such that the hue is maintained; and the computation and addition of the amount of black necessary to provide the gray of the original hue. Figure 3 illustrates the GCR process whereby the maximum amount of black has been used. In this case three color gray has been reintroduced where black has reached its maximum density.

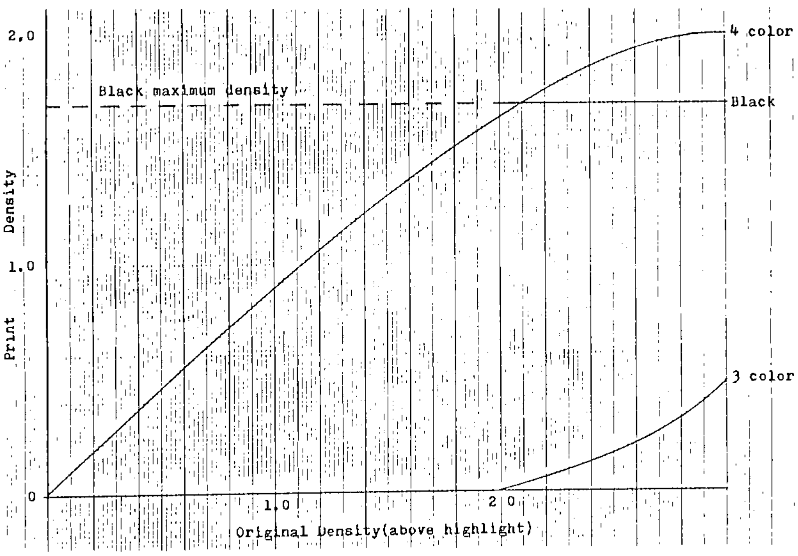


Figure 3

FOOTNOTES FOR CHAPTER ONE

[1]Dr. A. Ghany Saleh, "Investigation Into the Application of Achromatic Synthesis to the Printing Industry," TAGA Proceedings, 36 (1984), p. 151.

[2]Dr. E. Jung, "Programmed and Complementary Color Reduction," TAGA Proceedings, 36 (1984), p. 136.

[3]J.A.C. Yule, Principles of Color Reproduction (New York: John Wiley & Sons, 1967), p. 282.

[4]J.A.C. Yule, "Theory of Subtractive Color Photography: III. Four-Color Process and the Black Printer," Journal of the Optical Society of America, 30 (1940), p. 322.

[5]Ibid., p. 324.

[6]J.A.C. Yule, "Color Correction and the Black Printer," TAGA Proceedings, 1 (1949), n.p.

[7]M.F. Southworth, Color Separation Techniques, 2d ed. (Livonia, NY: Graphic Arts Publishing, 1979), p. 92.

[8]M.F. Southworth, "Undercolor Removal (UCR)," The Quality Control Scanner, 2(7), p. 3.

[9]J.A.C. Yule, "Theory of Subtractive Color Photography," p. 324.

[10]A.C. Hardy, and F.L. Wurzburg Jr., "Color Correction in Color Printing," Journal of the Optical Society of America, 38 (1948), pp. 300-307.

[11]P.E. Tobias, "A Color Correction Process," TAGA Proceedings, 6 (1954), pp. 85-90.

[12]Ibid., p. 86.

[13] A. Johnson, "Practical Implementation of Optimum Colour Reproduction," The Journal of Photographic Science 32 (1984), p. 147.

[14] F. Sigg, and P. Cost, "On Second Thought, Let's Call It 'Gray-Component Replacement'", T & E Center Newsletter, 12(4) (1984), p. 5.

CHAPTER TWO

BACKGROUND THEORY

The process of reproducing a color original by half-tone lithography rests upon the use of three selectively transparent inks, each of which absorbs one third of the visible spectrum and transmits the other two thirds of the visible spectrum. The visible spectrum is that portion of the electromagnetic spectrum extending from approximately 380 nanometers to 750 nanometers. For the sake of simplicity the visible spectrum has been divided into three equal bands: a blue band ranging from 400 to 500 nanometers; a green band ranging from 400 to 600 nonometers; and a red band ranging from 600 to 700 nanometers.

Due to the transparent qualities of the three inks two inks can be overprinted yet still permit the transmission of the one band that is not absorbed by either ink. Black ink, however, is opaque and functions to absorb all three bands. When black overprints any of the other three inks it will absorb the band or bands that would otherwise be transmitted and prevent the inks from absorbing their respective bands.

It is the presence of the three bands, in various proportions, that ultimately results in the sensation of color. Color has three qualities or attributes: hue, chroma and value. Hue is the quality that is under investigation.

Hue is a visual sensation according to which an area appears to be similar to one, or to proportions of two, of the perceived colors red, yellow, orange, green, blue and purple.[1] For the purposes of this study hue will be defined as the single or combined reflectances from one or more of the process inks and in excess of the common reflectances of all inks present in a given unit area. A unit area will be defined as a location in a halftone reproduction where there is a maximum of one dot present from each of the process inks used to reproduce that halftone. The size of any unit area is determined by the screen ruling of the halftone.

The three process color inks, yellow, magenta and cyan, are used to control the amount reflected by the blue, green and red bands respectively. Where a percentage of yellow ink has been printed the blue band will be absorbed by the same amount. Magenta absorbs the green band and in the same manner as cyan absorbs the red band. Where these inks are present in varying proportions, varying amounts of each band will be absorbed. The light which is not absorbed is relfected and a hue will be observable. Though these concepts are based on ideal inks the principles may still be applied to real inks.

The difference between real inks and ideal inks is that real inks have certain deficiencies. Real inks, unlike ideal inks, do not completely absorb the one band they were designed to nor do they transmit the remaining two bands equally. For example, a typical cyan ink transmits more of the blue band than it transmits the green band. Magenta ink is considered to be the most deficient as it transmits much more of the red band than it transmits of the blue band. Yellow ink, on the other hand, is considered to be the closest to an ideal ink, transmitting the green and red bands nearly equal.

The reflectance curves of a halftone reproduction will consist of three horizontal lines, one in each band of the visible spectrum. Due to the inability of the lithographic process to vary the ink film thickness of each printer across a unit area the reflectance curves of the reproduction is an average of those reflectance curves that would be present in the same unit area of the original (Figure 4). One can illustrate the effect on the reflectance curves of a unit area of a reproduction by the introduction of black ink. If one started with a 10% tint of yellow, magenta and cyan, printed beside one another,

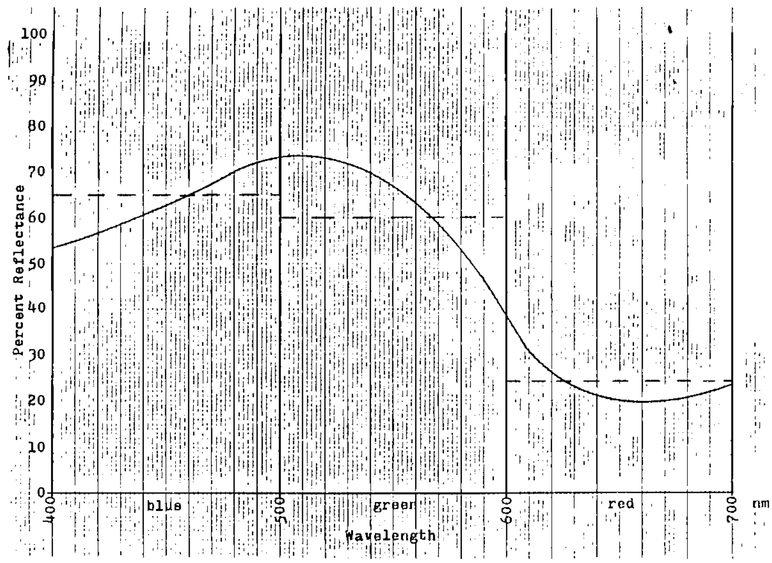


Figure 4

the reflectance curve of a unit area would be as illustrated in Figure 5.

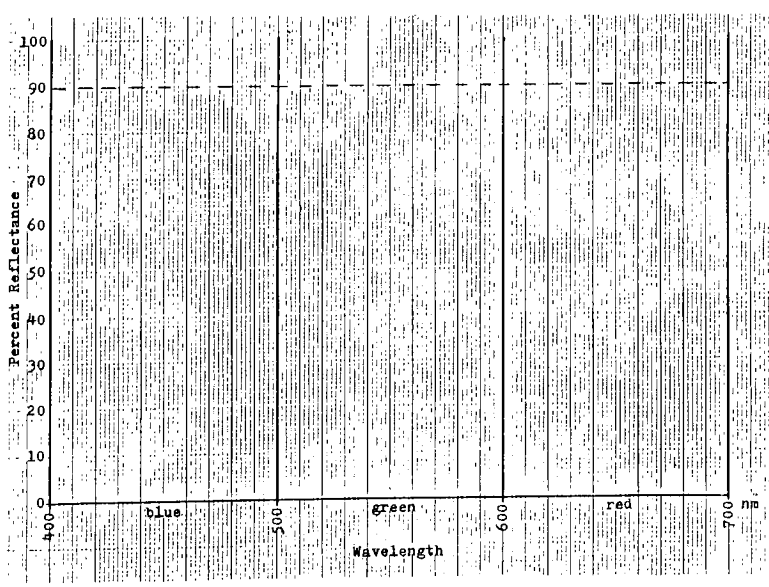


Figure 5

Each ink would absorb 10% of its respective band and transmit the remaining 90% with the visual result being a light gray. Once a 10% black tint is added to the three color tint, with no overprinting of any of the other inks, an additional 10% of each band will be absorbed with the result being close to a medium gray (Figure 6).

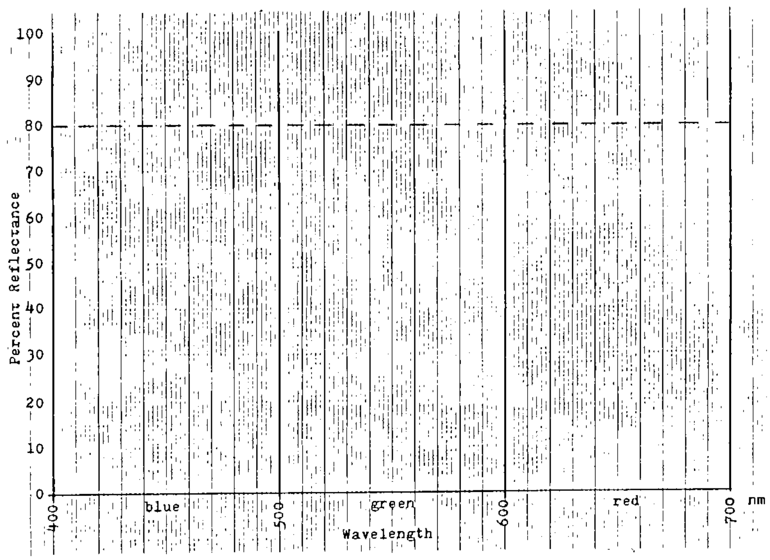


Figure 6

If this black is allowed to overprint the cyan dot by 50%, then the ability of cyan to absorb the red band has been reduced from 10% to 5%. Thus theoretically the hue of the unit area should shift slightly to the red band (Figure 7). If this procedure is repeated with the magenta dot there should be a shift to the green band and black overprinted the yellow dot should result in a shift to the blue band. Theoretically the greater the overprint, the greater the resulting shift in hue will be.

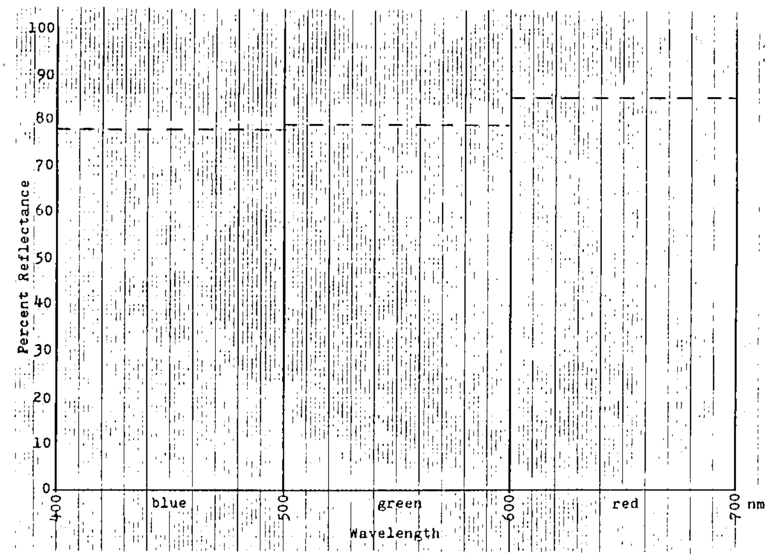


Figure 7

As the amount of black ink used in halftone reproductions increases, as in gray-component replacement, there is a greater possibility of unwanted overprinting of the three colored inks with black ink.

The result of such overprinting would be the absorption of a band or bands that would otherwise be reflected and a reduction in absorption of the bands that should be absorbed. In the highlight to middletone sections of a reproduction this condition would arise from misregister between the black printer and the other three colors. From the middletones to the shadows, however, this overprinting must take place.

FOOTNOTES FOR CHAPTER TWO

[1]F.W. Billmeyer Jr., and M. Saltzman, Principles of Color Technology, 2d ed (New York: John Wiley and Sons, 1981), p. 186.

CHAPTER THREE

HYPOTHESIS

The use of gray-component replacement or any degree of undercolor removal results in the use of black ink to print a halftone reproduction. It was the experimental objective of this study to demonstrate that the inclusion of an opaque black ink into a system of selectively transparent inks will result in a hue shift when this black ink is overprinted one or more of the transparent inks in a given unit area. The hue shift can be predicted by determining the color or colors of those inks which have been overprinted by the black ink.

CHAPTER FOUR

LITERATURE REVIEW

The literature dealing with the four color process of lithographic printing largely overlooks the black printer. Such literature emphasizes the theory of the three subtractive process inks and their application in practice. Those few sources that did address the black printer have formed the foundation upon which this research is based. The most significant of these is Yule[1,2,3] in which the development of the ideas of gray-component replacement can be traced.

In his chapter on moiré patterns and screen angles, Yule makes reference to the problems encountered when overprinting the other process colors with black:

> One interesting consequence of this is that printing a black halftone over a neutral three-color gray (composed of yellow, magenta and cyan) can make it slightly greenish or pinkish depending on the register of the dots.[4]

Yule made further reference to the black printer and the affects encountered with screen angles but he does not develop the reasons for the shifts in color.

FOOTNOTES FOR CHAPTER FOUR

[1]J.A.C. Yule, "Theory of Subtractive Color Photography: II. Four-Color Process and the Black Printer," Journal of the Optical Society of America, 30, 1940, pp. 322-331.

[2]J.A.C. Yule, "Color Correction and the Black Printer," TAGA Proceedings, 1, 1949, n.p.

[3]J.A.C. Yule, Principles of Color Reproduction (New York: John Wiley & Sons, 1967), pp. 282-304.

[4]Ibid., p. 342.

CHAPTER FIVE

METHODOLOGY

The following methodology was used to test the proposed hypothesis of this research project.

A layout was prepared for the imposition of twelve, one inch square tint patches. These were positioned equal distance from each other towards the center of the sheet and close to the lead edge of the paper. This was done to minimize the number of inking keys that would have to be set across the image area and to ensure the best possible register.

A 10% 50-line positive tint was generated on a scanner. The dot configuration was square and angled at 45 degrees. This positive tint film was then contacted to produce a negative tint. The positive tint film was used for positioning purposes while the negative tint film was used to expose the printing plates.

Using the positive tint film as a key the position of each color within each tint was determined. The negative tint film was then positioned using these keys.

The variation in the location of the black printer was achieved by varying the location of the black negative tint relative to the three color positive tint key. The overprint was adjusted visually so as to achieve approximately 50% overprint in one series of tint patches and approximately 75% in a second series of tint patches.

The tint patches can be identified as follows:

A: Four colors, yellow, magenta, cyan and black, printed with no color overprinted with black.

B: Four colors printed with black overprinted cyan approximately 50%.

C: Four colors printed with black overprinted yellow approximately 75%.

D: Four colors printed with black overprinted magenta approximately 50%.

E: Four colors printed with black to have overprinted cyan approximately 75%, however this tint did not produce the desired results on press and therefore was not considered in the analysis.

F: Four colors printed with black overprinted yellow approximately 50%.

G: Four colors printed with black overprinted magenta approximately 75%.

H: Three colors, yellow, magenta and black, printed with no color overprinted with black.

I: Three colors printed with black overprinted magenta approximately 75%.

J: Three colors printed with black overprinted yellow approximately 75%.

K: Three colors printed with black overprinted magenta approximately 50%.

L. Three colors printed with black overprinted yellow approximately 50%.

The tints patches A to G were printed by the four color process with A, as a neutral gray, representing the standard by which the tint patches B to G were compared. The tint patches H to L are to simulate the GCR process with only two process colors and black being present. Tint patch H, as an orangish-red, represents the standard by which the tint patches I to L were compared.

Included with the tint patches were color bars to monitor reflection densities and the trap achieved by the black ink. A color bar was run at the trail edge of the image for the purposes of the pressman.

The negative flats were then used to make final film positives which in turn were used to produce a positive Chromalin proof. The Cromalin proof was used to ensure the desired overprint results were being obtained. Negative working plates were made from the original negative flats.

The images were printed during three consecutive press runs. Yellow and cyan were printed during the first run. During the second run the magenta was printed.

After an hour and a half the black was printed during the third run.

From the press run samples were selected and analyzed. A sample from that press run is included in Appendix B. This, however, is not the sample used to generate the data for this research project.

CHAPTER SIX

DATA ANALYSIS

The analysis used in this experiment was designed to illustrate the effect on the average reflectance curves of a unit area in a halftone reproduction resulting from overprinting with black ink.

The samples selected from the press run were analyzed by a spectrophotometer which generated the full reflectance curve of the sample analyzed. The samples not only included the tint patches but also solid ink patches and the paper upon which the tint patches were printed. From the full reflectance curves the average reflectance curve for each band was constructed by determining the value of each fifth wavelength and dividing the sum of these by 20. The resultant was the average percent reflectance of each band.

The numerical data is presented in Tables 1 to 14. The average reflectance curves are presented as Figures 8 to 24. The full reflectance curves, from which the averages were derived, are presented as Figures 25-41 in Appendix A.

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND

SAMPLES: PAPER WITH MAGNESIUM OXIDE AS THE REFERENCE MATERIAL (P_1) AND PAPER WITH THE PAPER AS THE REFERENCE MATERIAL

BLUE BAND			GREEN BAND			RED BAND		
Samples:	P_1	P_2	Samples:	P_1	P_2	Samples:	P_1	P_2
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	91	91	500	89	90	600	88	91
405	90	91	505	89	90	605	88	91
410	90	91	510	90	90	610	88	91
415	90	91	515	90	91	615	88	91
420	90	91	520	90	91	620	88	91
425	90	91	525	90	91	625	88	91
430	90	91	530	90	91	630	88	90
435	90	91	535	90	91	635	88	90
440	90	91	540	90	91	640	87	90
445	90	91	545	89	91	645	87	90
450	90	91	550	89	91	650	88	90
455	90	91	555	89	91	655	88	90
460	90	91	560	89	91	660	88	91
465	90	91	565	89	91	665	88	91
470	90	90	570	88	91	670	88	91
475	90	90	575	88	91	675	88	91
480	90	90	580	88	91	680	88	91
485	90	90	585	88	91	685	88	92
490	89	90	590	88	91	690	88	92
495	89	90	595	88	91	695	88	92
Total:	1809	1814	Total:	1781	1817	Total:	1758	1817
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	91%	91%	Average:	89%	91%	Average:	88%	91%

TABLE 1

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
SAMPLES: SOLID YELLOW (Y) AND SOLID BLACK (BK)

BLUE BAND			GREEN BAND			RED BAND		
Samples:	Y	BK	Samples:	Y	BK	Samples:	Y	BK
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	10	9	500	12	6	600	30	6
405	9	9	505	16	6	605	30	6
410	9	8	510	19	6	610	30	6
415	8	8	515	23	6	615	30	6
420	8	7	520	26	6	620	30	6
425	7	7	525	28	6	625	30	6
430	7	7	530	29	6	630	30	6
435	7	7	535	30	6	635	30	6
440	7	7	540	30	6	640	30	7
445	7	7	545	30	6	645	30	7
450	7	7	550	30	6	650	31	7
455	7	7	555	30	6	655	31	7
460	7	7	560	30	6	660	30	8
465	7	7	565	30	6	665	30	8
470	7	7	570	30	6	670	31	8
475	7	7	575	30	6	675	31	8
480	8	6	580	30	6	680	32	8
485	9	6	585	30	6	685	32	9
490	9	6	590	30	6	690	33	9
495	10	6	595	30	6	695	34	9
Total:	157	141	Total:	543	120	Total:	615	143
	÷ 20	÷ 20		÷ 20	÷ 20		÷ 20	÷ 20
Average:	8%	7%	Average:	27%	6%	Average:	31%	7%

TABLE 2

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
SAMPLES: SOLID CYAN (PB) AND SOLID MAGENTA (PR)

BLUE BAND

Samples:	PB	PR
nm	%R	%R
400	20	15
405	20	14
410	21	14
415	21	13
420	21	13
425	22	13
430	22	13
435	23	13
440	24	13
445	25	13
450	25	12
455	25	12
460	25	12
465	25	11
470	25	10
475	25	10
480	25	9
485	24	9
490	24	8
495	24	8
Total:	466	235
	÷20	÷20
Average:	23%	12%

GREEN BAND

Samples:	PB	PR
nm	%R	%R
500	23	8
505	22	7
510	22	7
515	21	7
520	20	7
525	19	7
530	18	6
535	17	6
540	15	6
545	14	6
550	13	6
555	11	6
560	10	6
565	9	6
570	8	6
575	8	6
580	7	6
585	7	7
590	7	10
595	7	14
Total:	278	141
	÷ 20	÷ 20
Average:	14%	7%

RED BAND

Samples:	PB	PR
nm	%R	%R
600	6	17
605	6	20
610	6	22
615	6	24
620	6	25
625	6	26
630	7	26
635	7	27
640	7	27
645	7	27
650	8	28
655	8	28
660	9	28
665	9	28
670	9	28
675	9	28
680	9	29
685	9	29
690	10	30
695	10	30
Total:	153	527
	÷ 20	÷ 20
Average:	8%	26%

TABLE 3

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND TINT PATCHES: "A" YELLOW (A_y) AND "A" YELLOW PLUS BLACK (A_{yb})

BLUE BAND			GREEN BAND			RED BAND		
Tint:	A_y	A_{yb}	Tint:	A_y	A_{yb}	Tint:	A_y	A_{yb}
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	82	71	500	84	71	600	91	78
405	82	70	505	85	72	605	91	78
410	82	70	510	87	74	610	92	78
415	82	70	515	89	76	615	92	79
420	81	70	520	90	77	620	92	79
425	81	69	525	91	78	625	91	79
430	81	69	530	91	78	630	91	78
435	81	69	535	91	78	635	91	78
440	81	69	540	92	79	640	91	78
445	81	69	545	92	79	645	91	78
450	81	69	550	91	78	650	91	78
455	81	69	555	91	78	655	91	79
460	81	69	560	91	78	660	92	79
465	81	69	565	91	78	665	92	79
470	81	69	570	91	78	670	92	79
475	81	69	575	91	78	675	92	79
480	81	69	580	91	78	680	92	79
485	81	69	585	91	78	685	93	80
490	81	69	590	91	78	690	93	80
495	82	70	595	91	78	695	92	80
Total:	1625	1385	Total:	1802	1542		1833	1575
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	81%	69%		90%	77%		92%	79%

TABLE 4

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "A" THREE COLOR (A_3) AND "A" FOUR COLOR (A_4)

BLUE BAND			GREEN BAND			RED BAND		
Tint:	A_3	A_4	Tint:	A_3	A_4	Tint:	A_3	A_4
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	70	60	500	71	60	600	76	64
405	69	59	505	73	62	605	77	66
410	70	59	510	74	63	610	78	67
415	70	59	515	75	64	615	79	67
420	70	59	520	76	64	620	79	68
425	70	59	525	76	64	625	80	68
430	70	59	530	75	64	630	80	68
435	70	59	535	75	63	635	80	68
440	71	60	540	74	63	640	80	68
445	71	60	545	74	62	645	80	68
450	71	60	550	73	61	650	80	68
455	71	61	555	72	60	655	80	69
460	71	60	560	72	59	660	81	69
465	71	60	565	70	59	665	81	69
470	71	60	570	70	58	670	81	69
475	70	59	575	70	58	675	81	69
480	70	59	580	70	58	680	82	70
485	70	59	585	71	50	685	82	70
490	70	59	590	72	61	690	82	70
495	71	60	595	74	63	695	82	70
Total:	1407	1190	Total:	1456	1225	Total:	1601	1365
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	70%	60%	Average:	73%	61%	Average:	80%	68%

TABLE 5

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "A" FOUR COLOR AND "B" FOUR COLOR WITH BLACK OVERPRINTED CYAN APPROX. 50%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	A	B	Tint:	A	B	Tint:	A	B
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	58	57	500	59	56	600	63	64
405	58	57	505	60	58	605	64	65
410	58	57	510	61	59	610	65	67
415	58	57	515	62	60	615	66	67
420	58	56	520	63	61	620	66	68
425	58	56	525	63	61	625	66	68
430	58	56	530	63	61	630	66	68
435	58	56	535	62	61	635	66	68
440	59	56	540	61	61	640	66	68
445	59	57	545	61	61	645	67	68
450	59	57	550	60	60	650	67	69
455	59	57	555	59	60	655	67	69
460	59	57	560	58	59	660	68	69
465	59	56	565	58	59	665	68	69
470	59	56	570	57	59	670	68	69
475	58	56	575	57	58	675	68	69
480	58	55	580	57	59	680	68	70
485	58	55	585	58	59	685	68	70
490	58	55	590	59	61	690	68	70
495	58	55	595	60	62	695	68	70
Total:	1167	1124	Total:	1198	1195	Total:	1333	1365
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	58%	56%	Average:	60%	60%	Average:	67%	68%

TABLE 6

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "A" FOUR COLOR AND "C" FOUR COLOR WITH BLACK OVERPRINTED YELLOW APPROX. 75%

BLUE BAND

Tint:	A	C
nm	%R	%R
400	58	63
405	58	63
410	58	63
415	58	63
420	58	63
425	58	63
430	58	63
435	58	63
440	59	64
445	59	64
450	59	64
455	59	64
460	59	64
465	59	64
470	59	64
475	58	63
480	58	63
485	58	63
490	58	62
495	58	62
Total:	1167	1265
	÷20	÷20
Average:	58%	63%

GREEN BAND

Tint:	A	C
nm	%R	%R
500	59	63
505	60	63
510	61	63
515	62	63
520	63	63
525	63	63
530	63	63
535	62	62
540	61	61
545	61	61
550	60	60
555	59	59
560	58	58
565	58	57
570	47	57
575	47	57
580	47	57
585	48	59
590	49	59
595	60	61
Total:	1198	1208
	÷20	÷20
Average:	60%	60%

RED BAND

Tint:	A	C
nm	%R	%R
600	63	62
605	64	63
610	65	65
615	66	65
620	66	66
625	66	66
630	66	66
635	66	66
640	66	66
645	67	67
650	67	67
655	67	67
660	68	67
665	68	68
670	68	68
675	68	68
680	68	68
685	68	68
690	68	68
695	68	68
Total:	1333	1439
	÷20	÷20
Average:	67%	66%

TABLE 7

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "A" FOUR COLOR AND "D" FOUR COLOR WITH BLACK OVERPRINTED MAGENTA APPROX. 50%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	A	D	Tint:	A	D	Tint:	A	D
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	58	62	500	59	64	600	63	65
405	58	62	505	60	46	605	64	65
410	58	62	510	61	67	610	65	66
415	58	62	515	62	68	615	66	66
420	58	62	520	63	69	620	66	66
425	58	62	525	63	69	625	66	66
430	58	62	530	63	69	630	66	66
435	58	62	535	62	68	635	66	66
440	59	63	540	61	67	640	66	66
445	59	63	545	61	67	645	67	66
450	59	63	550	60	66	650	67	67
455	59	64	555	59	65	655	67	67
460	59	64	560	58	64	660	68	68
465	59	64	565	58	64	665	68	68
470	59	63	570	57	63	670	68	68
475	58	63	575	57	63	675	68	68
480	58	63	580	57	63	680	68	68
485	58	63	585	58	63	685	68	68
490	58	63	590	59	64	690	68	68
495	58	63	595	60	64	695	68	68
Total:	1167	1255	Total:	1198	1313	Total:	1333	1336
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	58%	63%	Average:	60%	66%	Average:	67%	67%

TABLE 8

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "A" FOUR COLOR AND "G" FOUR COLOR WITH BLACK OVERPRINTED MAGENTA APPROX. 75%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	A	G	Tint:	A	G	Tint:	A	G
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	58	60	500	59	63	600	63	63
405	58	60	505	60	64	605	64	63
410	58	60	510	61	65	610	65	63
415	58	60	515	62	66	615	66	63
420	58	60	520	63	67	620	66	63
425	58	60	525	63	67	625	66	64
430	58	60	530	63	67	630	66	64
435	58	60	535	62	67	635	66	64
440	59	61	540	61	65	640	66	64
445	59	61	545	61	66	645	67	64
450	59	61	550	60	65	650	67	64
455	59	61	555	59	64	655	67	64
460	59	62	560	58	64	660	68	64
465	59	62	565	58	63	665	68	65
470	59	61	570	57	62	670	68	65
475	58	61	575	57	61	675	68	65
480	58	61	580	57	61	680	68	65
485	58	61	585	58	61	685	68	65
490	58	61	590	59	62	690	68	65
495	58	62	595	60	62	695	68	65
Total:	1167	1215	Total:	1198	1277	Total:	1333	1282
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	58%	61%	Average:	60%	64%	Average:	67%	64%

TABLE 9

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "A" FOUR COLOR AND "F" FOUR COLOR WITH BLACK OVERPRINTED YELLOW APPROX. 50%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	A	F	Tint:	A	F	Tint:	A	F
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	58	64	500	59	64	600	63	64
405	58	64	505	60	64	605	64	65
410	58	64	510	62	65	610	65	66
415	58	64	515	62	65	615	66	67
420	58	64	520	63	65	620	66	67
425	58	64	525	63	64	625	66	68
430	58	64	530	63	64	630	66	68
435	58	64	535	62	64	635	66	68
440	59	65	540	61	63	640	66	68
445	59	65	545	61	62	645	67	68
450	59	65	550	60	61	650	67	68
455	59	65	555	59	59	655	67	69
460	59	65	560	58	58	660	68	69
465	59	65	565	58	58	665	68	69
470	59	65	570	57	57	670	68	69
475	58	64	575	57	57	675	68	69
480	58	64	580	57	57	680	68	69
485	58	64	585	58	58	685	68	70
490	58	64	590	59	59	690	68	70
495	58	64	595	60	60	695	68	70
Total:	1167	1287	Total:	1198	1235	Total:	1333	1361
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	58%	64%	Average:	60%	62%	Average:	67%	68%

TABLE 10

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "H" THREE COLOR AND "I" THREE COLOR WITH BLACK OVERPRINTED MAGENTA APPROX. 75%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	H	I	Tint:	H	I	Tint:	H	I
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	65	65	500	63	64	600	75	72
405	64	63	505	64	65	605	76	73
410	64	63	510	66	66	610	77	73
415	63	63	515	67	68	615	78	73
420	63	63	520	68	69	620	78	74
425	63	63	525	69	69	625	78	74
430	63	63	530	69	69	630	78	74
435	63	63	535	69	69	635	78	74
440	63	62	540	69	70	640	78	74
445	63	62	545	69	70	645	79	74
450	62	62	550	69	69	650	79	74
455	62	62	555	69	69	655	79	74
460	62	62	560	69	69	660	79	74
465	62	62	565	68	69	665	79	74
470	62	62	570	68	69	670	79	74
475	61	62	575	68	69	675	80	75
480	61	62	580	69	69	680	80	75
485	61	62	585	70	70	685	80	75
490	61	62	590	71	70	690	80	75
495	62	63	595	73	70	695	80	75
Total:	1251	1251	Total:	1367	1372	Total:	1570	1480
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	63%	63%	Average:	68%	69%	Average:	79%	74%

TABLE 11

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "H" THREE COLOR AND "J" THREE COLOR BLACK OVERPRINTED YELLOW APPROX. 75%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	H	J	Tint:	H	J	Tint:	H	J
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	63	66	500	62	64	600	74	71
405	63	66	505	63	64	605	75	73
410	62	66	510	65	65	610	76	74
415	62	66	515	66	65	615	77	75
420	62	66	520	67	66	620	77	75
425	62	66	525	68	66	625	77	75
430	62	66	530	68	66	630	77	75
435	62	66	535	68	66	635	77	76
440	61	66	540	68	66	640	77	76
445	61	66	545	68	66	645	77	76
450	61	66	550	68	66	650	77	76
455	61	65	555	68	66	655	77	76
460	61	65	560	68	65	660	77	76
465	61	65	565	67	65	665	77	76
470	61	65	570	67	65	670	78	77
475	60	64	575	67	65	675	79	77
480	60	64	580	68	66	680	79	77
485	60	64	585	69	66	685	79	77
490	60	64	590	70	68	690	79	77
495	61	64	595	72	70	695	79	77
Total:	1226	1306	Total:	1347	1316	Total:	1549	1512
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	61%	65%	Average:	67%	66%	Average:	77%	76%

TABLE 12

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "H" THREE COLOR AND "K" THREE COLOR WITH BLACK OVERPRINTED MAGENTA APPROX. 50%

BLUE BAND		
Tint:	H	K
nm	%R	%R
400	63	64
405	63	64
410	63	63
415	63	63
420	62	63
425	62	62
430	62	62
435	62	62
440	62	62
445	62	62
450	62	62
455	62	62
460	61	62
465	61	62
470	6k	62
475	6k	61
480	60	61
485	6o	61
490	6o	62
495	61	62
Total:	1233	1230
	÷20	÷20
Average:	62%	62%

GREEN BAND		
Tint:	H	K
nm	%R	%R
500	62	63
505	64	65
510	65	66
515	66	67
520	67	68
525	67	69
530	68	69
535	68	69
540	68	70
545	68	70
550	68	69
555	68	69
560	68	69
565	68	69
570	67	69
575	68	69
580	68	69
585	69	70
590	71	71
595	72	71
Total:	1350	1371
	÷20	÷20
Average:	68%	69%

RED BAND		
Tint:	H	K
nm	%R	%R
600	74	72
605	74	73
610	76	73
615	77	74
620	77	74
625	78	74
630	78	74
635	78	74
640	78	74
645	78	74
650	78	74
655	78	74
660	78	74
665	78	75
670	79	75
675	79	75
680	79	75
685	79	75
690	79	75
695	79	75
Total:	1550	1484
	÷20	÷20
Average:	78%	74%

TABLE 13

REFLECTANCE VALUES FOR EVERY FIFTH WAVELENGTH AND OVERALL AVERAGES FOR EACH BAND
TINT PATCHES: "H" THREE COLOR AND "L" THREE COLOR WITH BLACK OVERPRINTED YELLOW APPROX. 50%

BLUE BAND			GREEN BAND			RED BAND		
Tint:	H	L	Tint:	H	L	Tint:	H	L
nm	%R	%R	nm	%R	%R	nm	%R	%R
400	63	66	500	62	64	600	74	73
405	63	66	505	63	65	605	75	74
410	62	66	510	65	66	610	76	75
415	62	66	515	66	66	615	77	76
420	62	65	520	67	67	620	77	76
425	62	65	525	68	67	625	77	76
430	62	65	530	68	67	630	77	77
435	62	65	535	68	67	635	77	77
440	61	65	540	68	67	640	77	77
445	61	65	545	68	67	645	77	77
450	61	65	550	68	67	650	77	77
455	61	65	555	68	67	655	77	77
460	61	65	560	68	67	660	77	77
465	61	65	565	67	67	665	77	77
470	61	64	570	67	67	670	78	78
475	60	64	575	67	67	675	79	78
480	60	64	580	68	67	680	79	78
485	60	63	585	69	68	685	79	78
490	60	63	590	70	69	690	79	78
495	61	63	595	72	71	695	79	78
Total:	1226	1293	Total:	1347	1340	Total:	1549	1545
	÷20	÷20		÷20	÷20		÷20	÷20
Average:	61%	65%	Average:	67%	67%	Average:	77%	77%

TABLE 14

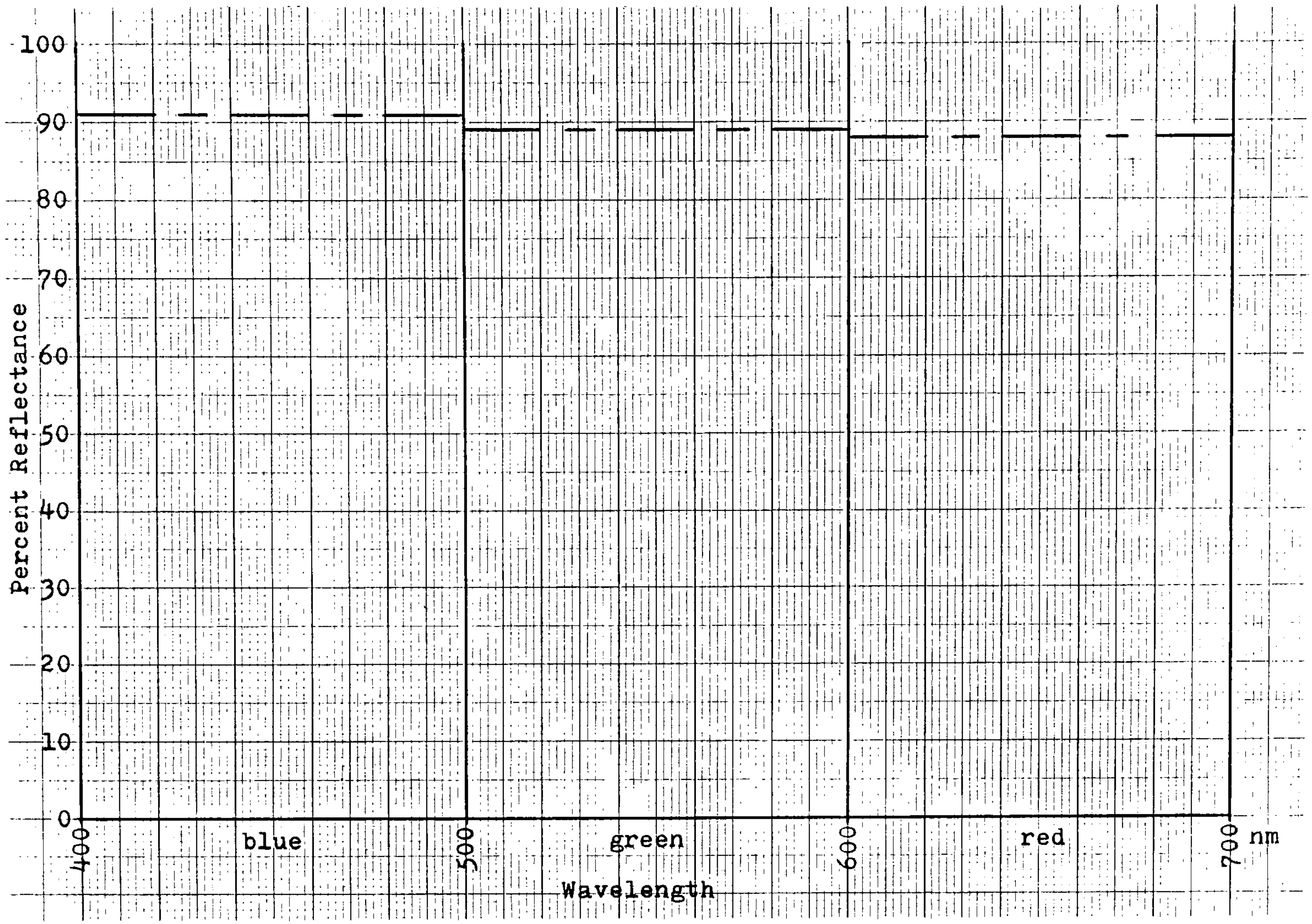


Figure 8. Average reflectance curve of the paper with Magnesium Oxide as the reference material.

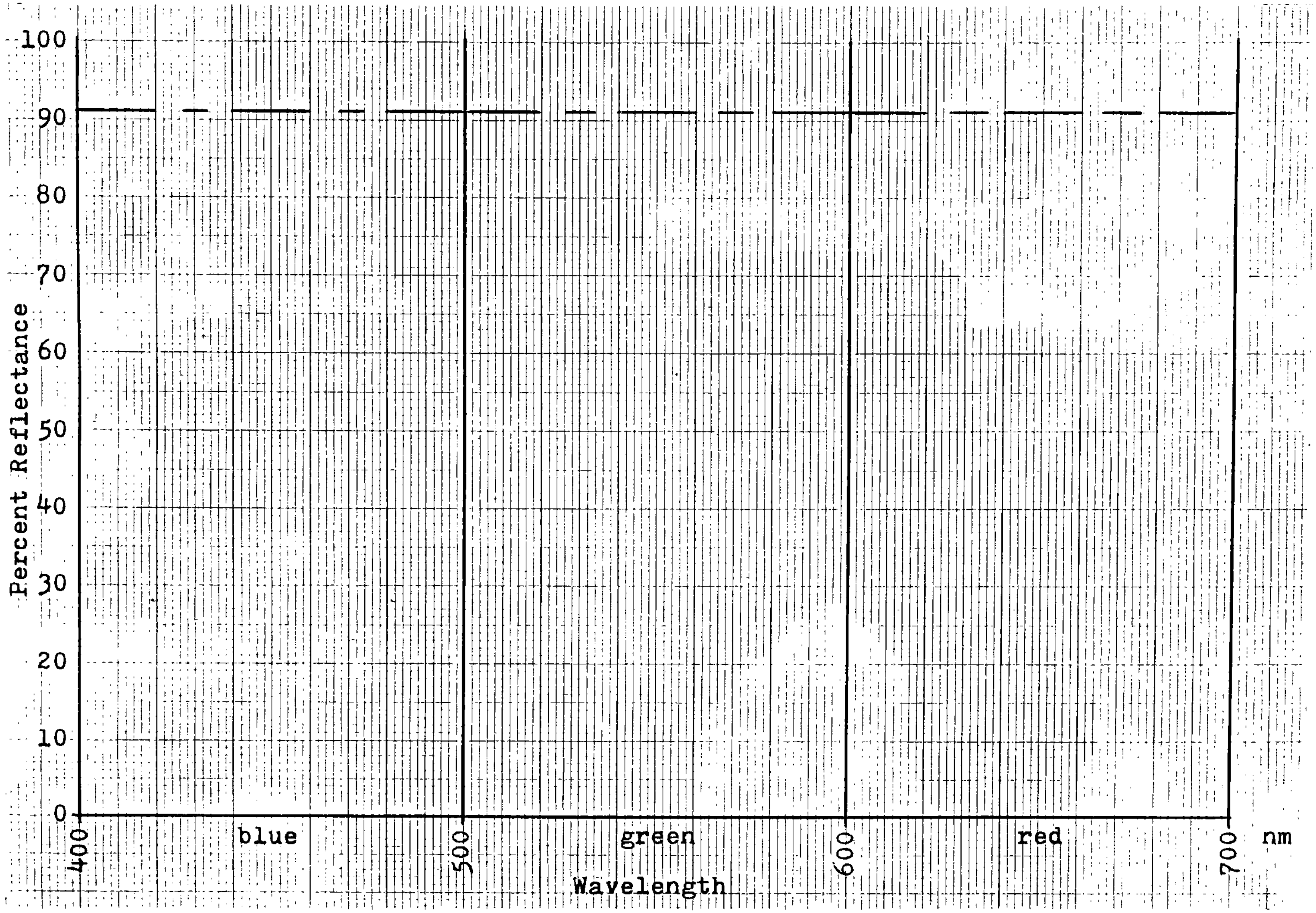


Figure 9. Average reflectance curve of the paper with paper as the reference material.

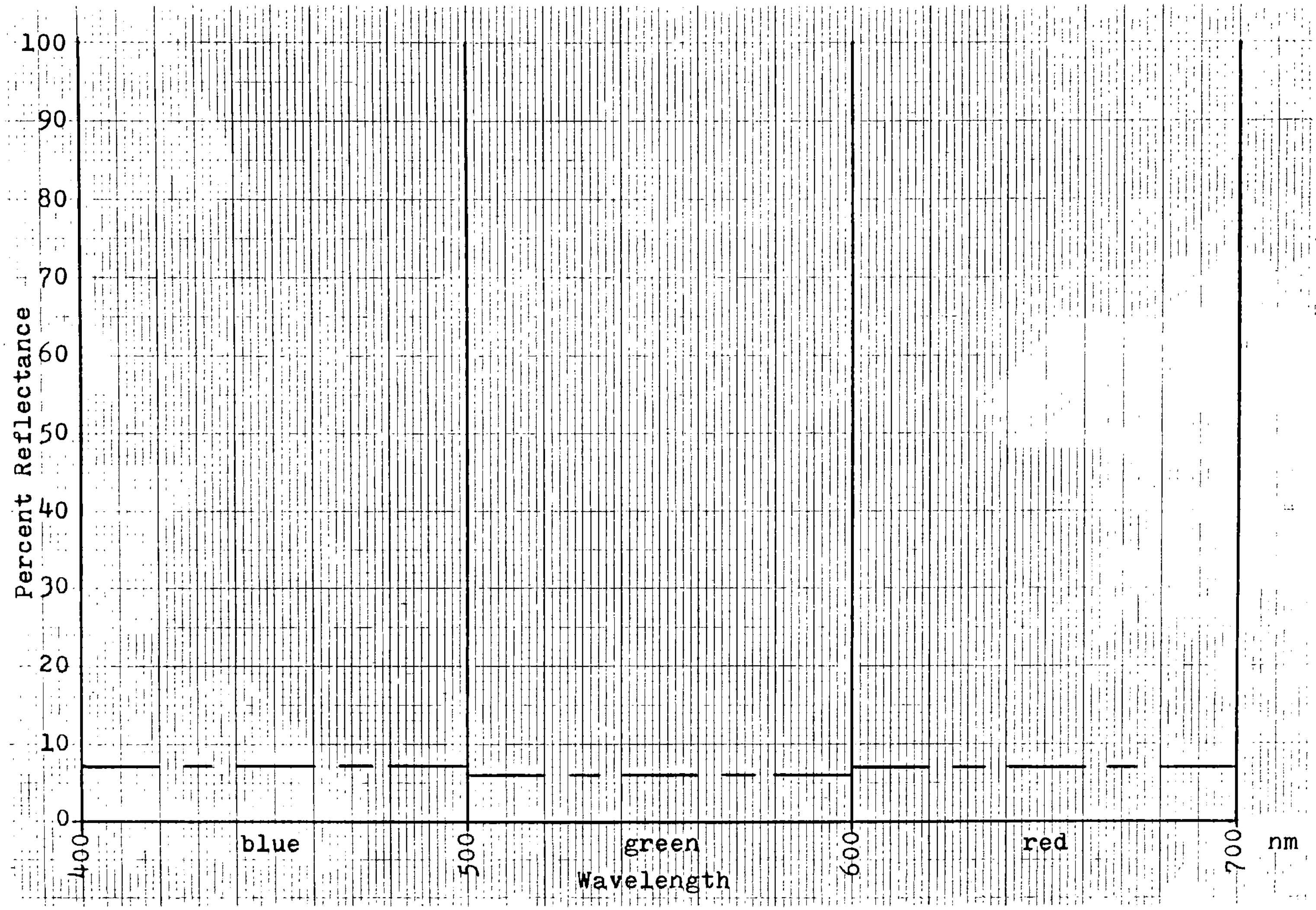


Figure 10. Average reflectance curve of solid black.

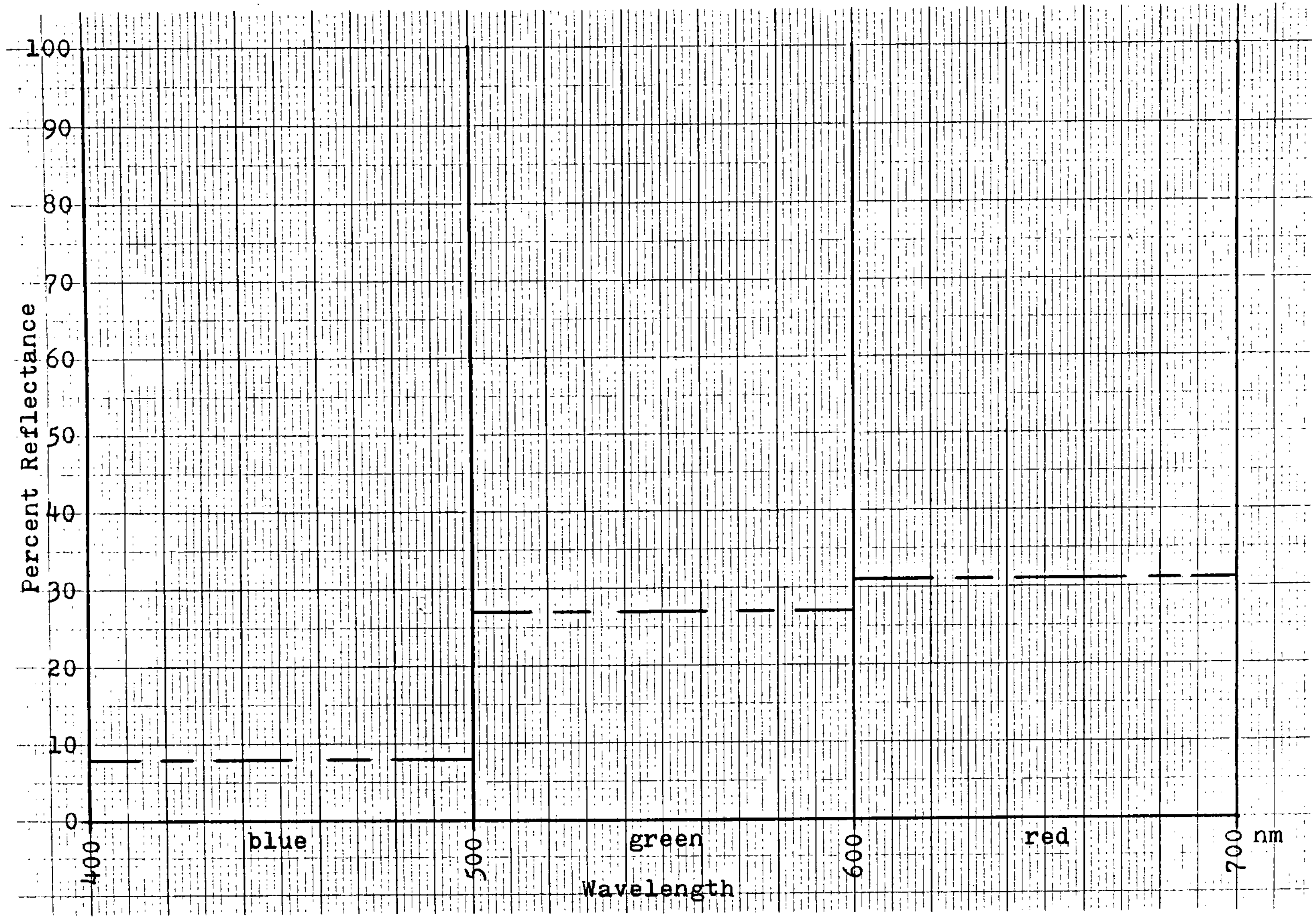


Figure 11. Average reflectance curve of solid yellow.

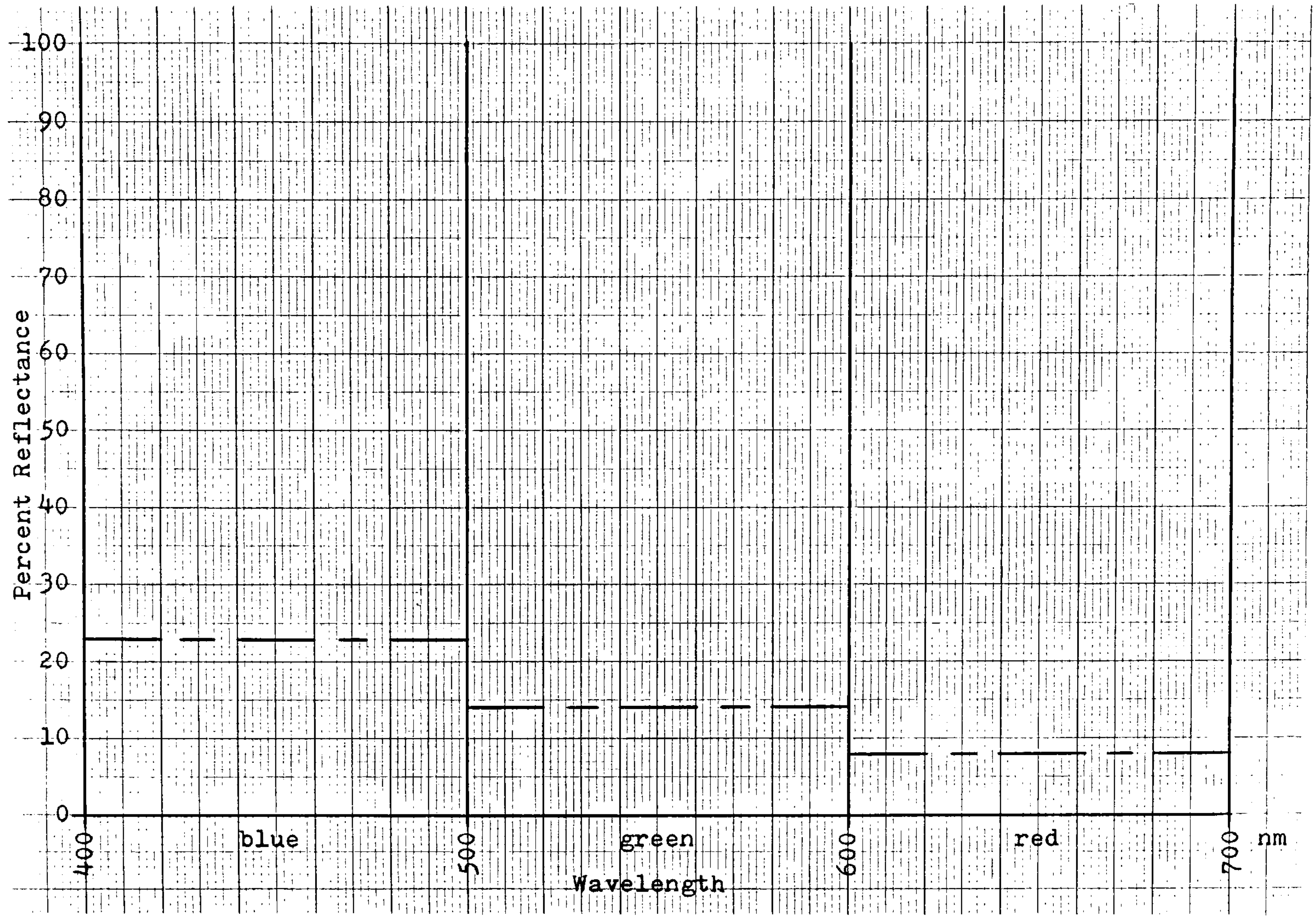


Figure 12. Average reflectance curve of solid cyan.

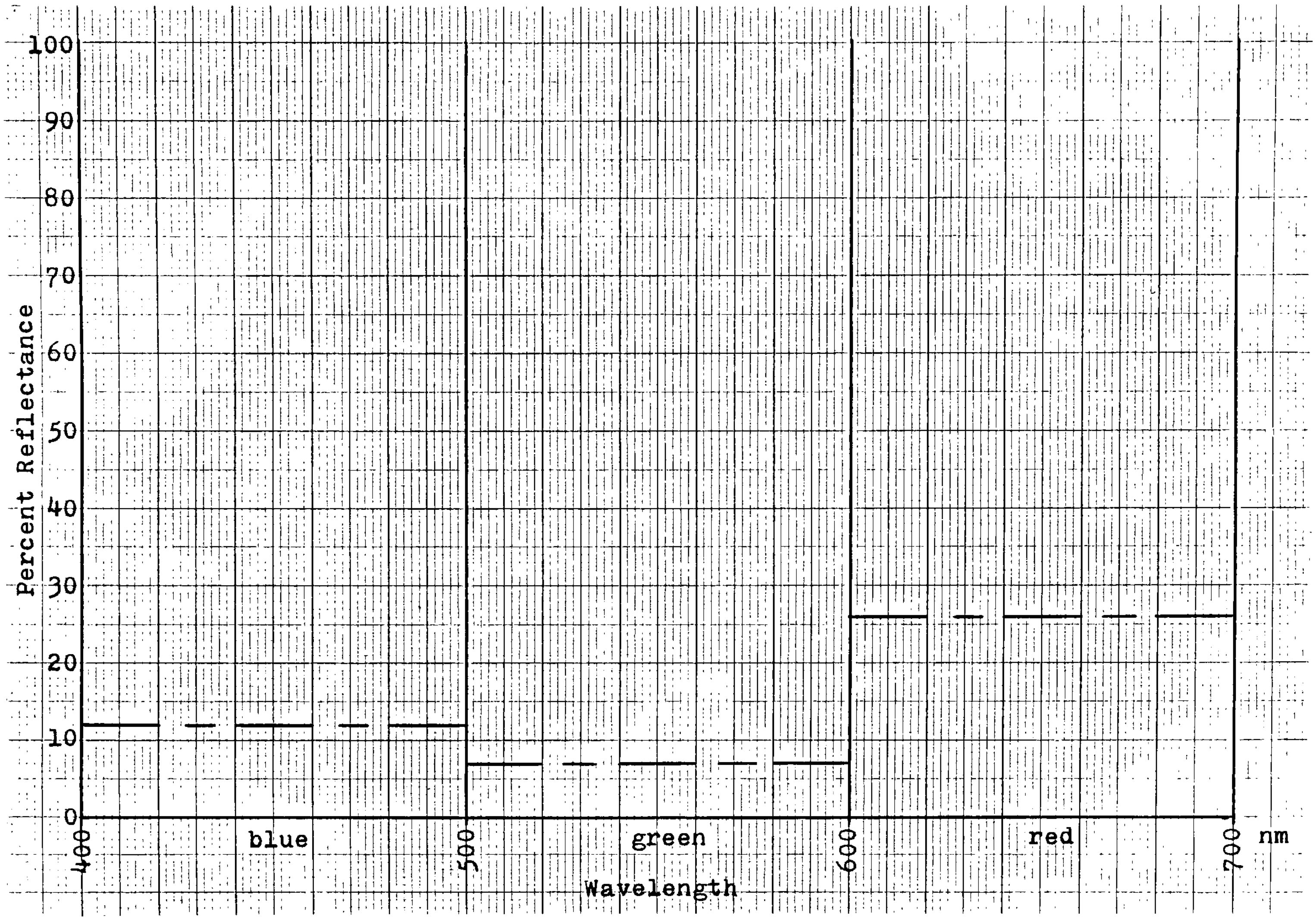


Figure 13. Average reflectance curve of solid magenta.

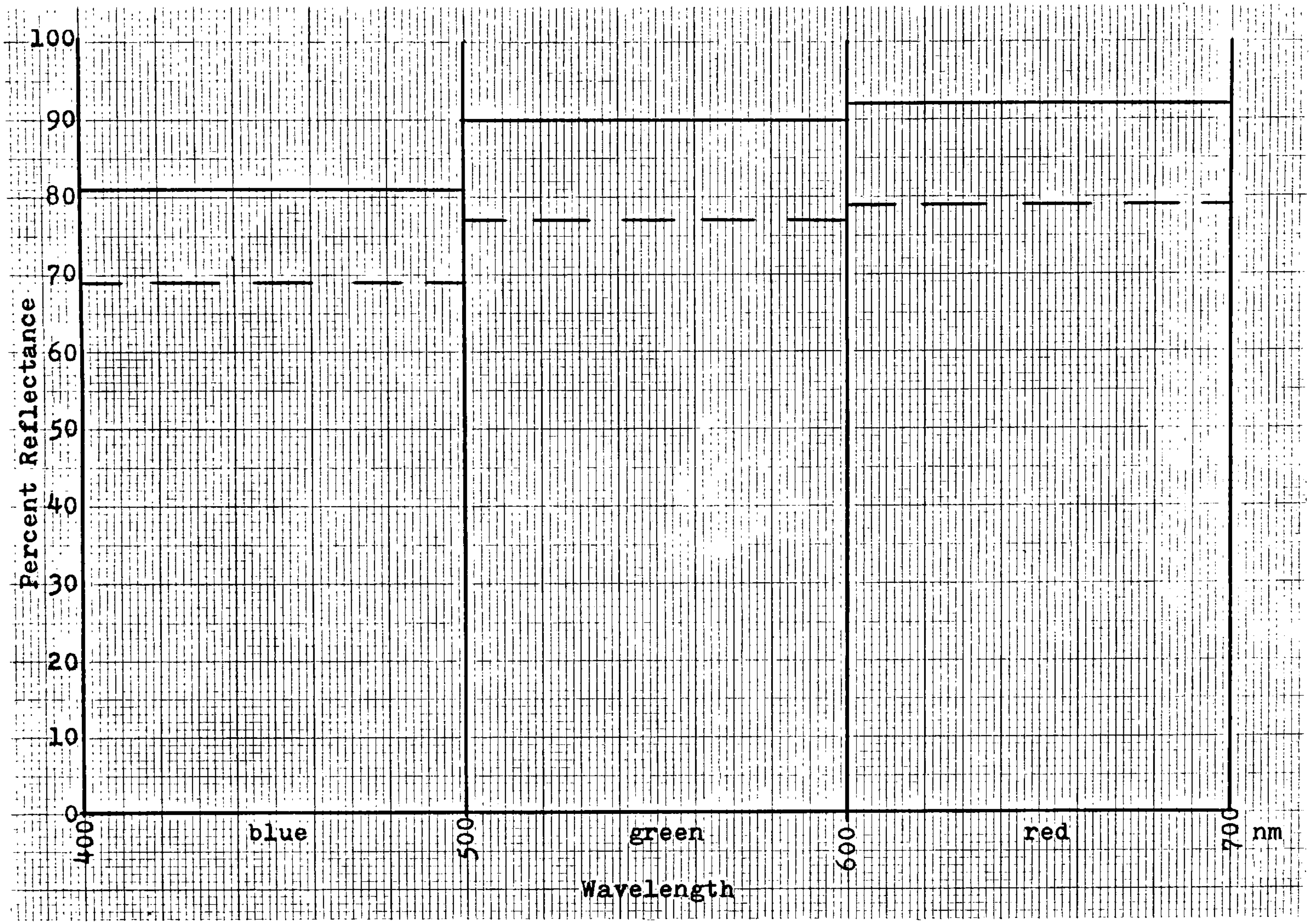


Figure 14. Average reflectance curves of tint patches "A", yellow (solid line) and "A", yellow plus black (broken line).

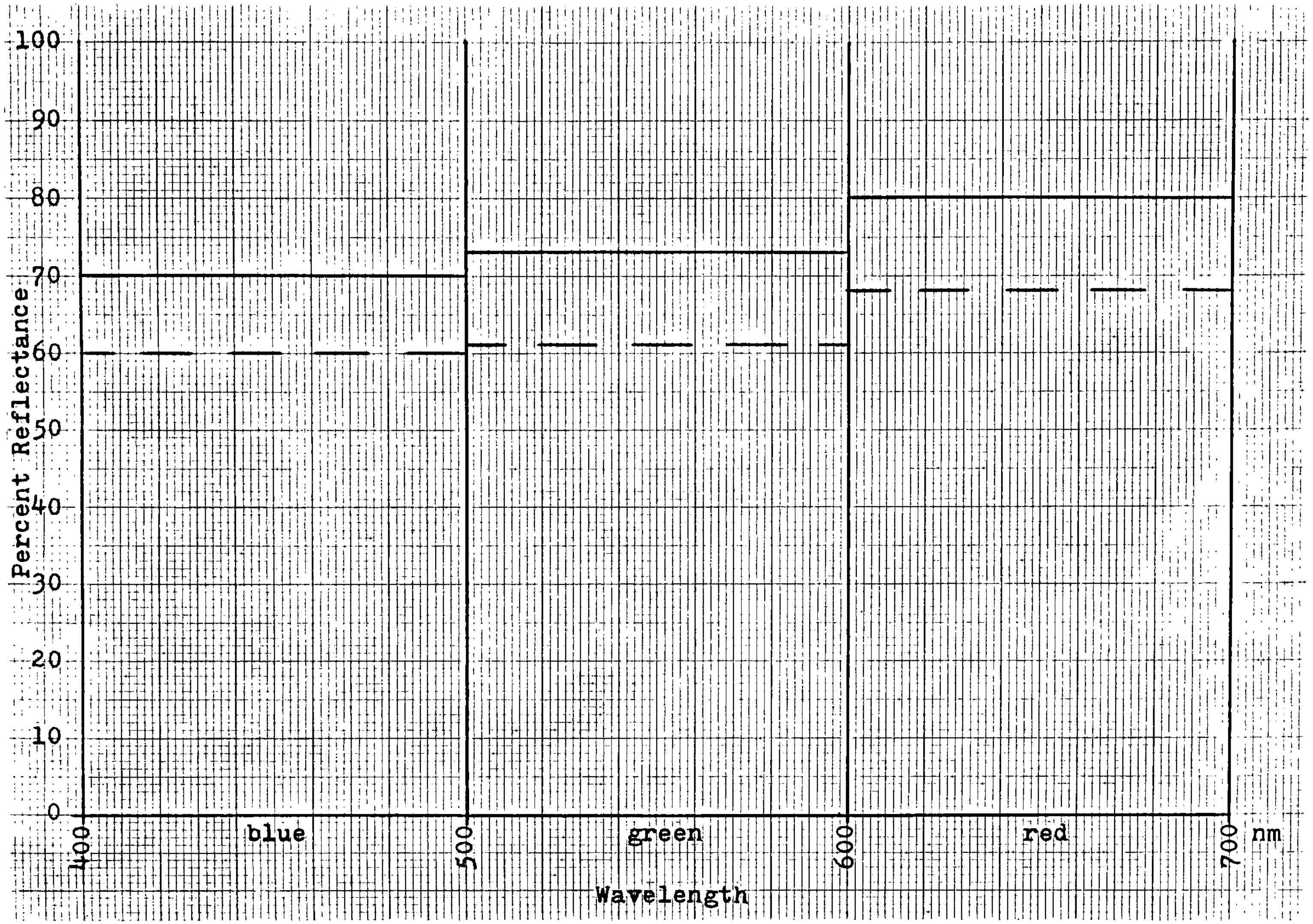


Figure 15. Average reflectance curves of tint patches "A", three color (solid line) and "A", four color (broken line).

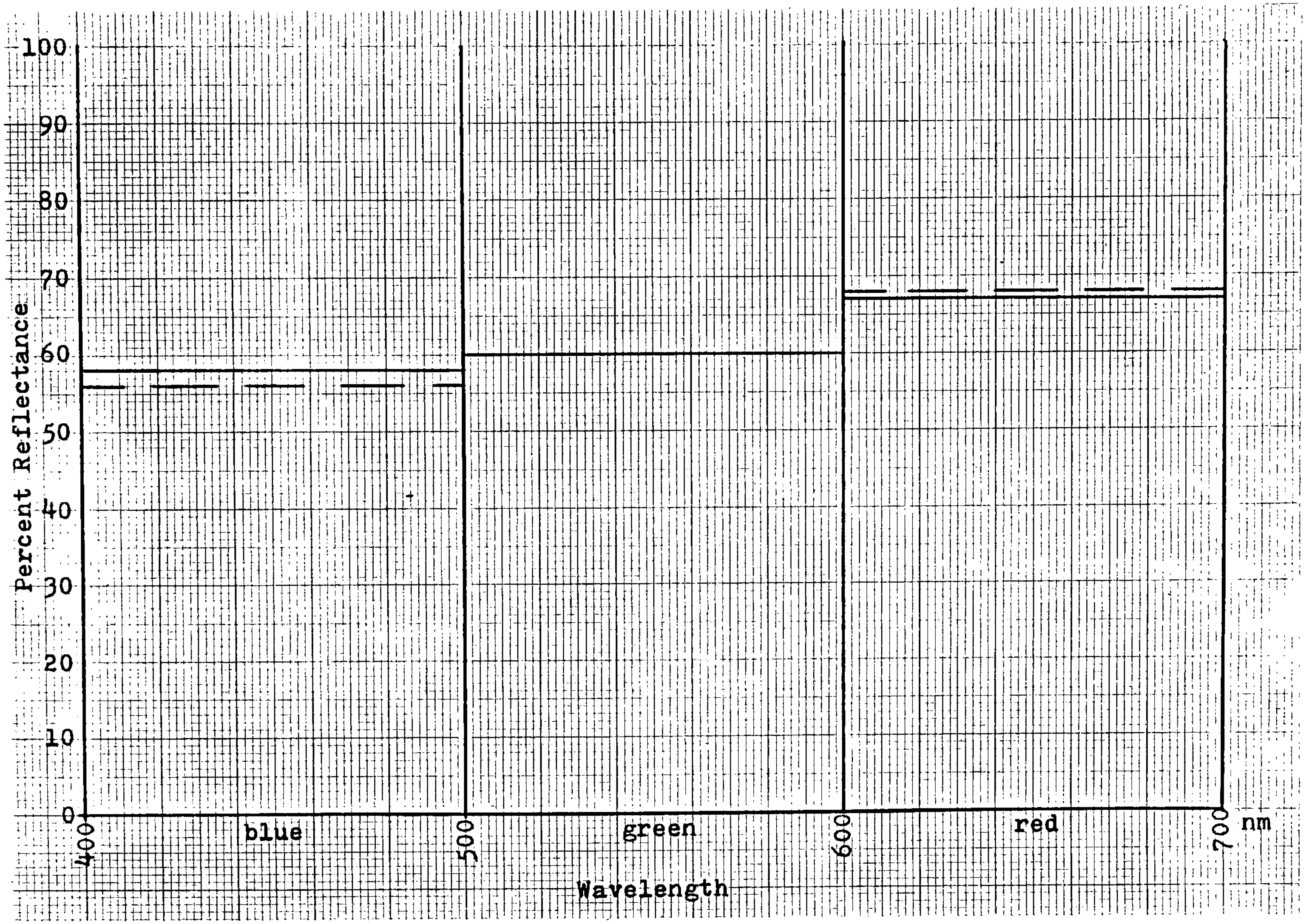


Figure 16. Average reflectance curves of tint patches "A", four color (solid line) and "B", four color with black overprinted cyan approximately 50% (broken line).

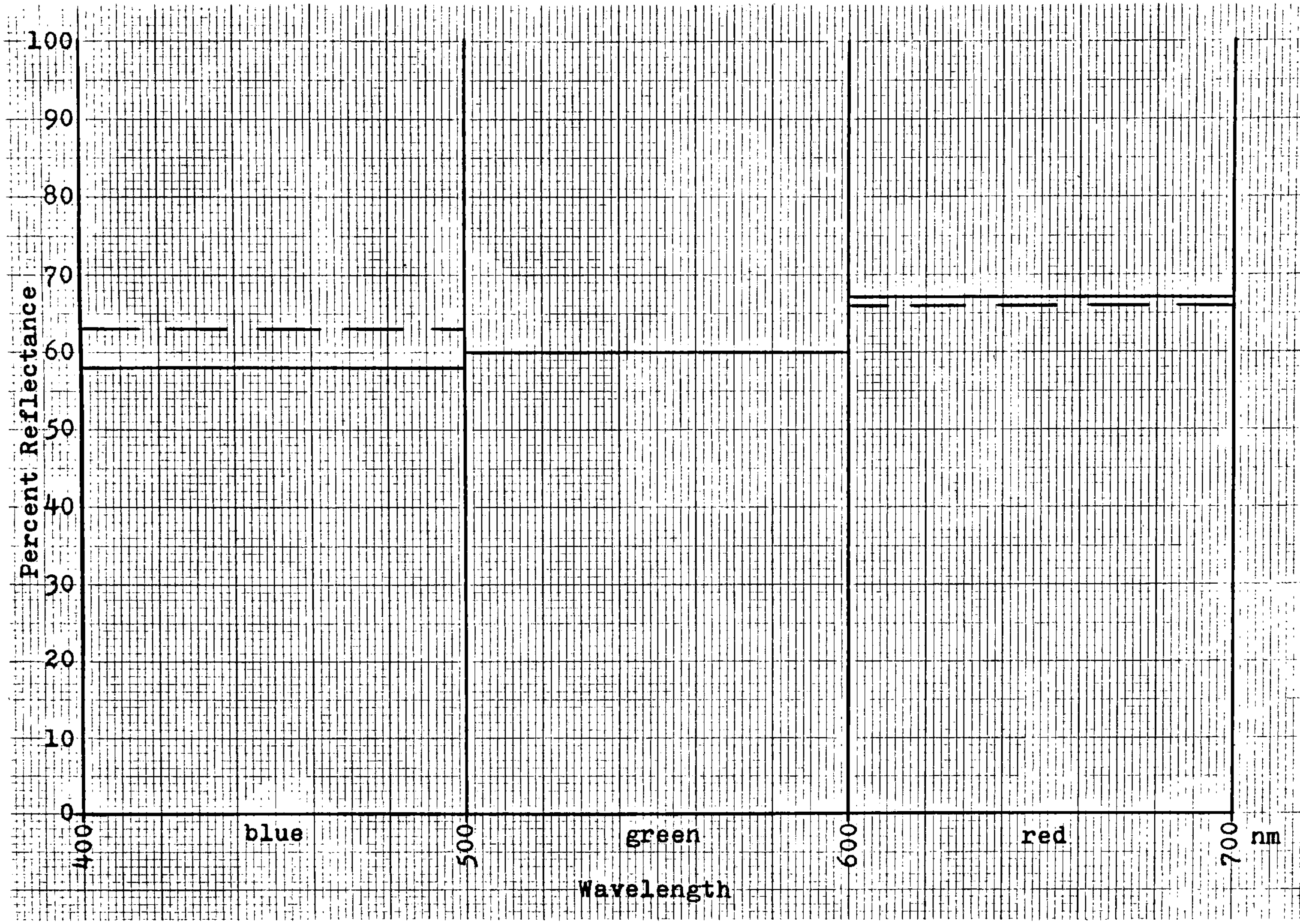


Figure 17. Average reflectance curves of tint patches "A", four color (solid line) and "C", four color with black overprinted yellow approximately 75% (broken line).

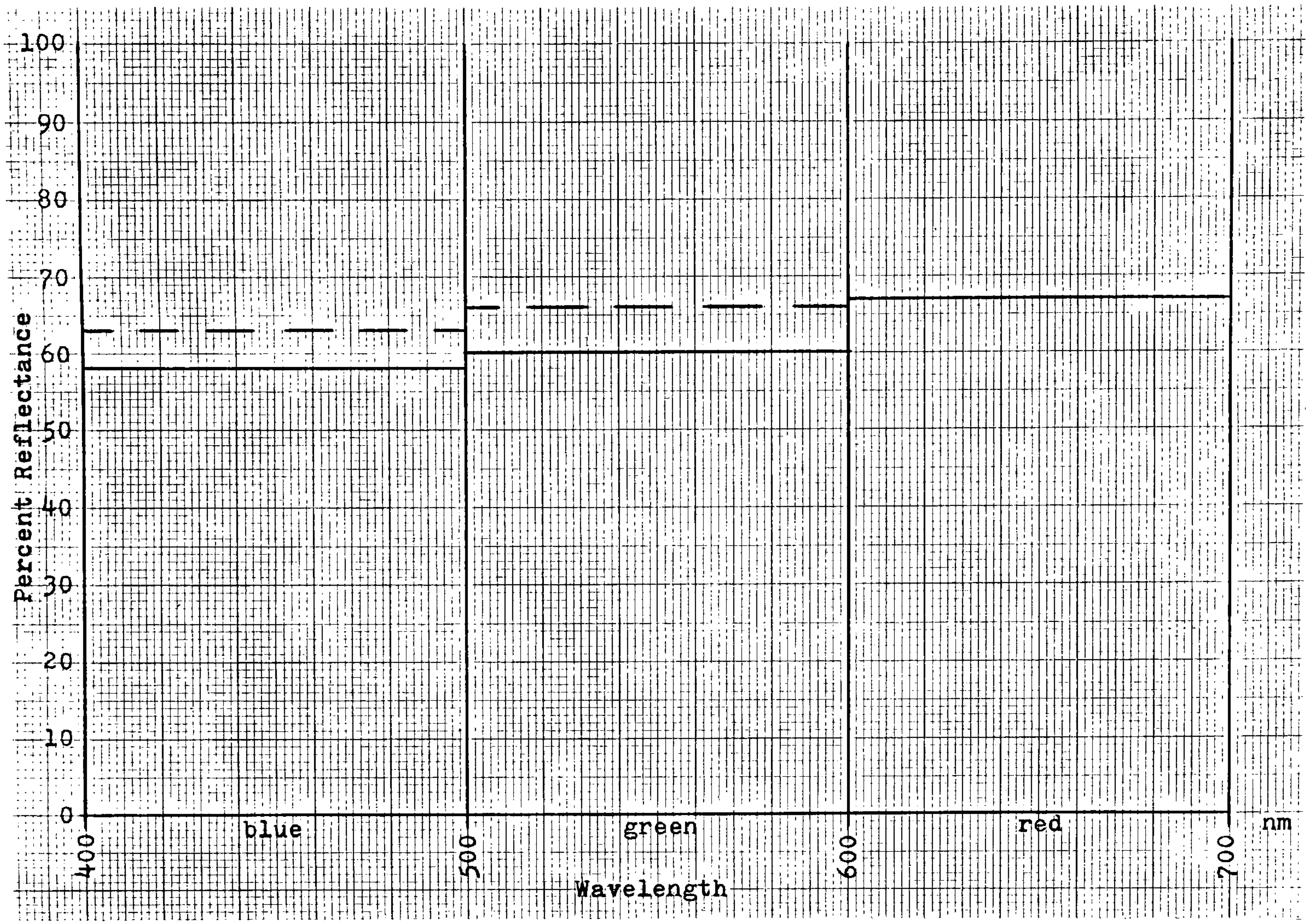


Figure 18. Average reflectance curves of tine patches "A", four color (solid line) and "D", four color with black overprinted magenta approximately 50% (broken line).

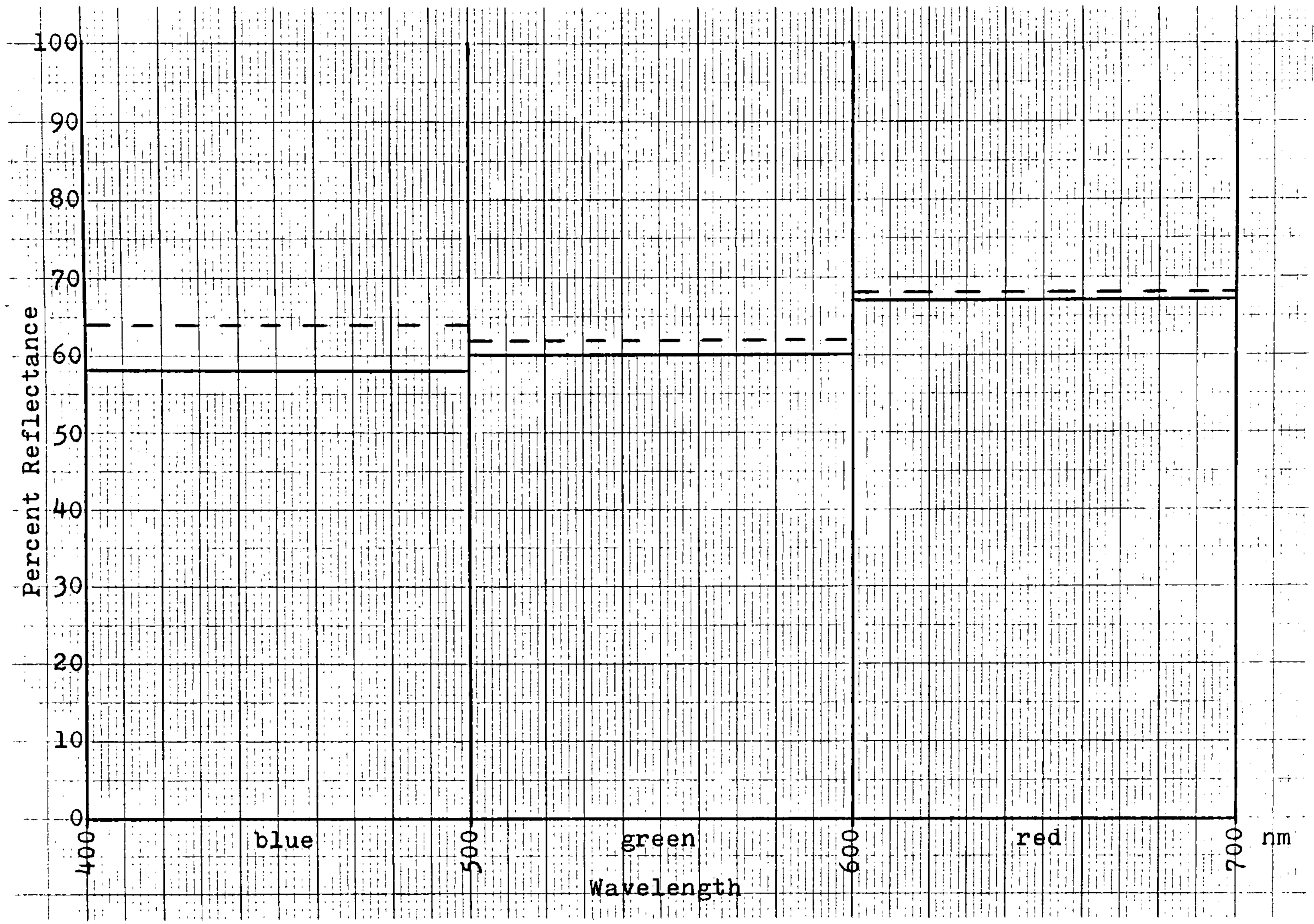


Figure 19. Average reflectance curves of tint patches "A", four color (solid line) and "F", four color with black overprinted yellow approximately 50% (broken line).

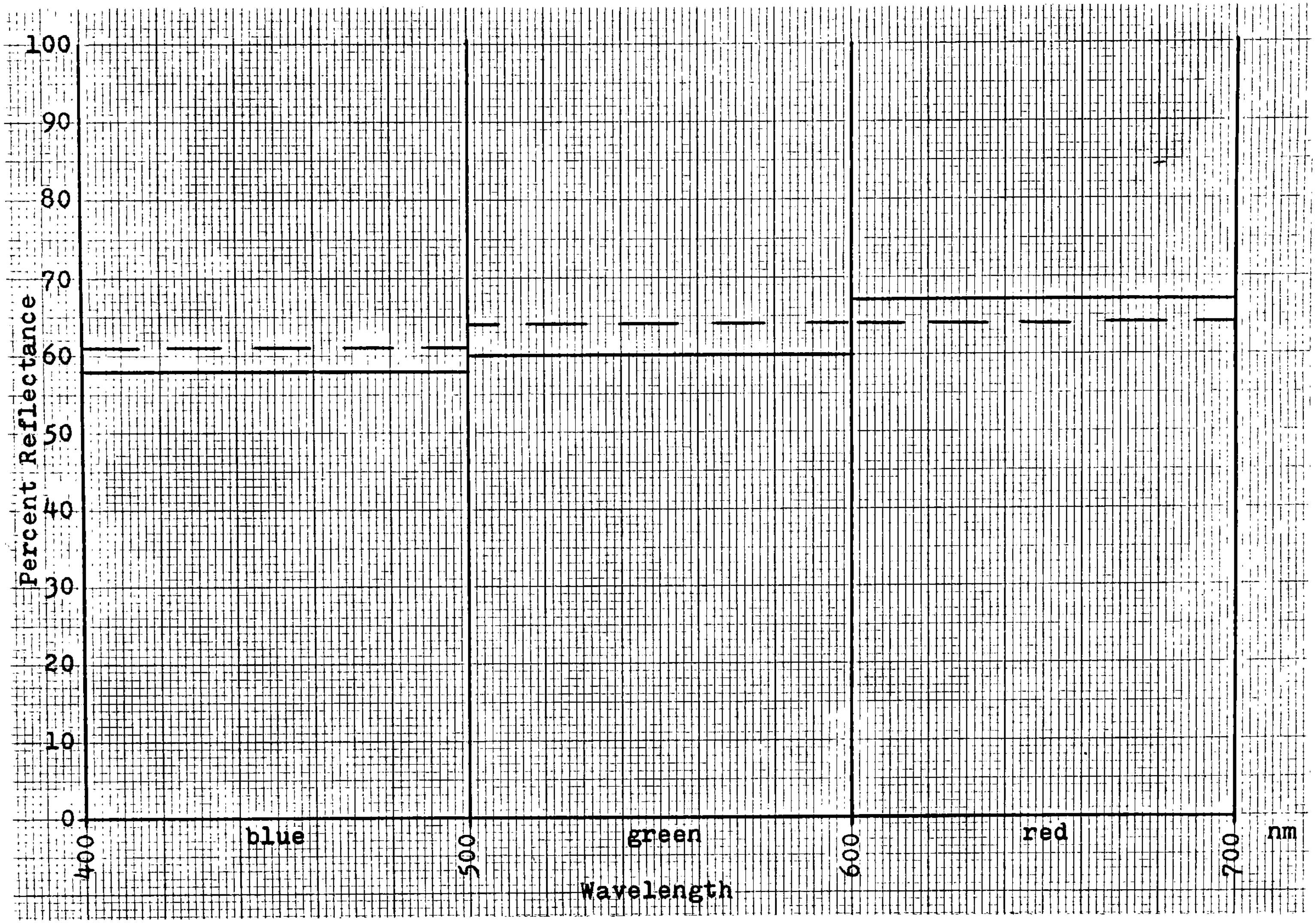


Figure 20. Average reflectance curves of tint patches "A", four color (solid line) and "G", four color with black overprinting magenta approximately 75% (broken line).

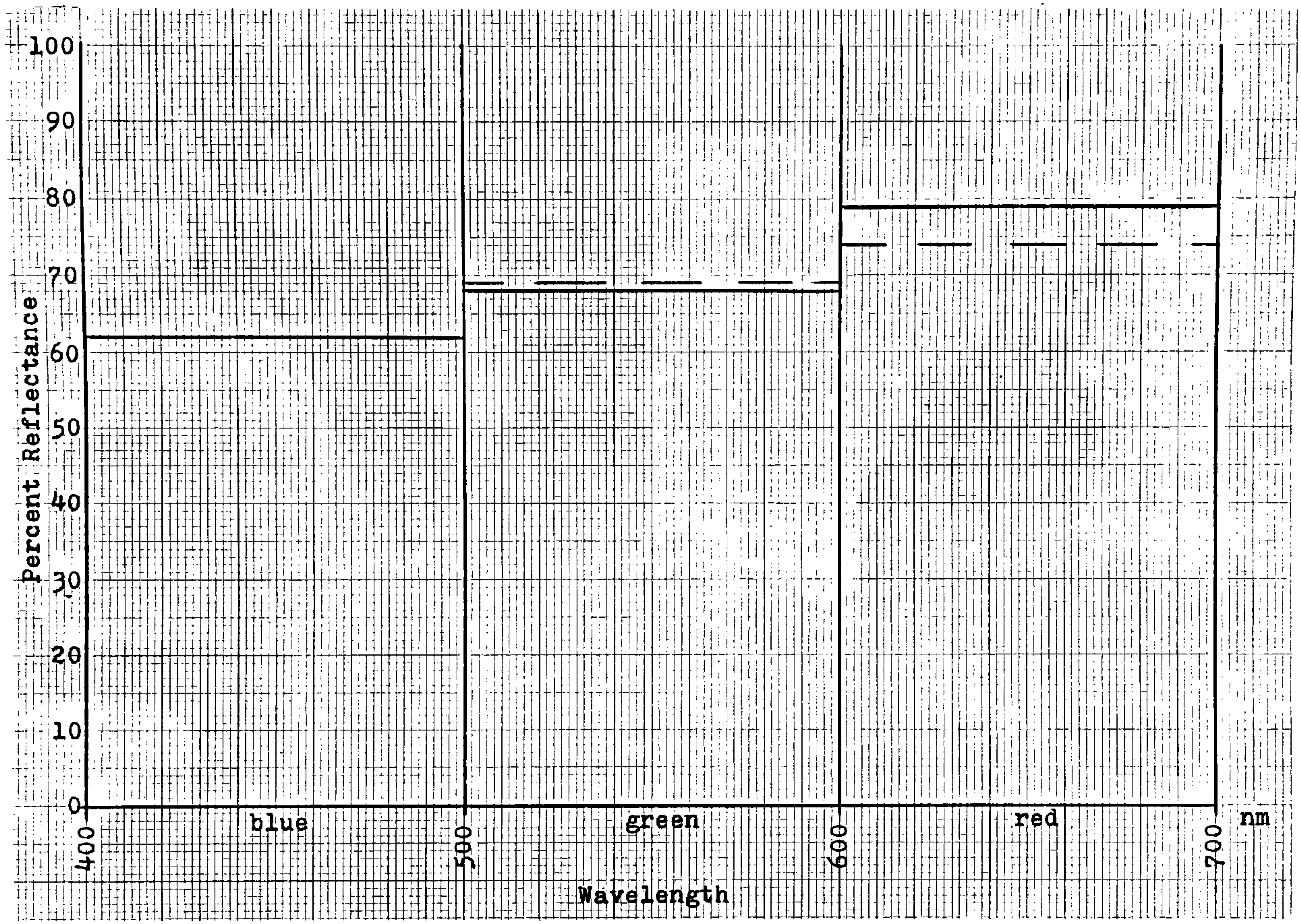


Figure 21. Average reflectance curves of tint patches "H", three color (solid line) and "I", three color with black overprinted magenta approximately 75% (broken line).

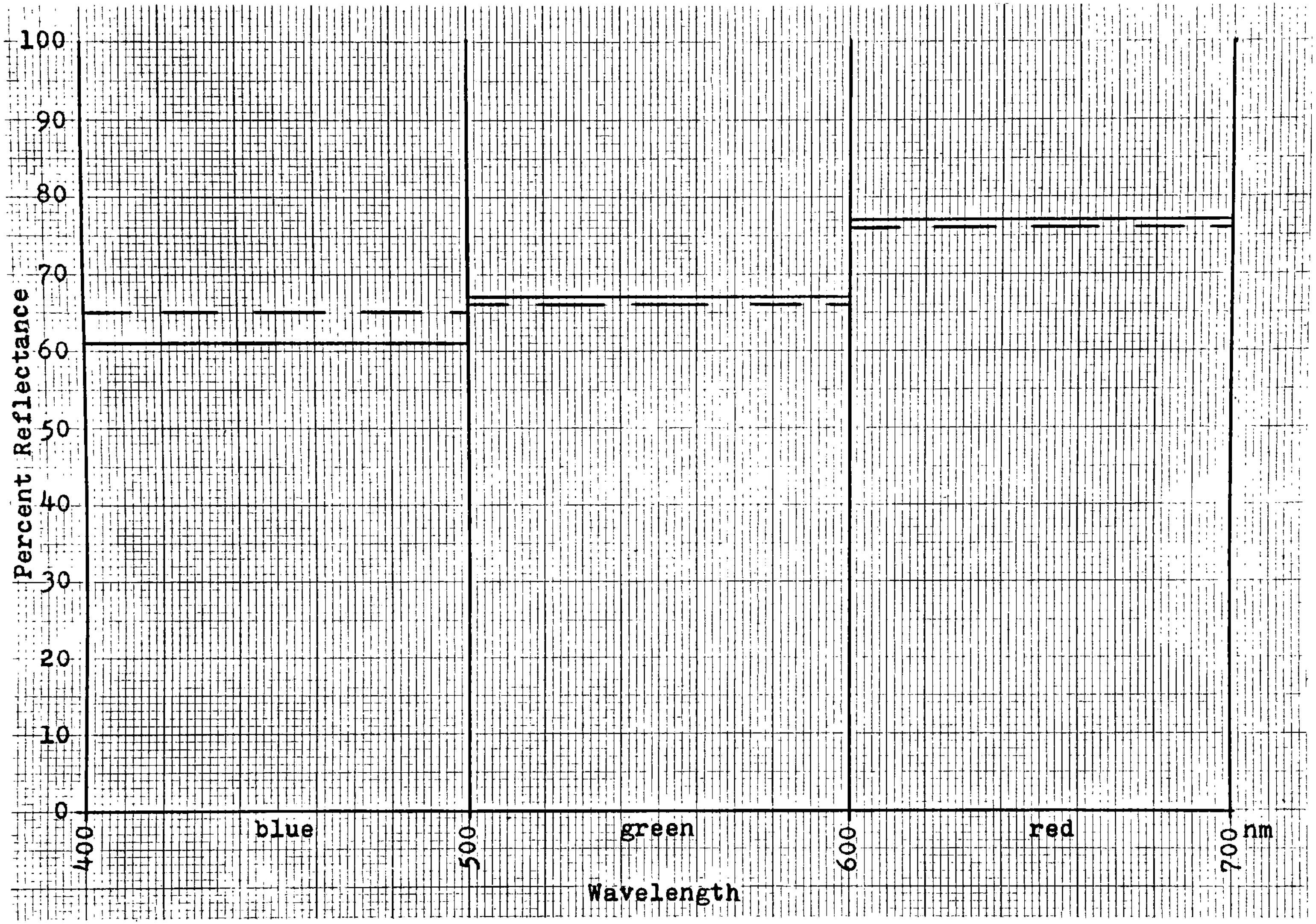


Figure 22. Average reflectance curves of tint patches "H", three color (solid line) and "J", three color with black overprinted yellow approximately 75% (broken line).

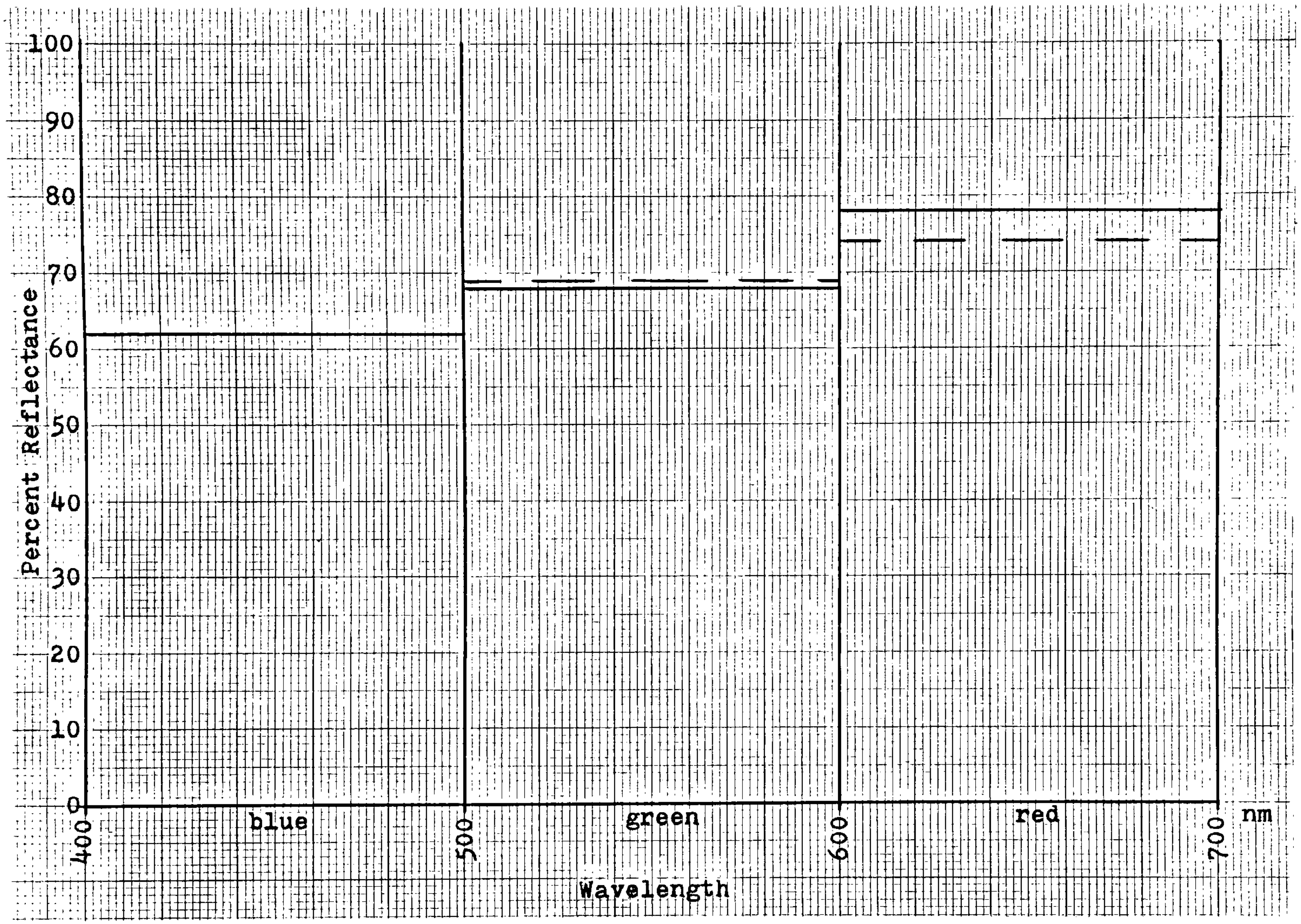


Figure 23. Average reflectance curves of tint patches "H", three color (solid line) and "K", three color with black overprinted magenta approximately 50% (broken line).

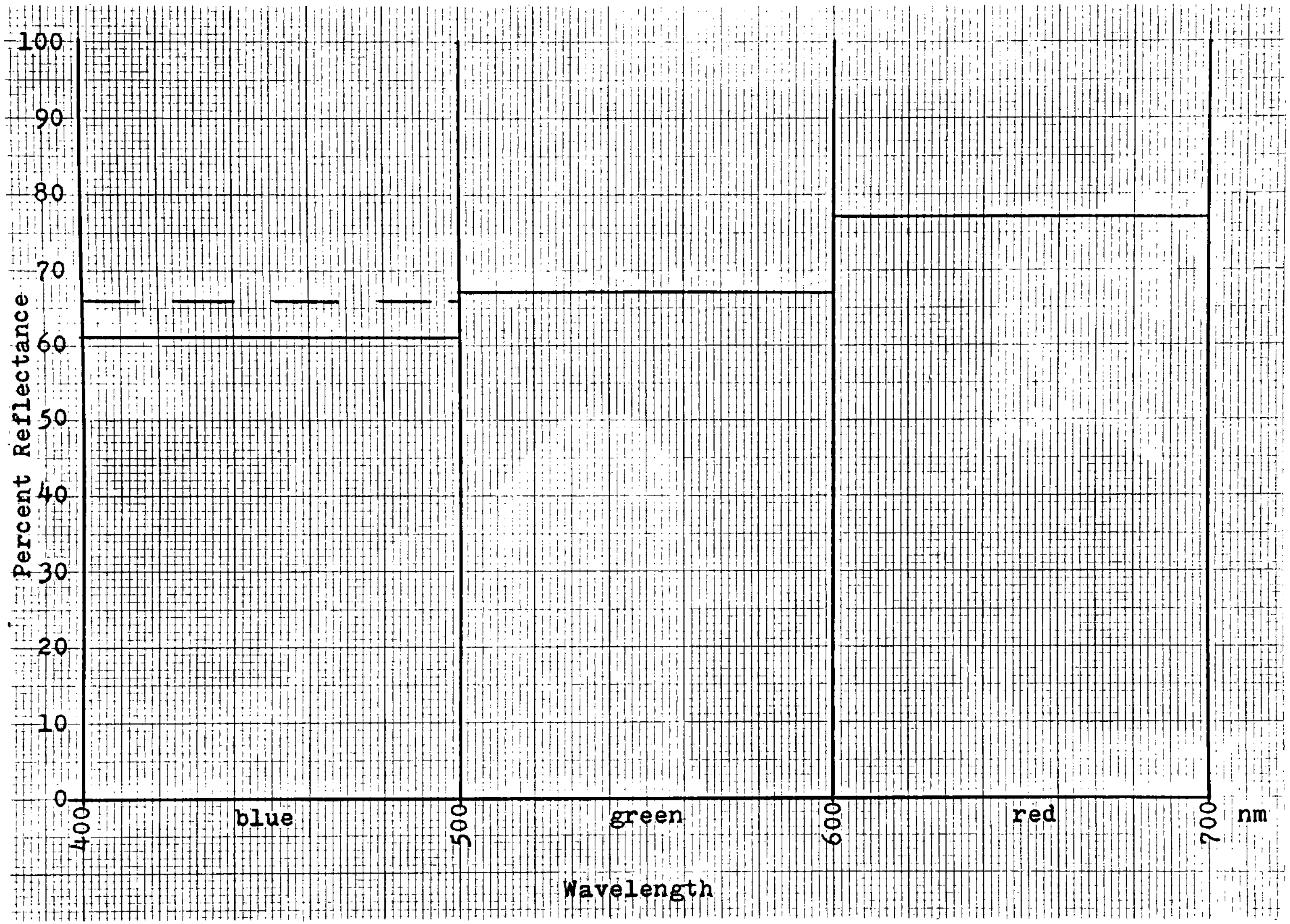


Figure 24. Average reflectance curves of tint patches "H", three color (solid line) and "L", three color with black overprinted yellow approximately 50% (broken line).

CHAPTER SEVEN

DISCUSSION OF RESULTS

The results of black overprinting in halftone reproductions were as expected with hue shifts between the tint patches visually apparent. The direction of the hue shifts also occurred as expected. Overprinting yellow with black leads to a hue shift to the blue band. The overprinting of magenta with black leads to a hue shift to the green band and the overprinting of cyan leads to a hue shift to the red band. These results can be seen from the average reflectance curves in Figures 16 to 20.

The hue shifts occurring are a combination of the increased reflectance in one band and a decrease in reflectance in the other two bands. There were also two factors that influenced some of the results of this research. Firstly, when the paper was analyzed against magnesium oxide by the spectrophotometer, the resulting curve showed a higher reflectance in the blue band relative to the green band, and a higher reflectance of the green band relative to the red band (Figures 8 and 25). Secondly, the overprinting of magenta with black caused the expected increase in the reflectance of the green band and a decrease in the reflectance of the red band, but an increase in the reflectance of the blue band (Figures 18 and 20).

This increased blue reflectance is probably due to two factors, one; that the paper has a higher reflectance in the blue band and two; the magenta ink absorbs a high percentage of the blue band (Figure 13). Therefore, overprinting magenta with black not only decreases the ability of the magenta ink to absorb the green band but also decreases the ability of magenta to absorb the blue band. The result of these two factors is an increased reflectance in the blue band as well as the green band when magenta is overprinted with black.

Another observation made was that a decrease in the reflectance of the green band did not occur when black overprinted yellow or cyan (Figures 16 and 17). This is probably due to the fact that overprinting yellow or cyan within a tint patch leads to a change in the full reflectance curve of the patches, but the change (Figures 33 and 34) in the green band averages out to the same value as in a tint with no overprint.

The only results that could not be explained are those from the spectrophotometric analysis of tint patch F (Figure 19). In this case black overprinted yellow by approximately 50% and although there was an increase in the reflectance of the blue band there was also an increase in reflectance of the green band and the red band. This sample was reanalyzed at a later date but produced the same results. Although the cause of this was not determined, the shift in hue was as expected with a greater increase in the reflectance of the blue band relative to the increase in reflectance of the green band and red band.

It was observed from the two different processes, four color and three color, that the hue shifts in the four color tint patches shifted towards one of the full bands, blue, green or red. The three color tint patches, however, shifted to one of the complimentary colors, yellow or magenta (Figures 21-24). Since tint patches using cyan were not included, this observation is not conclusive.

Finally, it was found that the spectrophotometer was not recording the complete reflectance of the three bands. This was determined by making a spectrophotometric analysis of the paper against the paper (Figure 26). The results of this analysis should have been a full reflectance curve close to 100% reflectance. Instead, a curve was produced close to 90% reflectance.

This, however, did not present a problem as this was a comparative study between average reflectance curves and not absolute values. The values themselves are 10% less than what they should be.

CHAPTER EIGHT

SUMMARY AND CONCLUSIONS

The observations made on the basis of the hypothesis were as expected. It can be concluded from this research that the overprinting with black of one or more of the three process colors in a halftone reproduction results in a hue shift. This is due to the fact that the overprint reduces an ink's ability to absorb the band it is suppose to, and also reduces the ink's ability to transmit those bands that it does not absorb.

The extent to which the hue shifts occur is dependent upon the amount of overprint by the black ink, the deficiencies of the inks used in the reproduction, and the paper upon which the reproduction is printed. It is also evident that the hue shifts that occur vary depending upon the number of inks used in the reproduction.

Hue shifts resulting in the highlight to middletone areas of a reproduction are most likely to be caused by misregister between the black printer and the other colors while hue shifts occurring in the middletone to shadow areas result from the increased coverage of black and process color inks.

It has been demonstrated that the increased use of black ink in printing halftone reproductions results in a hue shift. This problem was kept to a minimum when the black printer was used only in the shadow areas to extend the density range of the reproduction.

However, when black is printed at a lower denisty, as in the case of undercolor removal, or printed from highlight to shadow as in the case of gray-component replacement, the problems of hue shifts are increased. The extent to which these hue shifts are critical depends upon the nature of the final printed product. The process of extreme UCR or GCR would not be recommended for fine art reproductions or for high quality commercial printing. The process would be most useful where facsimile reproduction is not required and where a wide variation is acceptable.

CHAPTER NINE

RECOMMENDATION FOR FURTHER STUDY

As suggested in the introduction to this research, further investigation must take place to determine the implications of using the process of gray-component replacement. Given the conclusions of this reaearch, there are related studies that can be undertaken:

(1) Investigation of the effects on hue from using standard screen angles for each color and varying the register between the black printer and the other process colors.

(2) Using different degrees of gray-component replacement, repeat the above experiement.

(3) Using different degrees of gray-component replacement and varying the register between the black printer and the other process colors, investigate the effects on hue in actual reproduction images such as fine art reproductions and typical commercial printing.

BIBLIOGRAPHY

1. Billmeyer Jr., F.W., and Saltzman, M., (1981) Principles of Color Technology, Second Ed., New York: John Wiley and Sons.

2. Birkenshaw, J.W.B., (1977), The black printer, PIRA Report, PR 154.

3. Clapper, F.R., (1961), An empirical determination of halftone color-reproduction requirements, TAGA Proceedings, 13, pp. 31-41.

4. Hardy, A.C., and Wurzburg Jr., F.L., (1948), Color correction in color printing, Journal of the Optical Society of America, Vol. 38, pp. 300-307.

5. Johnson, A., (1984), Practical implementation of optimum colour reproduction, The Journal of Photographic Science, Vol. 32, pp. 145-148.

6. Jung, Dr. E., (1984), Programmed and complementary color reduction, TAGA Proceedings, 36, pp. 135-147.

7. Saleh, Dr. A. Ghany, (1984), Investigation into the application of achromatic synthesis to the printing industry, TAGA Proceedings, 36, pp. 151-163.

8. Sigg, F., (1984), A plea for appropriate terminology, T&E Center Newsletter, Vol. 12, No. 4, p. 3.

9. Sigg, F., and Cost, P., (1984), On second thought, let's call it 'Gray-Component Replacement', T&E Center Newsletter, Vol. 12, No. 6, p. 5.

10. Southworth, M.F., (1979), Color Separation Techniques, Second Ed., Livonia, NY: Graphic Arts Publishing.

11. Southworth, M.F., (1981), Undercolor Removal (UCR), The Quality Control Scanner, Vol. 2, No. 7.

12. Southworth, M.F., (1984), Achromatic Color: Programmed Color Removal, The Quality Control Scanner, Vol. 4, No. 7.

13. Tobias, P.E., (1954), A Color correction process, _TAGA Proceedings_, 6, pp. 85-90.

14. Wentzel, F., Blair, R., and Destree, T., (1983), _Graphic Arts Photography: Color_, Pittsburgh: Graphic Arts Technical Foundation.

15. Yule, J.A.C., (1940), Theory of subtractive color photography: III. Four-color process and the black printer, _Journal of the Optical Society of America_, Vol. 30, pp. 322-331.

16. Yule, J.A.C., (1949), Color correction and the black printer, _TAGA Proceedings_, 1, n.p.

17. Yule, J.A.C., (1967), _Principles of Color Reproduction_, New York: John Wiley & Sons.

APPENDIX A

FULL REFLECTANCE CURVES OF TINT PATCHES AND OTHER SAMPLES

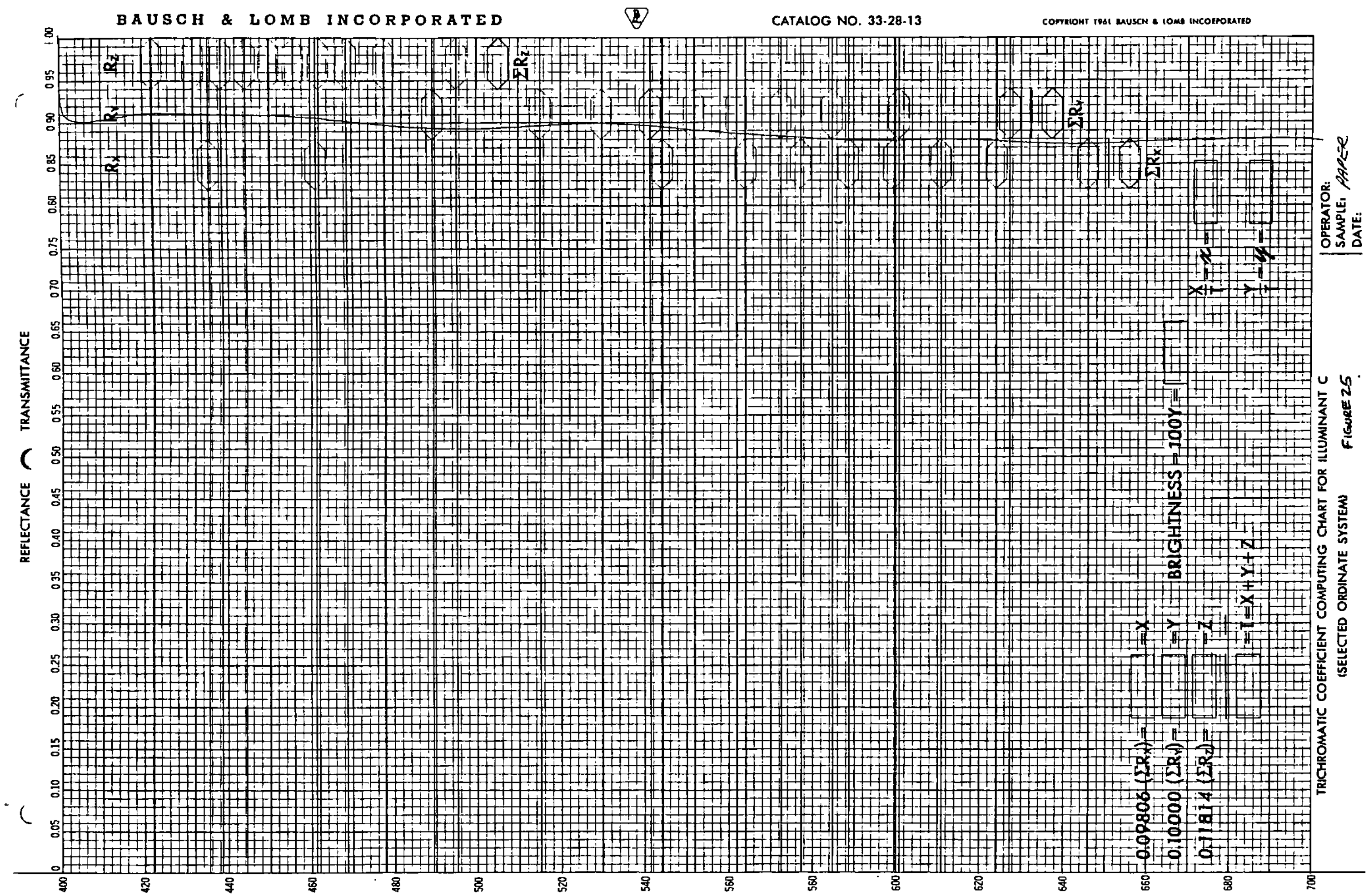


Figure 25. Full reflectance curve of the paper with Magnesium Oxide as the reference material.

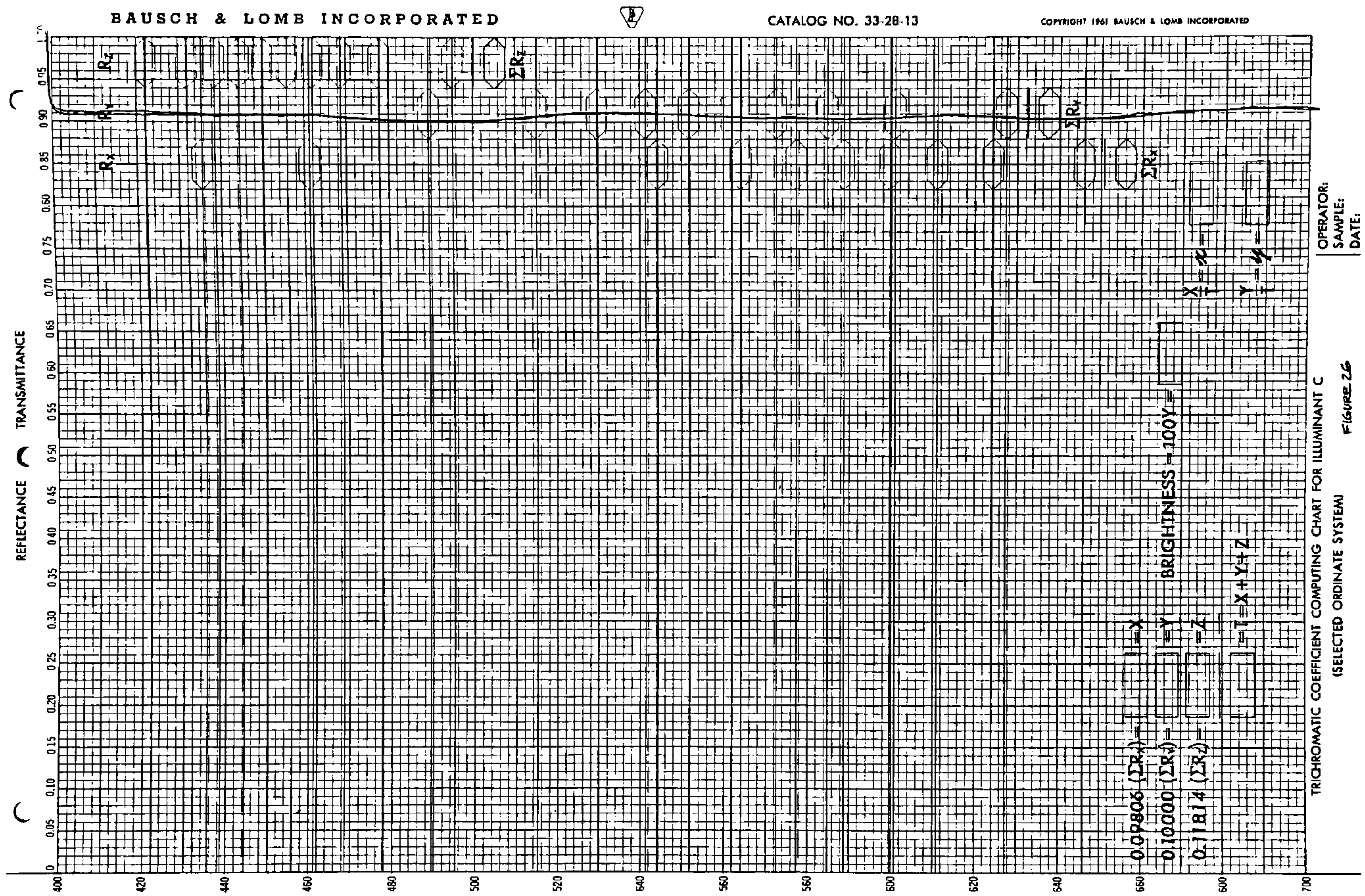


Figure 26. Full reflectance curve of the paper with the paper as the reference material.

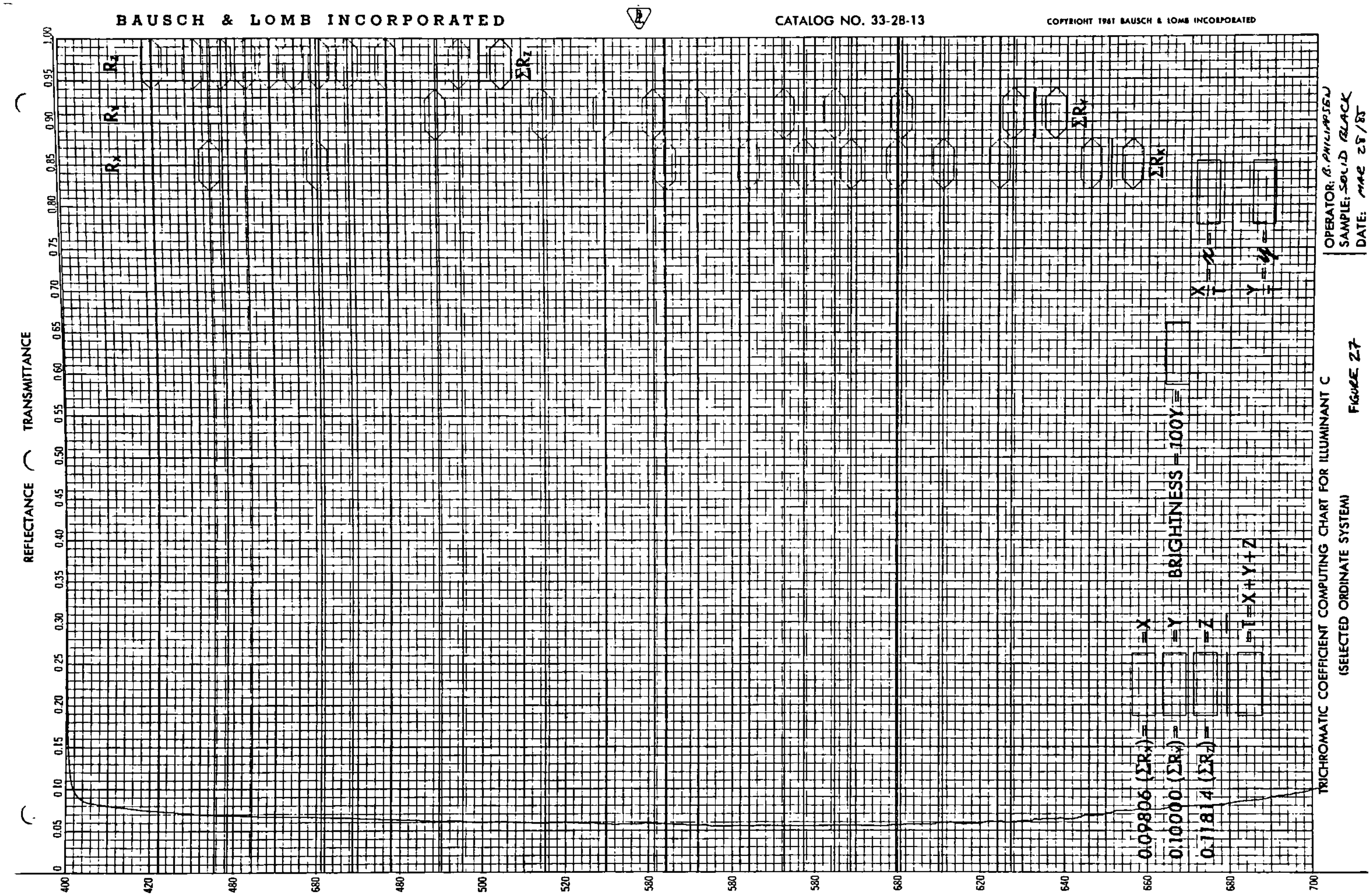


Figure 27. Full reflectance curve of solid black.

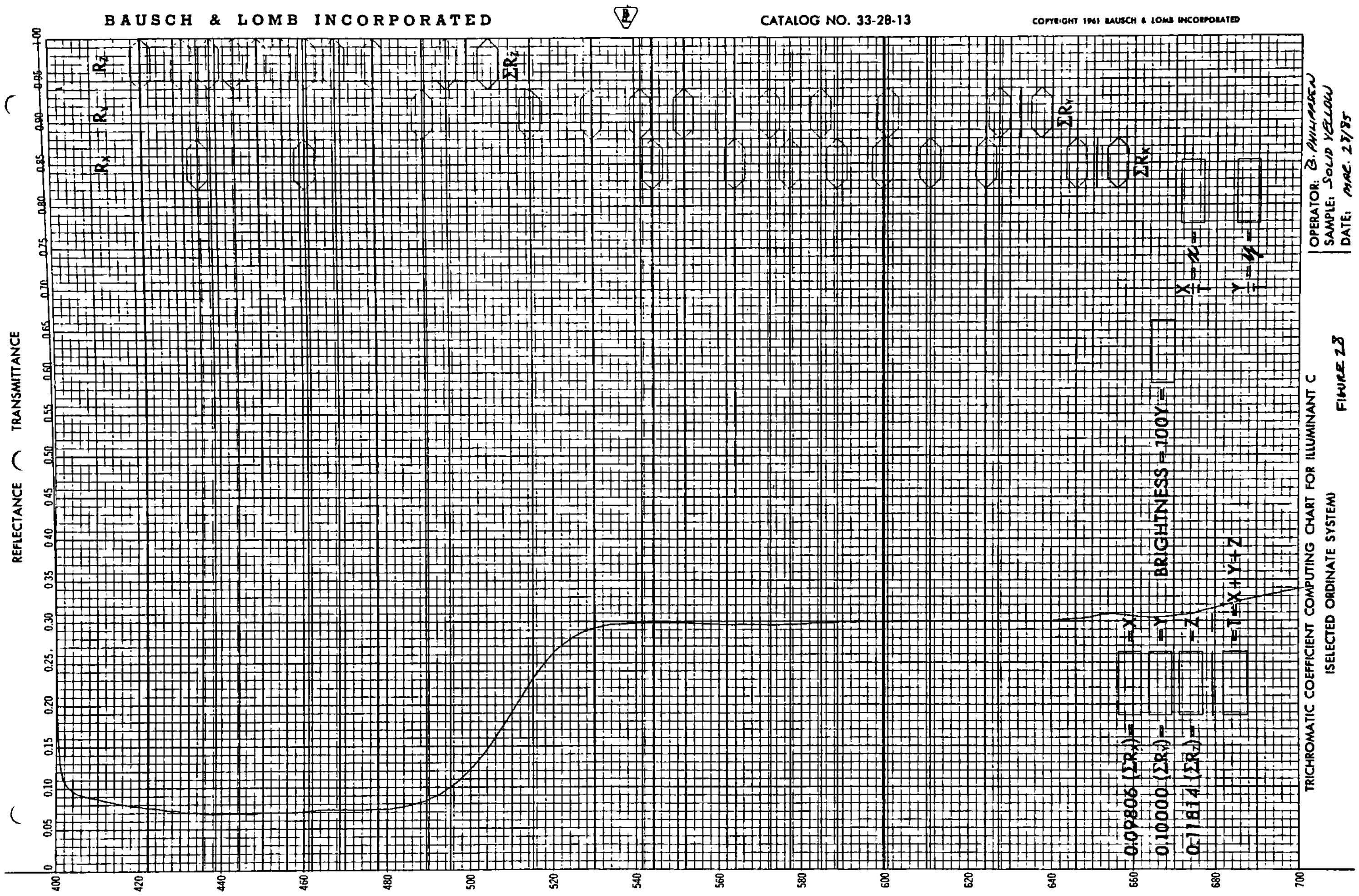


Figure 28. Full reflectance curve of solid yellow.

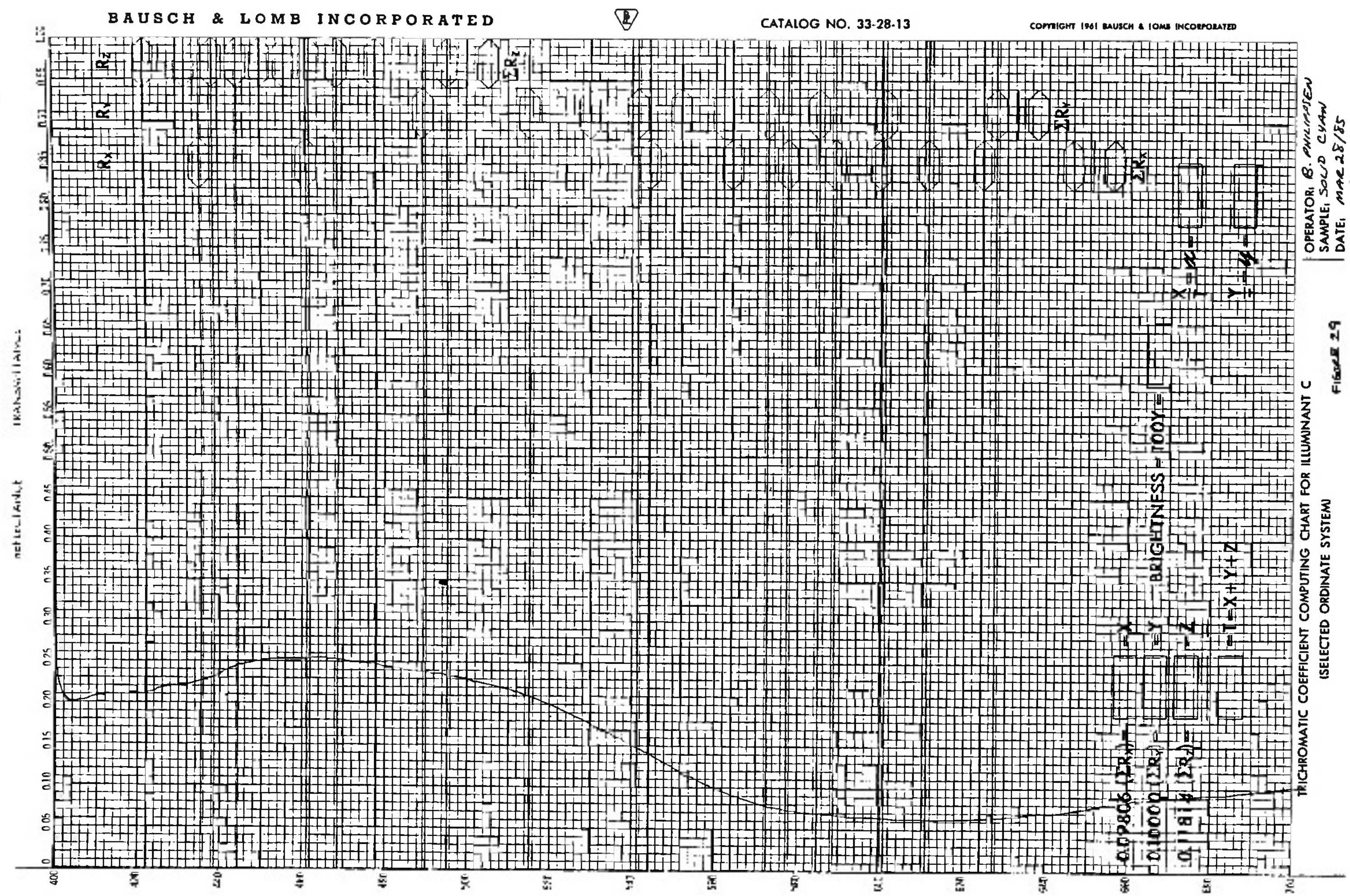


Figure 29. Full reflectance curve of solid cyan.

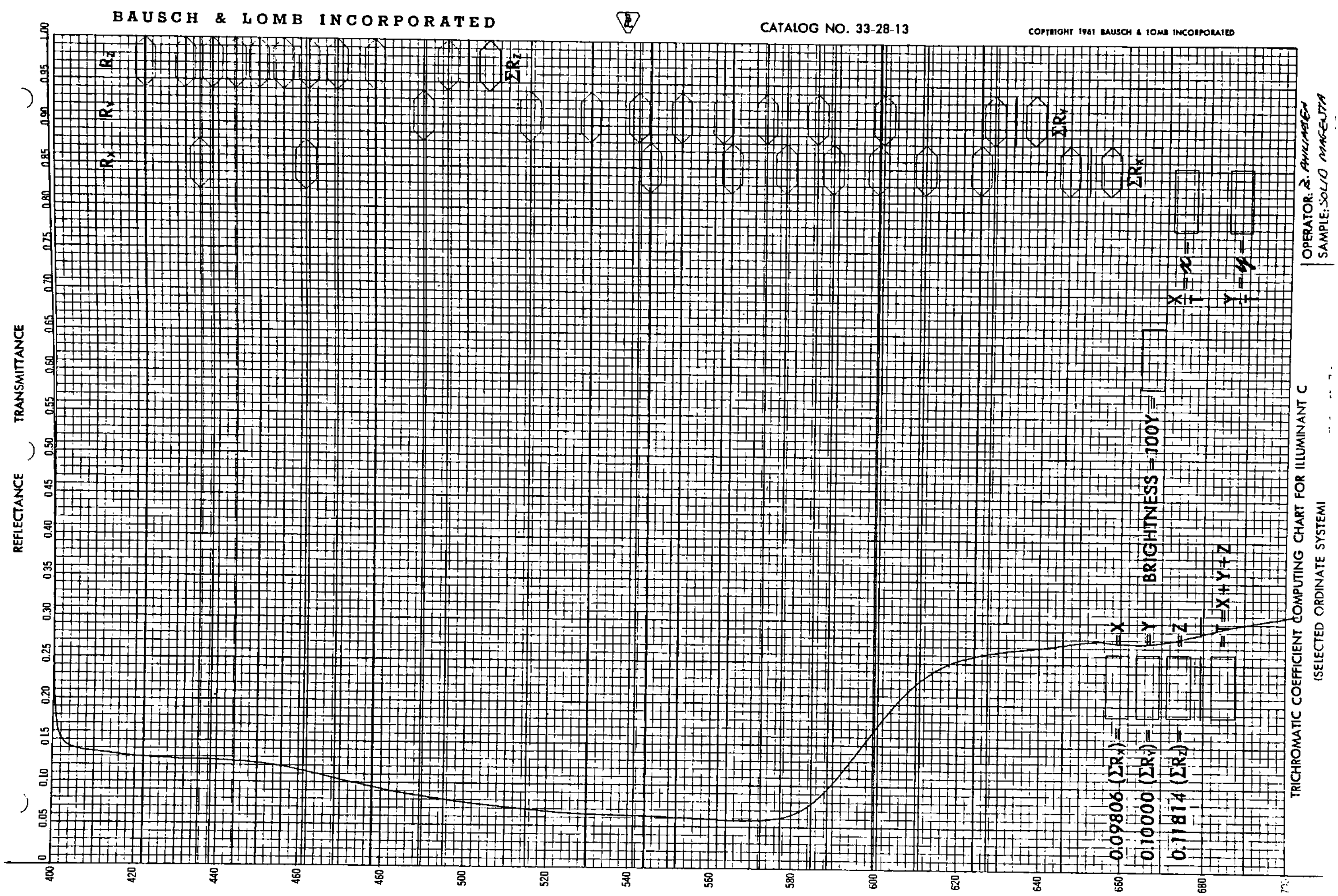


Figure 30. Full reflectance curve of solid magenta.

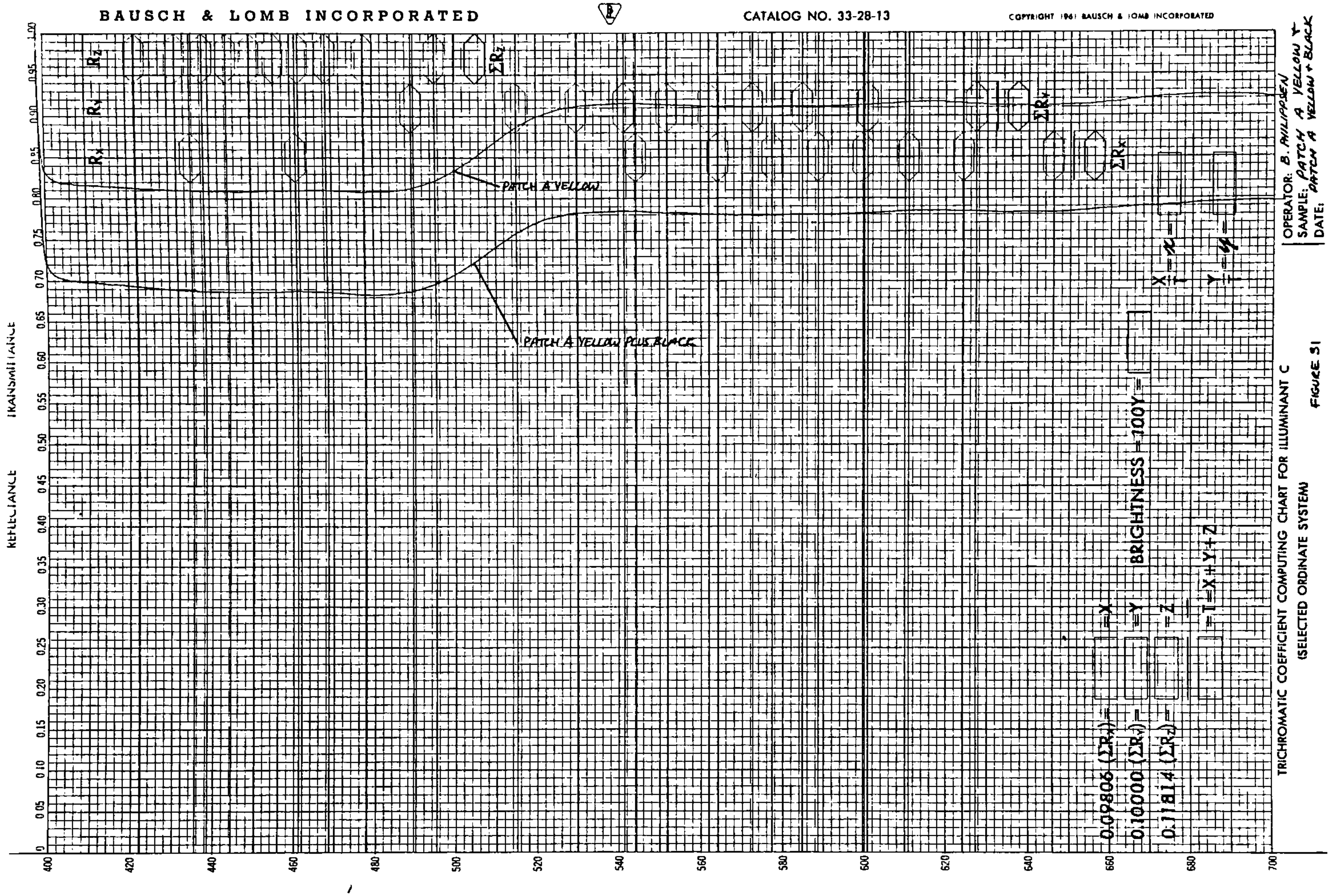


Figure 31. Full reflectance curve of tint patches "A", yellow and "A", yellow plus black.

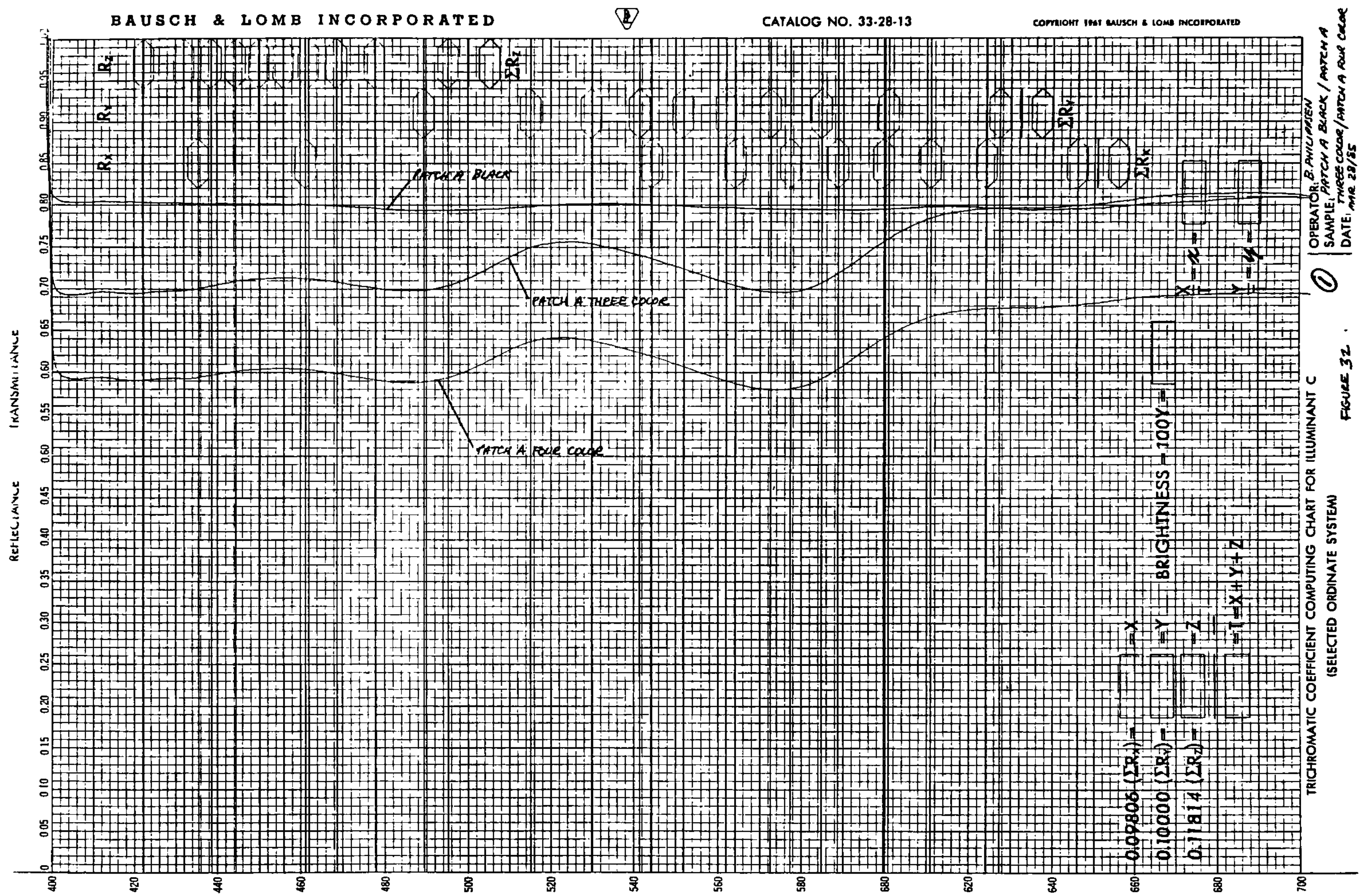


Figure 32. Full reflectance curves of tint patches "A", three color and "A", four color.

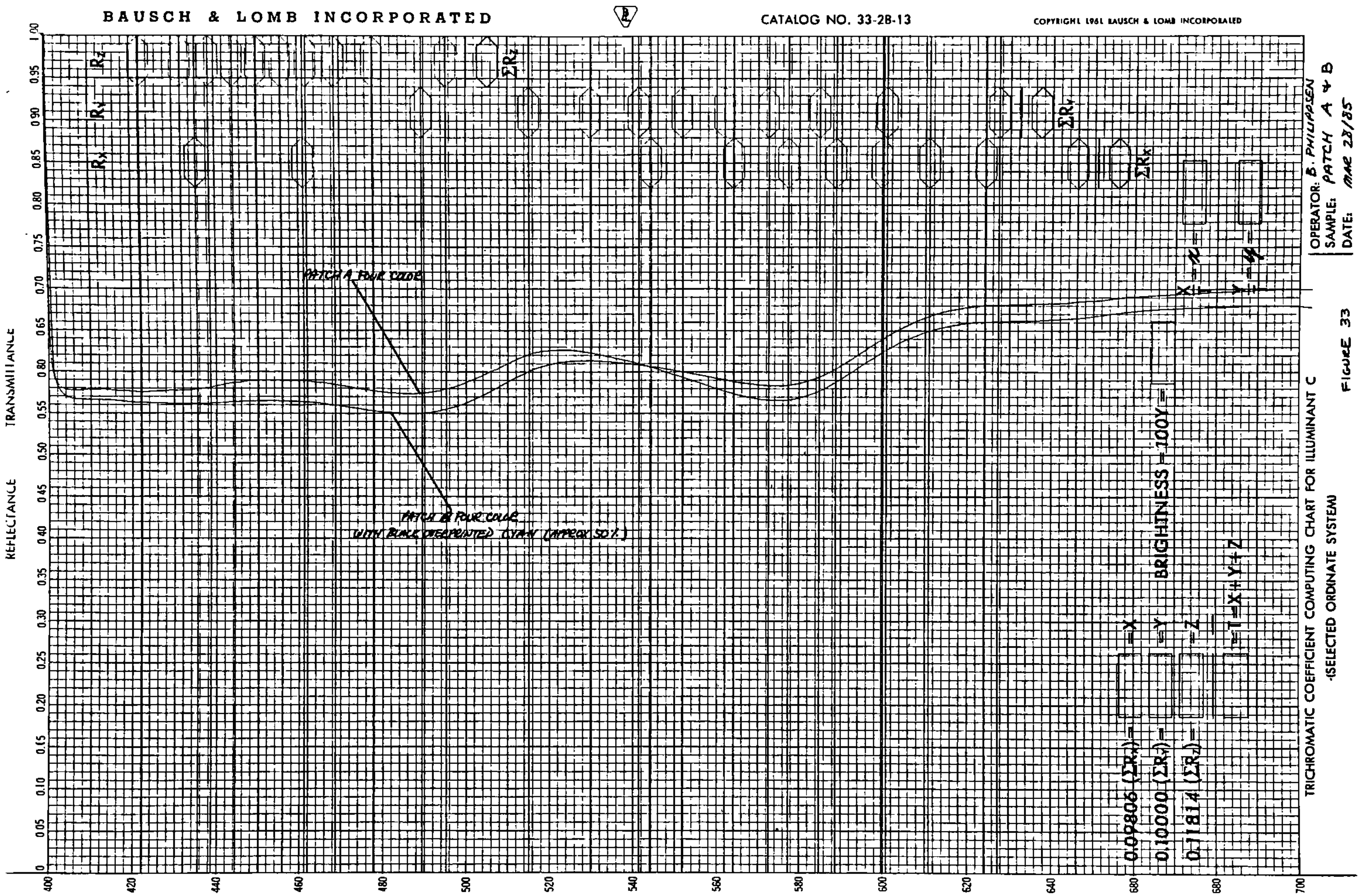


Figure 33. Full reflectance curves of tint patches "A", four color and "B", four color with black overprinting cyan approximately 50%.

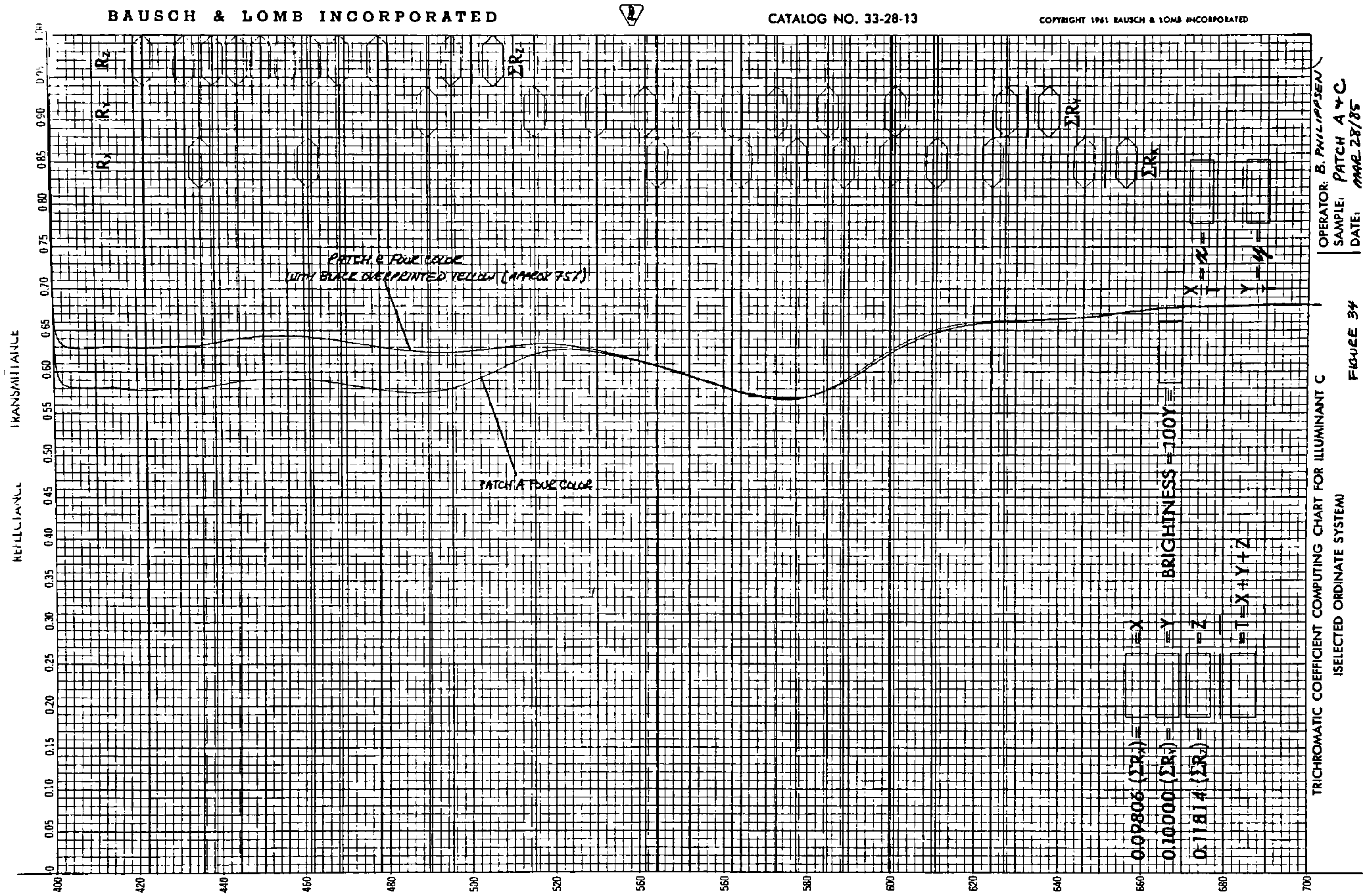


Figure 34. Full reflectance curves of tint patches "A", four color and "C", four color with black overprinted yellow approximately 75%.

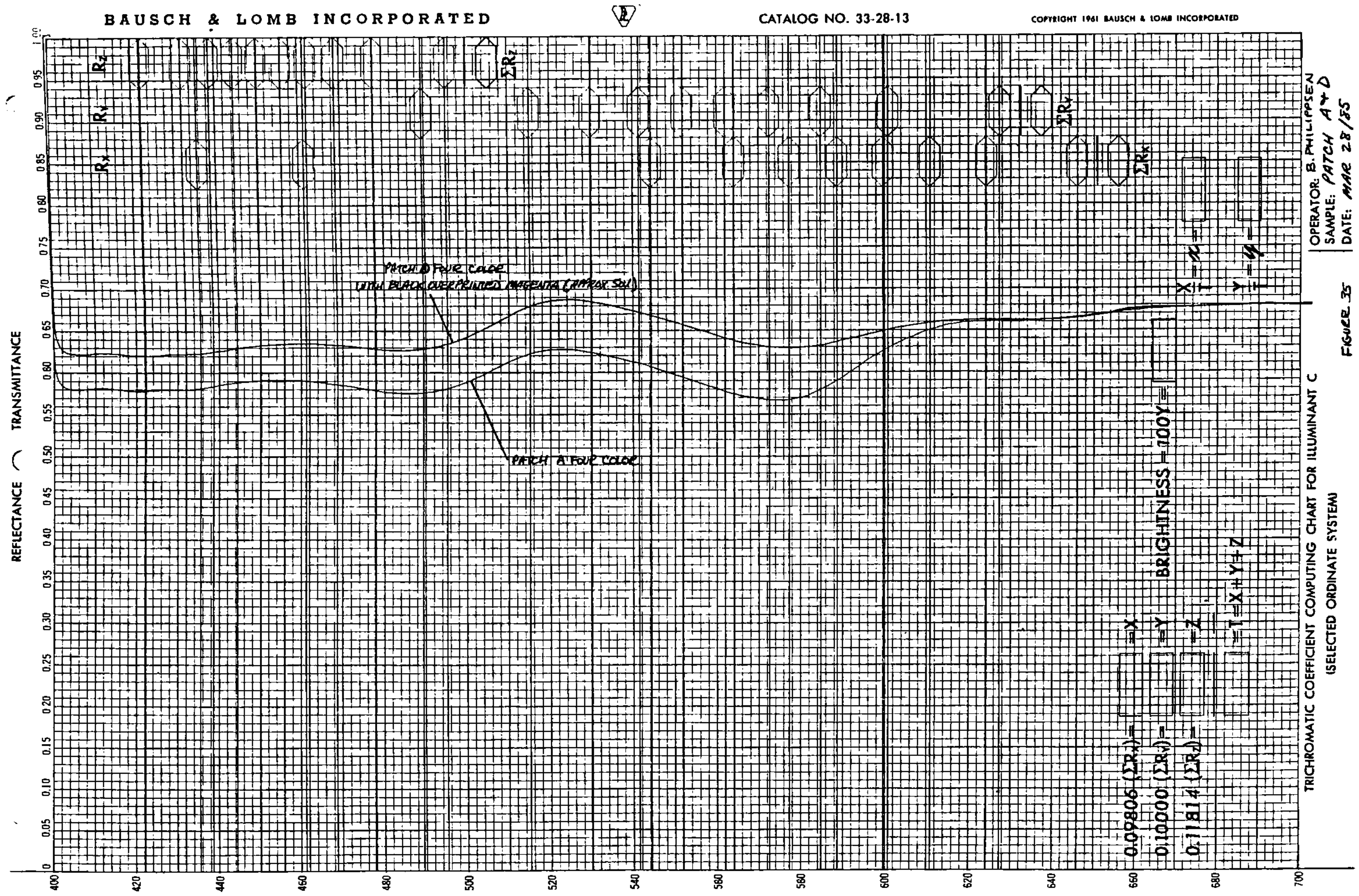


Figure 35. Full reflectance curves of tint patches "A", four color and "D", four color with black overprinted magenta approximately 50%.

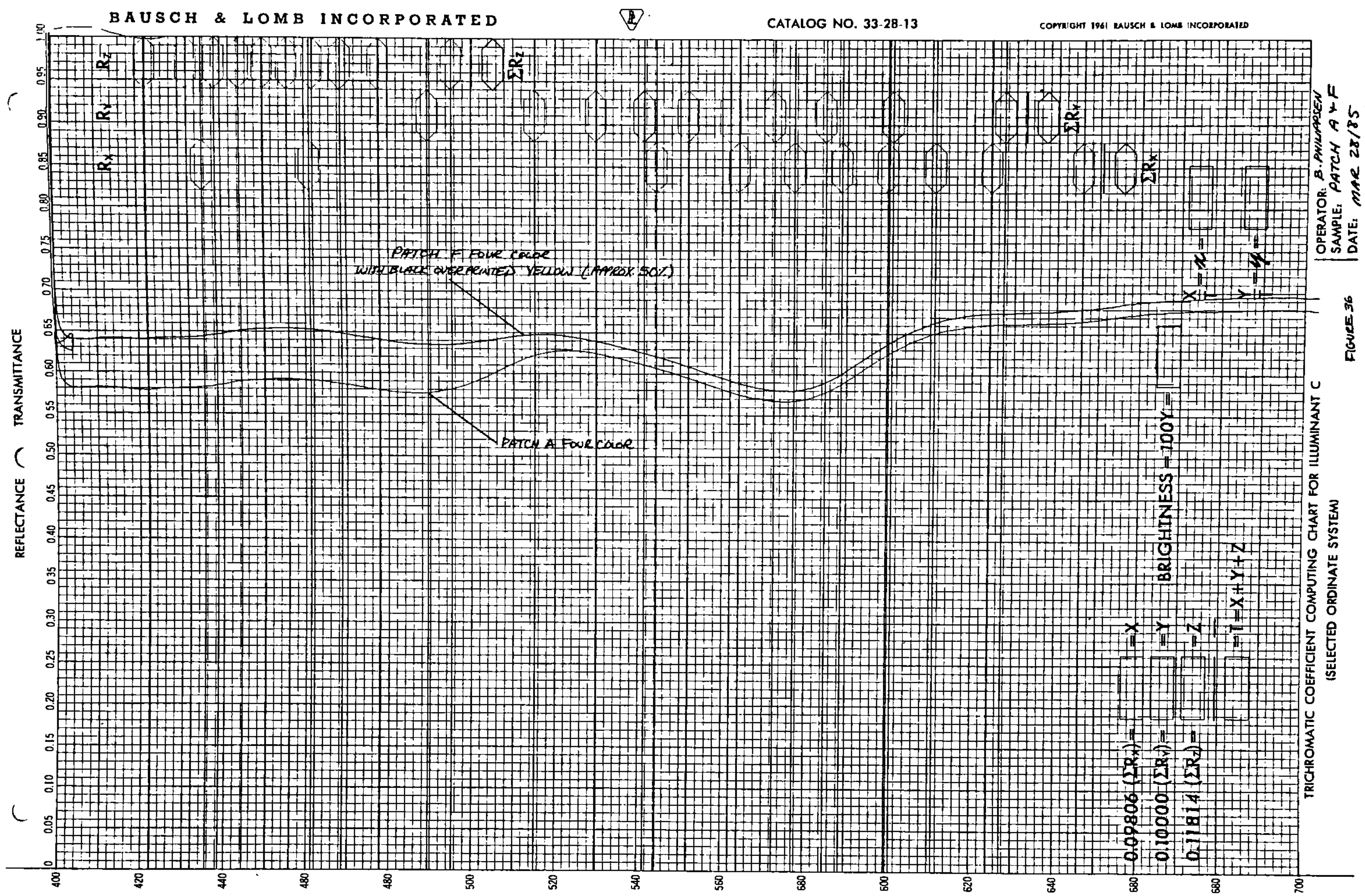


Figure 36. Full reflectance curves of tint patches "A", four color and "F", four color with black overprinted yellow approximately 50%.

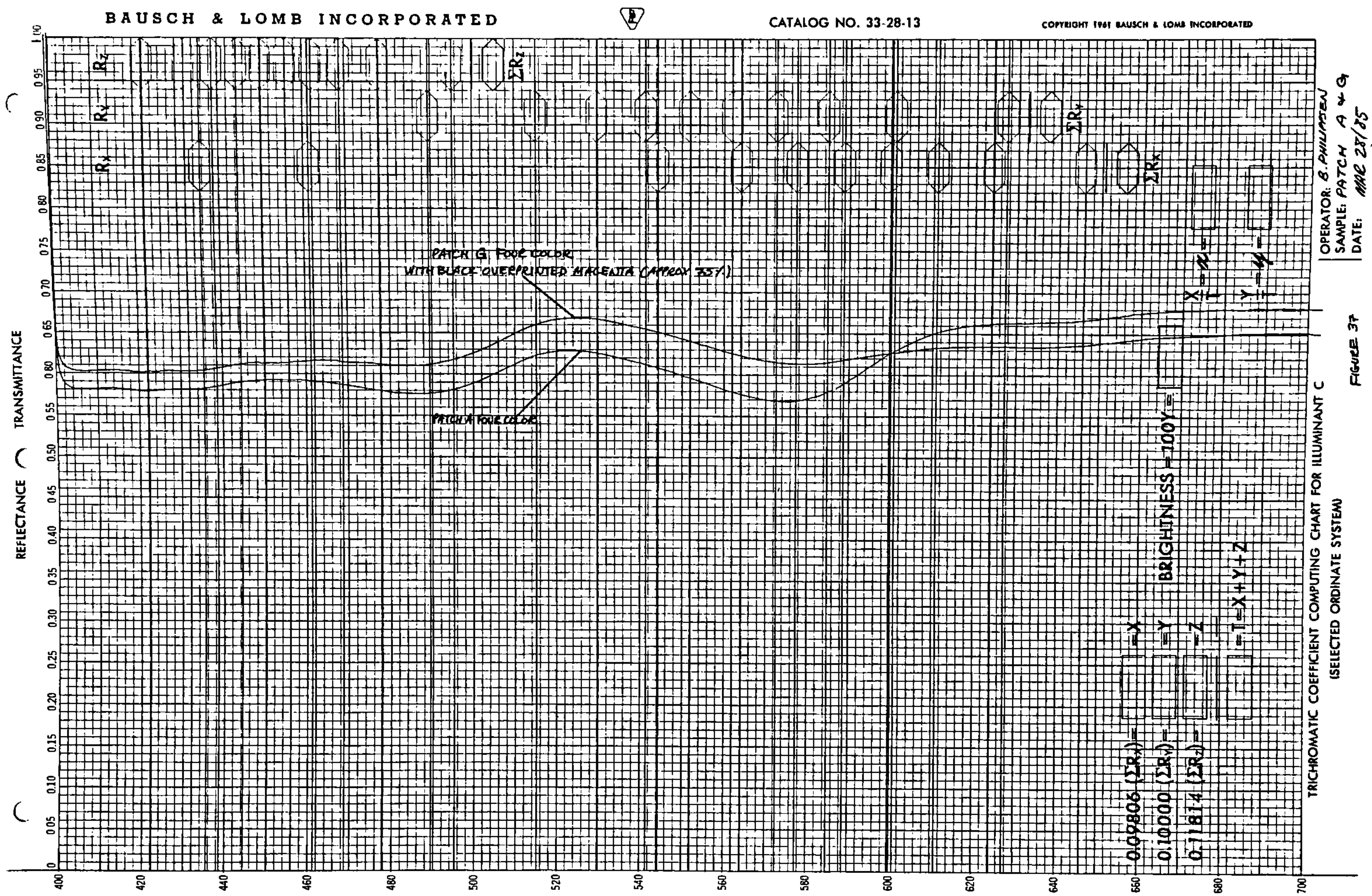


Figure 37. Full reflectance curves of tint patches "A", four color and "G", four color with black overprinted magenta approximately 75%.

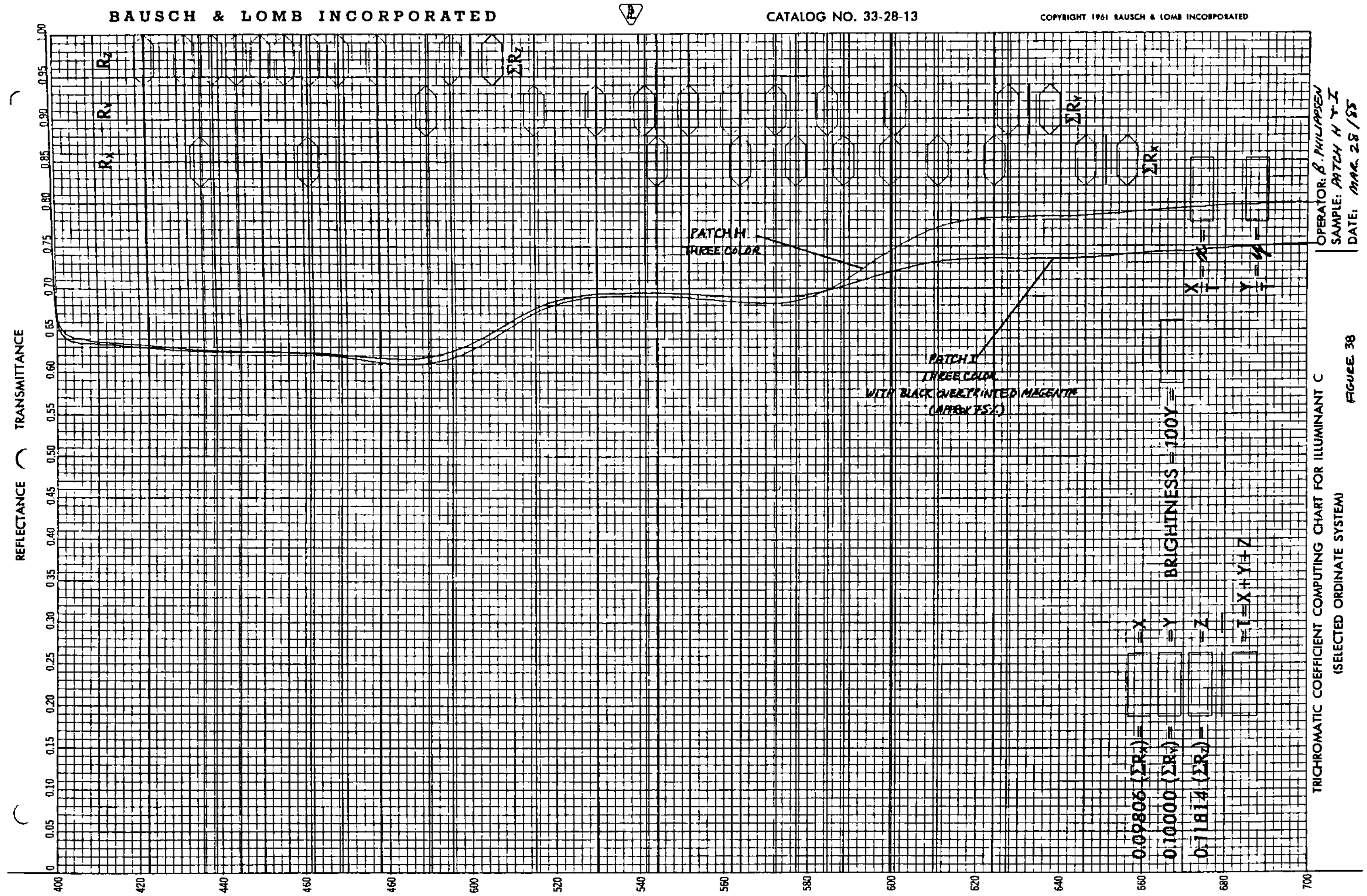


Figure 38. Full reflectance curves of tint patches "H", three color and "I", three color with black overprinted magenta approximately 75%.

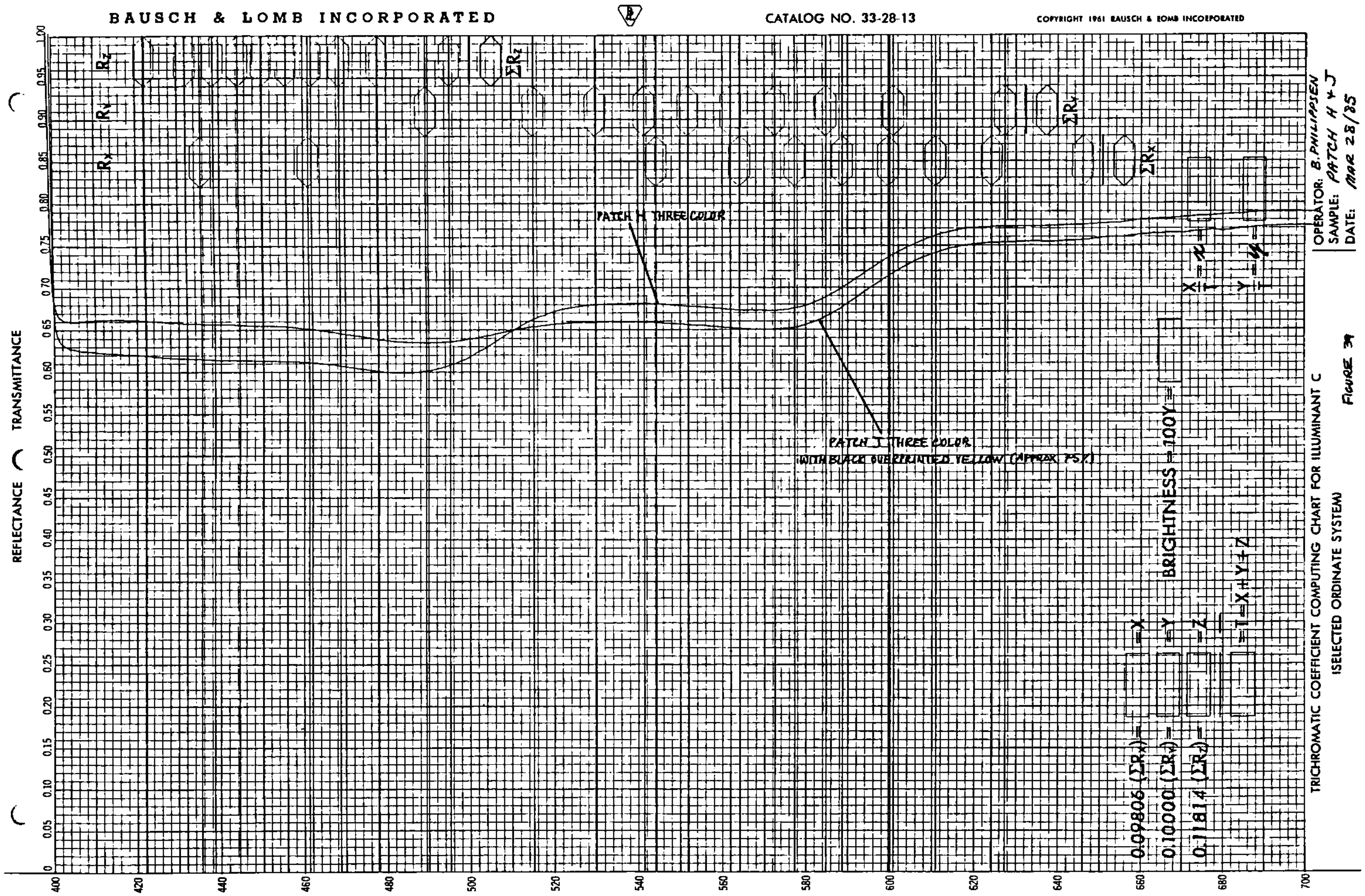


Figure 39. Full reflectance curves of tint patches "H", three color and "J", three color with black overprinting yellow approximately 75%.

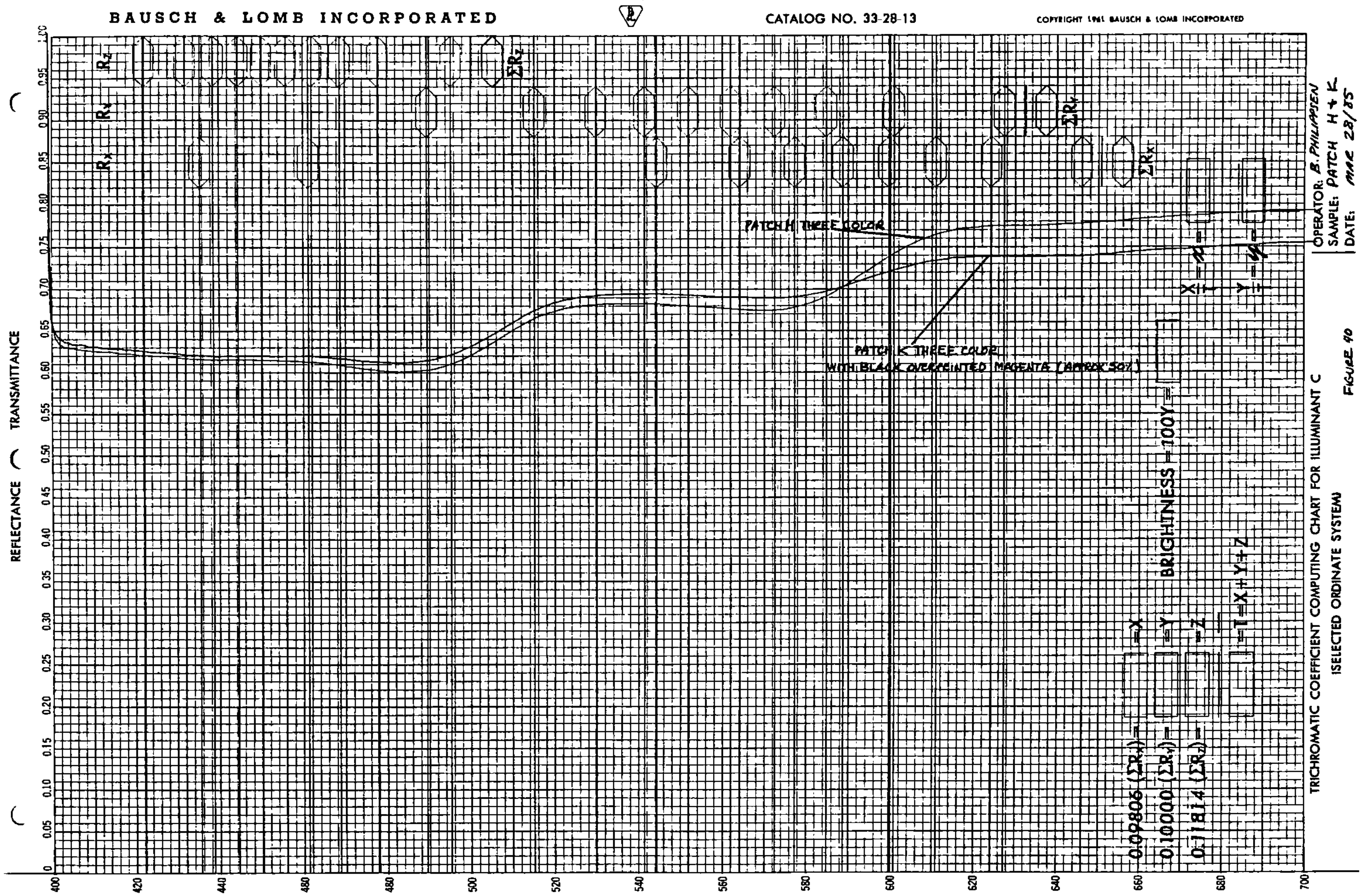


Figure 40. Full reflectance curves of tint patches "H", three color and "K", three color with black overprinted magenta approximately 50%.

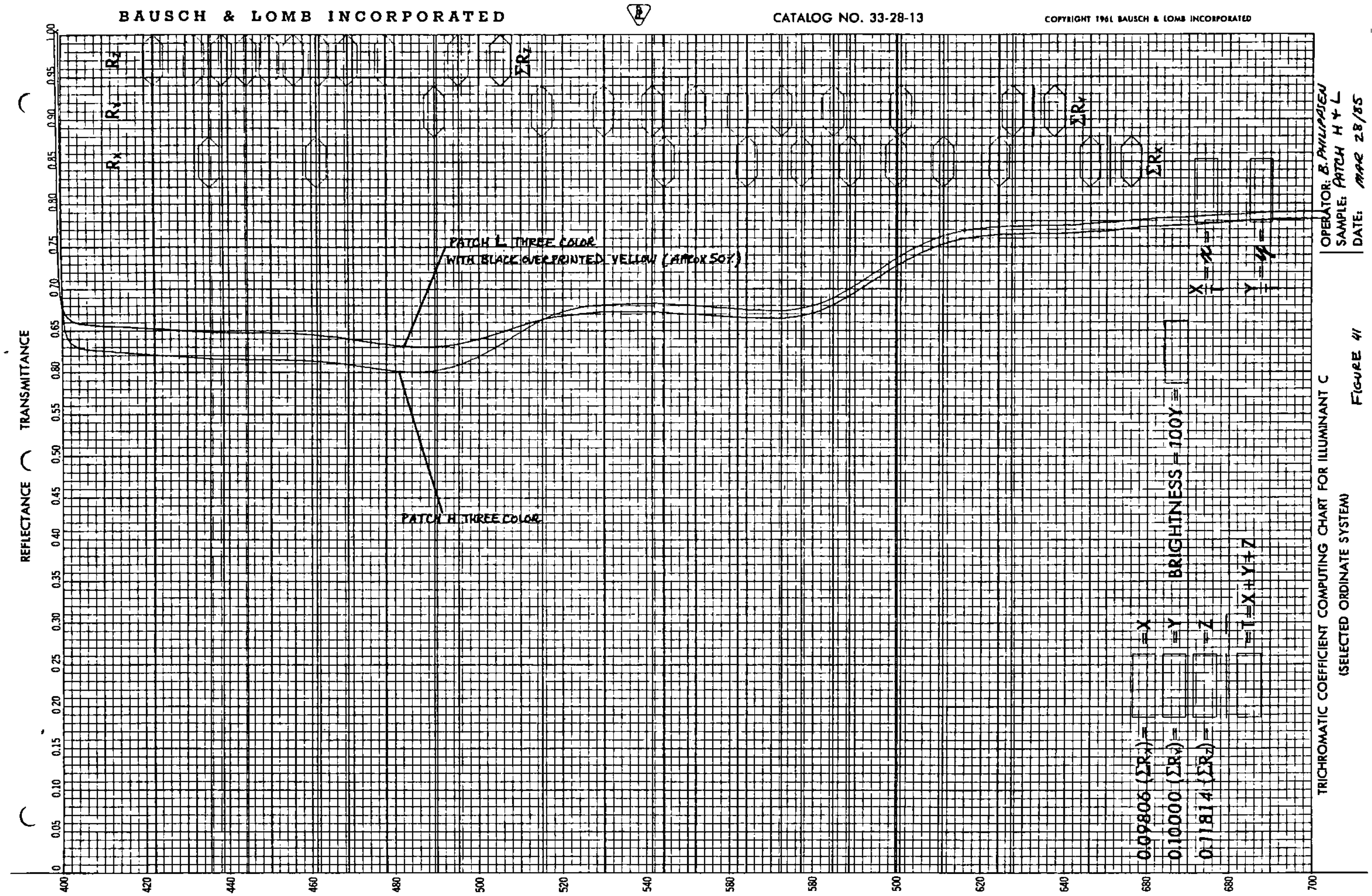
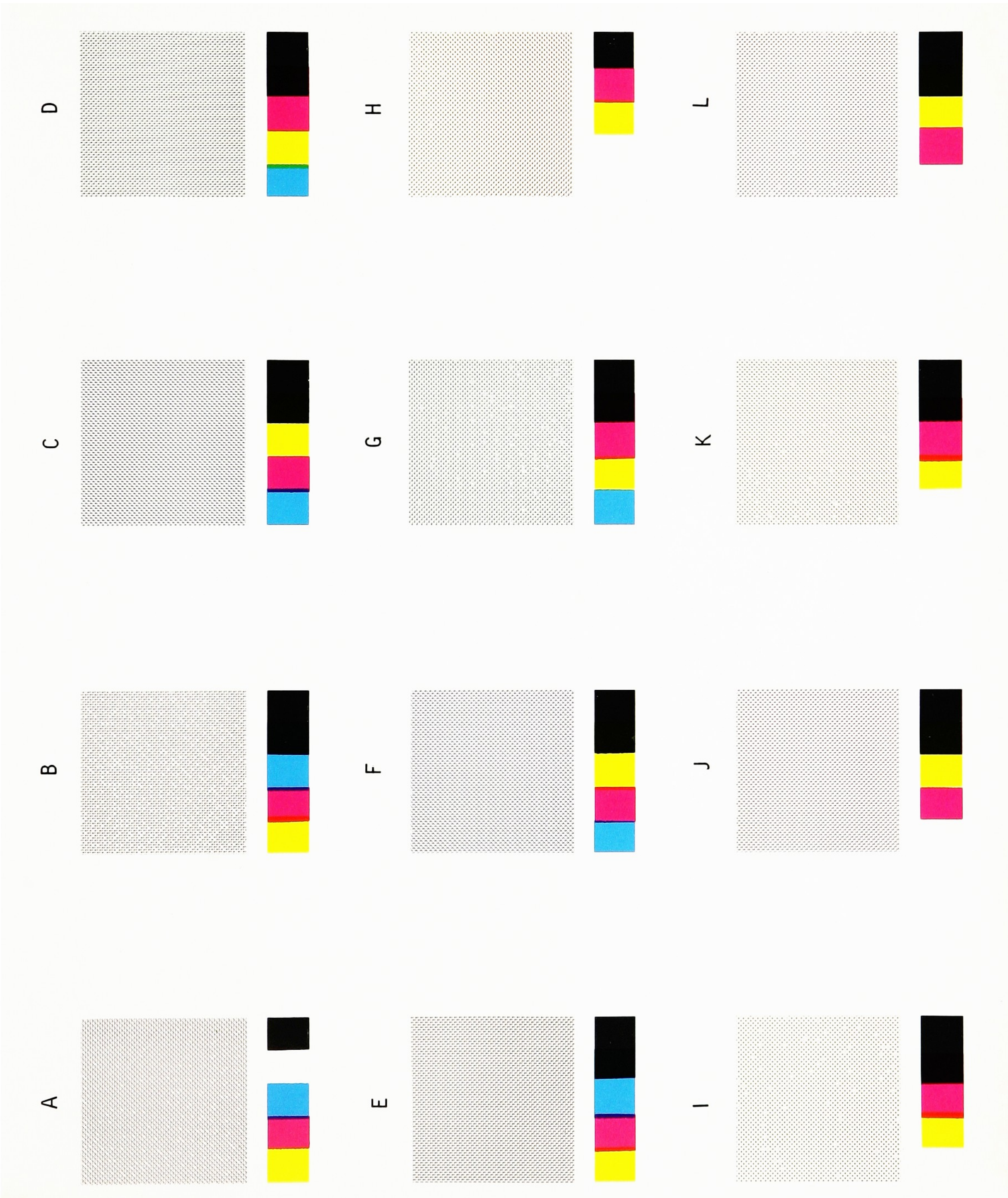


Figure 41. Full reflectance curves of tint patches "H", three color and "L", three color with black overprinted yellow approximately 50%.

APPENDIX B

PRINTED SAMPLE FROM EXPERIMENT

THESIS PROJECT: THE EFFECTS ON HUE RESULTING FROM BLACKDOT OVERLAP IN HALFTONE REPRODUCTIONS



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APPENDIX C

EQUIPMENT

Crosfield 640I Scanner

Douthitt Vacuum Frame

Carlson LI-44 Integrator

DuPont ATM 2 Cromalin Machine

28" x 40" Heidelberg SORSZ Press

Macbeth RD514 Reflection Densitometer

Bausch and Lomb 505 Spectrophotometer

APPENDIX D

MATERIALS

DuPont CSC-4 Film for 10%, 50 Line Positive Tint

Fuji FT-21 Film for 10%, 50 Line Negative Tint

DuPont Positive Cromalin

Fuji FPN Plates

Paper: 19" x 25" Barber-Ellis Extracote Gloss 100 lb.

Inks: Sinclair & Valentine, Kolith Process Yellow; YL 201320

Sinclair & Valentine, Kolith Process Magenta No. 3; RL 203489

Sinclair & Valentine, Kolith Process Cyan; BL 201324

Canadian Fine Color, Quadraset Prointensity Black; 5617505