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Project Title:

TESTING THE CONCEPT AND PRACTICAL APPLICATION

OF MULTIBAND RECONNAISSANCE

by

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This semi-annual progress report is submitted in partial fulfillment of research performed under NASA sponsorship to cover the reporting period from October, 1966 through March, 1967. It contains descriptions and selected illustrations of work already performed, work currently in progress and work contemplated for inclusion in the final report to be submitted in September, 1967.

Introduction

The primary objectives of this research are (1) to define the important concepts comprising "multiband reconnaissance" and (2) to demonstrate the usefulness of this technique by means of image examples from which positive target identifications can be made. Tone discriminations that are "enhanced" by color additive techniques are also incorporated as an important aspect of this research. The making of accurate target identifications from multispectral tone signatures is necessary if meaningful interpretations are to be made eventually of earth orbital imagery.

A multiband approach for reconnaissance systems is based on the concept that unique tone signatures may only be obtained by tone analysis of those targets imaged in more than one spectral band. While two or more targets may reflect similar amounts of energy in any one spectral band, it is unlikely that these targets will reflect the same amount of energy in all spectral bands for which a remote sensing capability exists. Hence, if the targets are sensed in two or more properly selected selected bands, target discriminations based upon resultant tone signature contrasts are greatly improved.

Tone Signature Analysis

The reason for placing great emphasis on image tone signatures is that image analysts depend largely upon target tone renditions of imagery obtained from high altitudes due to the relative degradation of other related identifying characteristics such as target geometry and texture. Before suitable interpretations can be made from this airborne or spaceborne multiband imagery, however, it is necessary to know the spectral response of each terrain feature that is to be identified. It is these spectral responses, together with the detector sensitivity (film emulsion or electronic signal, etc.), filter transmittance, and illumination level (solar energy, primarily), that are transformed into distinct greylevel tones or color renditions.

In order to study tone responses (for target identification) without the aid of target geometry or texture relationships, a specially designed color panel was constructed which could be readily photographed using a large number of film-filter combinations. Figure 1 shows a print from an Ektachrome exposure of this color panel depicting the colors and backgrounds used. Numerous exposures have now been made of this color panel, using a Polaroid panchromatic type film and fifteen different Wratten gelatin filters. Figure 2 illustrates shifts in tone response as a function of just two of these filters: WR-25A and WR-47B. By examining these tone shifts in all the film-filter combinations used, information leading to accurate target identification (in this case, target color identification) is assembled. Some of these preliminary results are tabulated in the Appendix.

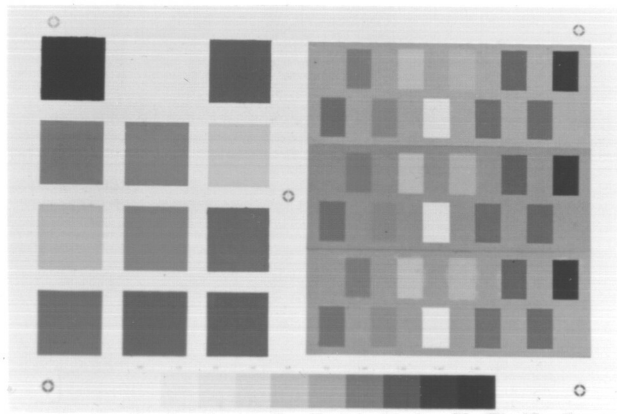
The energy source used for these exposures consisted of four 150 watt flood lamps directed from both sides of the panel; all optimum exposures were obtained by bracketing around that camera setting which gave the maximum negative density range between the black and white steps on the greyscale strip. The optimum exposure from each set of film-filter combinations was then made into a $3\frac{1}{4}$" x 4" lantern slide positive transparency. Some preliminary trials to test registration problems have been made and the results so far have been encouraging. Some difficulty has been encountered in attempting to produce good prints from color negatives or color transparencies because of color balance problems. We have found it helpful to include a suitable color chip with print requests which the commercial processing company can use as a reference. Without this sort of reference, we are apt to obtain less desirable photo prints, especially with some of the exotic false-color renditions we would like to study.

Color Composites by Color Additive Techniques

Figures 3 and 4 contain illustrations produced by simultaneously projecting various film-filter combinations through selected Wratten color filters. Both the technique and the apparatus are relatively simple, the main problem being that of getting the projected transparencies in common register on a translucent screen. Color composites formed in this manner can then be viewed or photographed from behind the screen. The total number of possible color composites is quite large considering available filters (15) and projectors (6). From densitometric analysis of the lantern slides, proper color filters will be specified for maximum enhancement contrasts both for (1) any pair of the color targets, and (2) the greatest number of color targets. This analysis is currently in progress. Once the specifications for color rendition can be quantified from a controlled model (such as the color panel described), it remains for practical application tests to be made of terrain examples. The principal investigator has, already in hand, numerous examples from various portions of the electromagnetic spectrum from which such tests can be made. In addition, a proposed experiment to be conducted at the Davis campus water tower platform will yield imagery and photography of cereal crops and range grasses that can be incorporated in this enhancement work.

The advantage of color composites derived from color additive processes is based on the concept that one color-enhanced image--derived from two or more black and white images obtained in different portions of the spectrum--is more interpretable than the original black and white images used in its composition. It is difficult to interpret between imaged tone shifts in two, three, or more black and white film-filter combinations. Even when they are combined to form one black and white composite, the tendency is to "mask" or reduce important differences in certain or all features to be identified. With color additive techniques these differences are enhanced by the resulting color renditions that are possible and the more varied contrasts that can be produced, rather than masked.

By referring to Figures 3 and 4, it will be noted that different renditions are possible with various color filters. In Figure 3, the vegetation has been rendered in two colors, "red" and "green". This was accomplished by placing these colored filters in front of the IR-89B black and white transparency for each exposure. But notice the apparent



<u>Figure 1</u>: Color Panel Display.

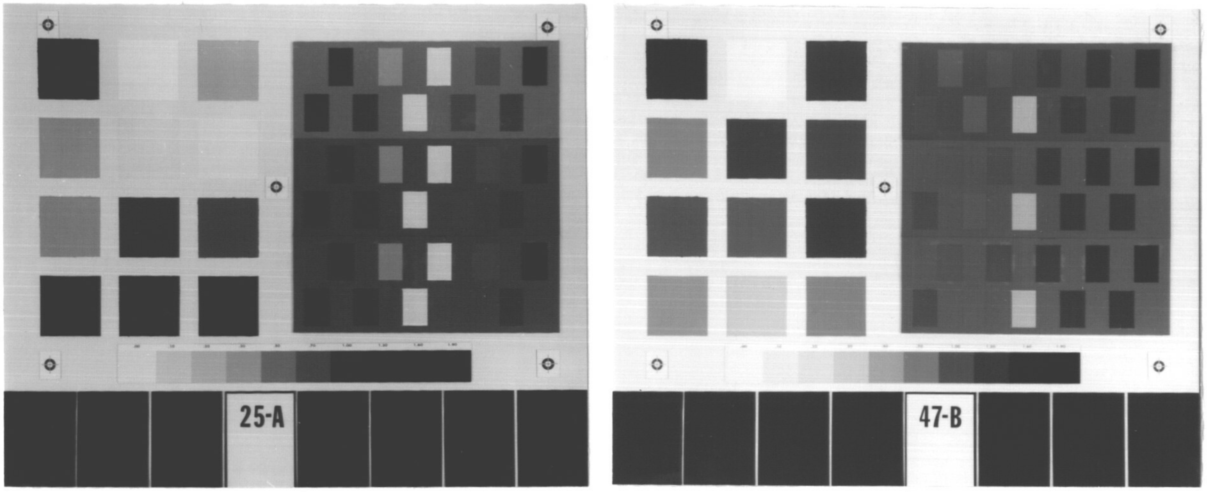
The above print is from an Ektachrome exposure and represents a true rendition of colors used in the color panel mentioned in the text. These target colors (egg tempera pigments) were applied directly to the board surface. On the right-hand portion of the panel additional colors were applied to three different-colored background surfaces: dull brown at the top, charcoal in the middle, and flat green at the bottom. The same color appears on each of the three backgrounds in the same relative position. These ten colors were chosen to simulate vegetative, soil and related terrain colors. Included at the lower edge of the panel is a standard Kodak greyscale strip which can be used to calibrate the tones obtained on the black and white photography.

level of contrast achieved within each vegetation rendition. The left-hand illustrations of each show considerably more contrast than the right-hand examples. The viewer might get a false impression of "total live vegetation" if only the right-hand color composites were examined. The good contrast achieved by the particular combination of color filters used for the left-hand illustrations points out the need for quantifying densities as a means of selecting color filters which will produce the best results possible using this technique.

Figure 4, despite its poor resolution, also shows the advantages of rendering combined densities into one color composite for interpretive purposes. The separate black and white transparencies from which this color composite was made each possess the density or tonal anomalies from which this illustrations is derived. The process of interpreting the scene is greatly improved, however, when one color photo illustration is used instead of three black and white illustrations of the same area.

Work Contemplated

The process of selecting appropriate color filters with which to obtain the most interpretable color composites is being analyzed currently, with the intention that tables be prepared and included in the final report. Tests will be performed to determine how well and efficiently target distinctions can be performed using these tables. More illustrations of the type included in this report will be used to demonstrate the usefulness of color composites for a variety of target identifications. The experiment to be conducted at Davis will provide new image resources from which further tests of image density relationships can be studied.



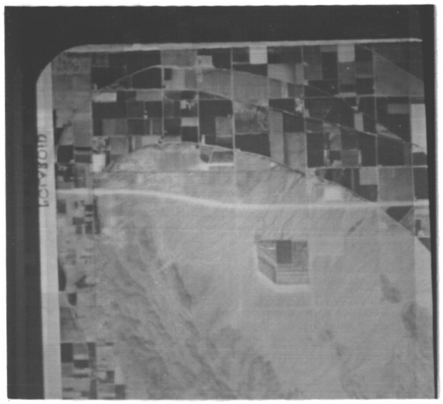
WRATTEN 25-A　　　　WRATTEN 47-B

Figure 2: Tone Shifts Between Two Film-Filter Combinations

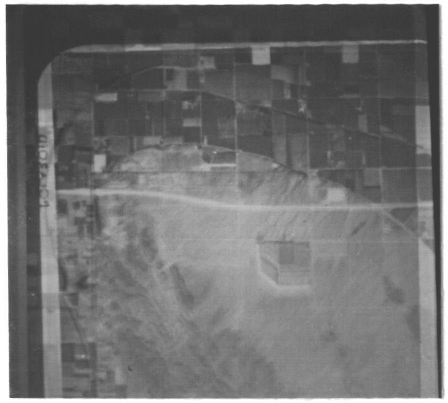
The above illustrations indicate shifts in tone response due solely to the use of different transmittance filters--the other factors contributing to these tones (vis., film sensitivity, reflected target energy and light source) were unchanged for each exposure. Note the marked shift in tone response for the orange and yellow targets on each exposure. Contrasts are also very marked in the background targets, both between exposures and within exposures. These shifts are resolved by noting the ranges of filter transmittance: the Wratten 25-A does not transmit light energy below wavelengths of 580 to 600 millimicrons; Wratten 47-B transmits light energy only in a small portion of the spectrum, namely, 380 to 490 millimicrons.

These tone shifts are exploited in color additive techniques whereby selected color filters are placed in front of simultaneously projected lantern slides of these and other film-filter combinations, rendering color images of greater interpretability than the black and white illustrations.

"Red Vegetation" Rendition

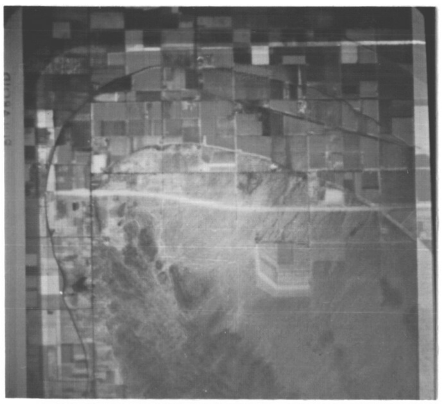


Good Contrast



Poor Contrast

"Green Vegetation" Rendition



Good Contrast

Poor Contrast

Figure 3: Color-Enhanced Examples of Tucson Multispectral Photography.

The above four illustrations are the result of projecting, in common registration and through colored filters, three different black and white positive transparencies made from high-altitude photography of the Tucson, Arizona area flown last year. The film-filter combinations used were: (1) Panchromatic-25A, (2) Panchromatic-58, and (3) Infrared-89B. For a more detailed description of the interpretation of these color composites, see text.

<u>Figure 4</u>: Color Composite of a Rangeland Area in Northern California.

This illustration indicates the importance of tone renditions by color additive techniques. In this example, the identification of terrain types is greatly improved by color-enhancing through the use of selected color filters. The terrain types described below were difficult to interpret on the original black and white transparencies from which this illustration was derived. By contrasting color renditions (together with accurate ground truth information) the following identifications were made:

(1) Light blue areas - low sagebrush type.

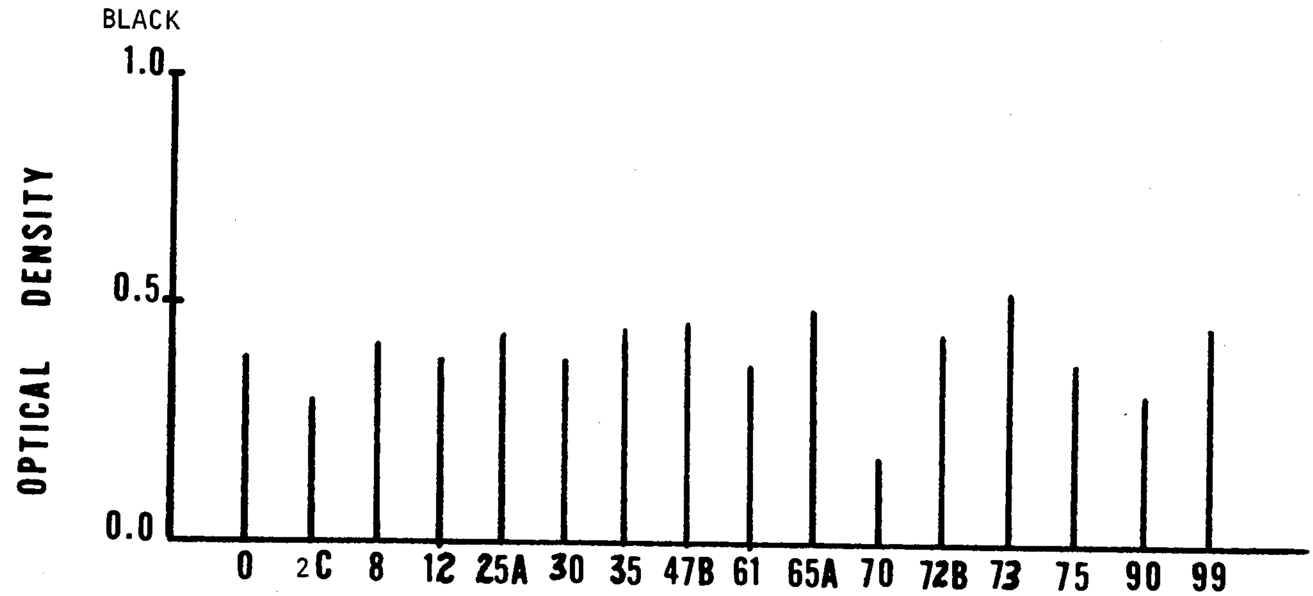
(2) Green areas - wet meadow type dominated by rushes (<u>Juncus</u> sp.)

(3) Red-orange areas - wet meadow sites dominated by sedges, grasses and forbs; very high in IR reflectance.

(4) Dark areas - standing water from adjacent springs.

APPENDIX

The tables which follow contain density measurements taken from images of the color panel described in the text. Each color used in the panel is tabulated listing the optical density obtained for each film-filter combination included in this analysis. The data are unadjusted for differences between film-filter exposures, etc., but are included to give some relative indications of tone contrasts for the different filter characteristics.


BLACK
1.0
0.5
0.0
OPTICAL DENSITY
0
2C
8
12
25A
30
35
47B
61
65A
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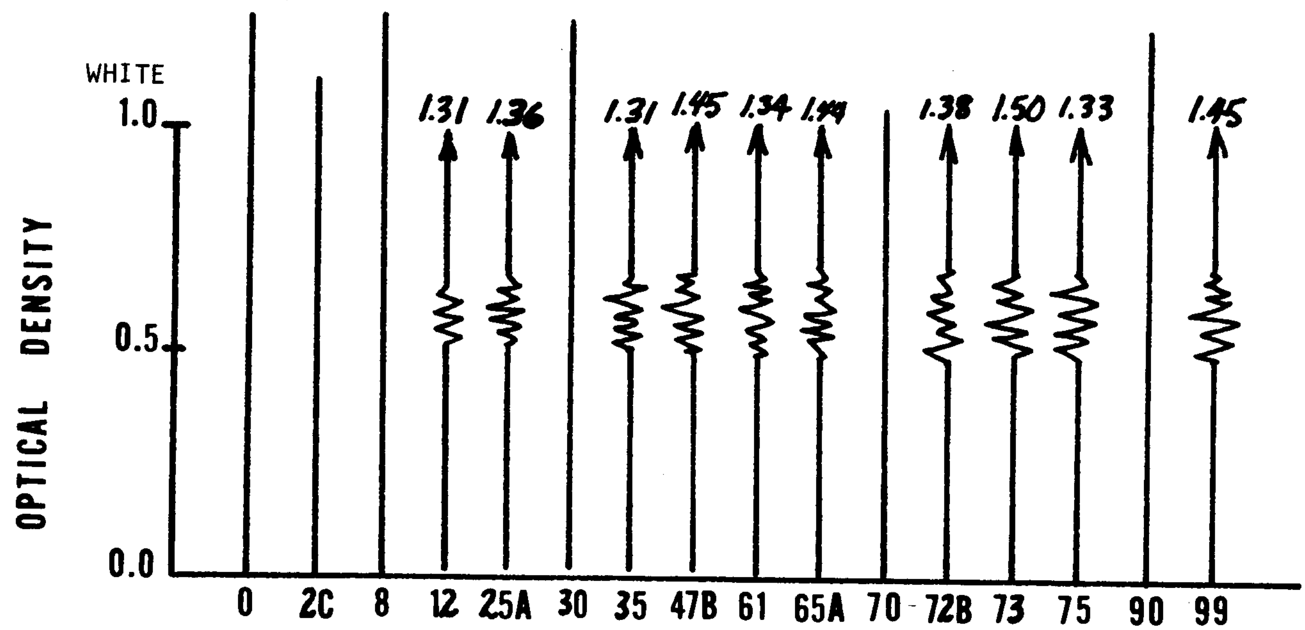
72B
73
75
90
99


WHITE
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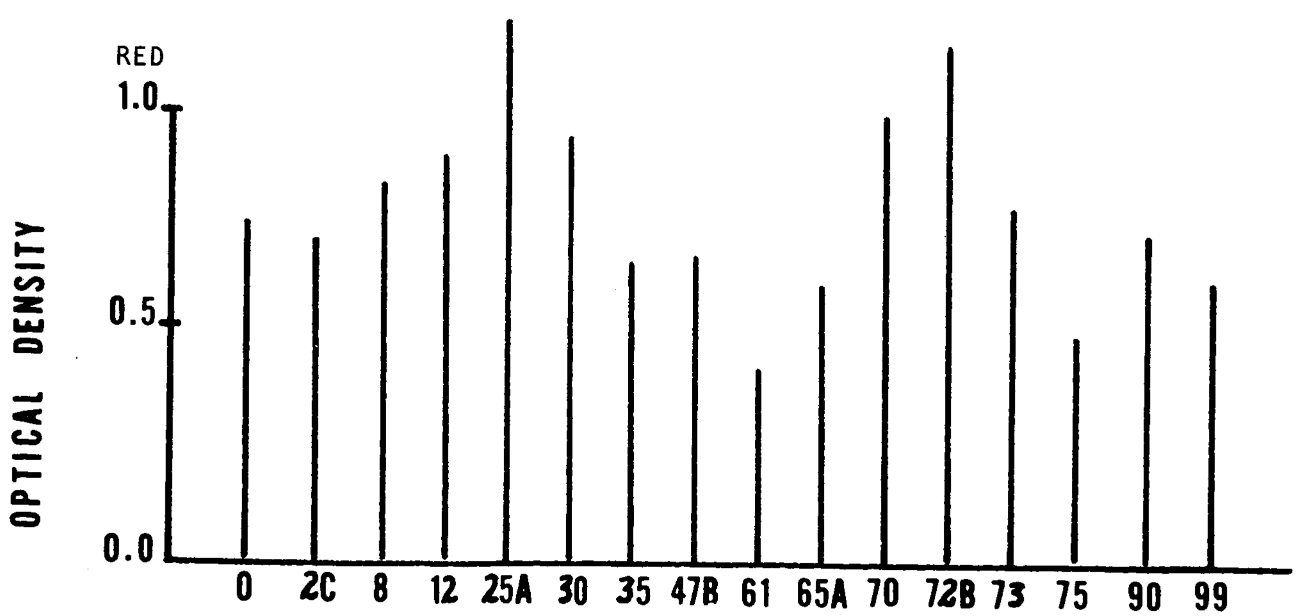
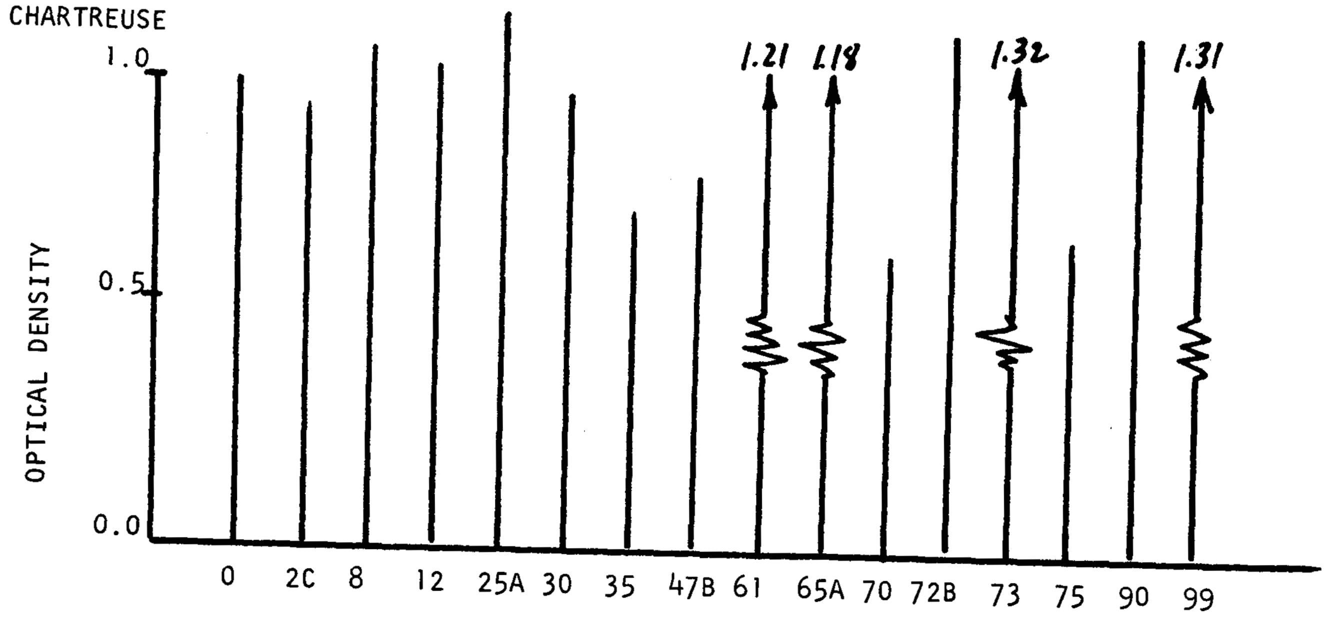
0.5
0.0
OPTICAL DENSITY
1.31
1.36
1.31
1.45
1.34
1.44
1.38
1.50
1.33
1.45
0
2C
8
12
25A
30
35
47B
61
65A
70
72B
73
75
90
99


RED
1.0
0.5
0.0
OPTICAL DENSITY
0
2C
8
12
25A
30
35
47B
61
65A
70
72B
73
75
90
99


CHARTREUSE
1.0
0.5
0.0
OPTICAL DENSITY
1.21
1.18
1.32
1.31
0
2C
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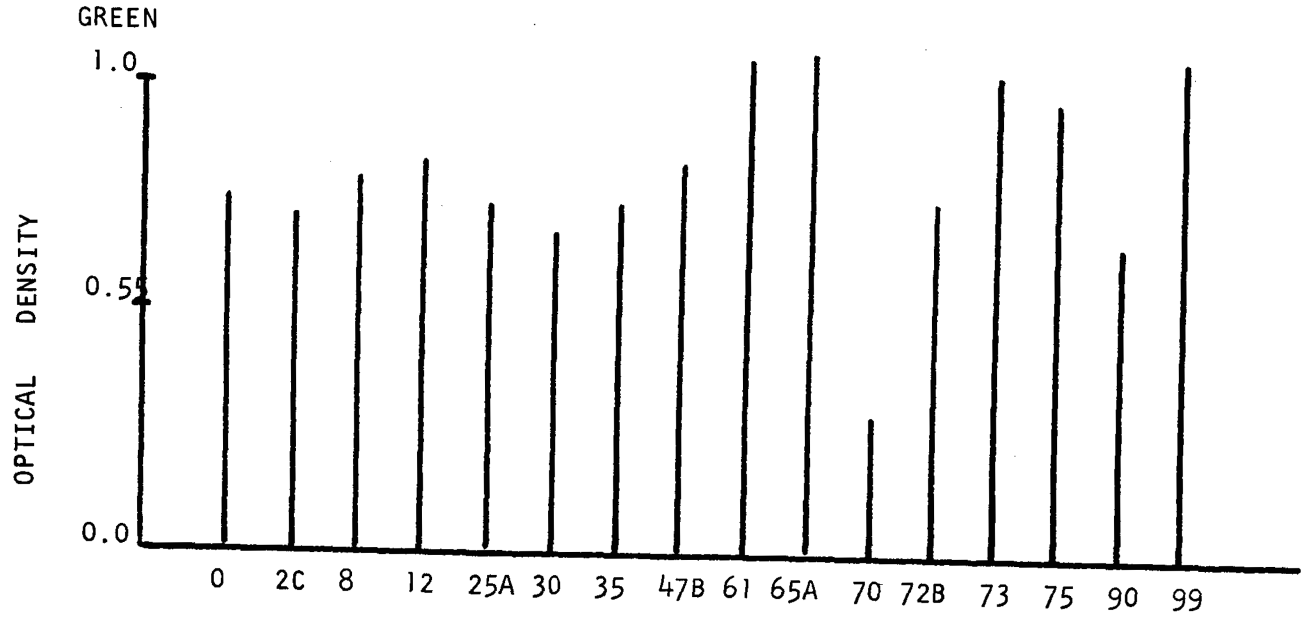
12
25A
30
35
47B
61
65A
70
72B
73
75
90
99


GREEN
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0.0
OPTICAL DENSITY
0
2C
8
12
25A
30
35
47B
61
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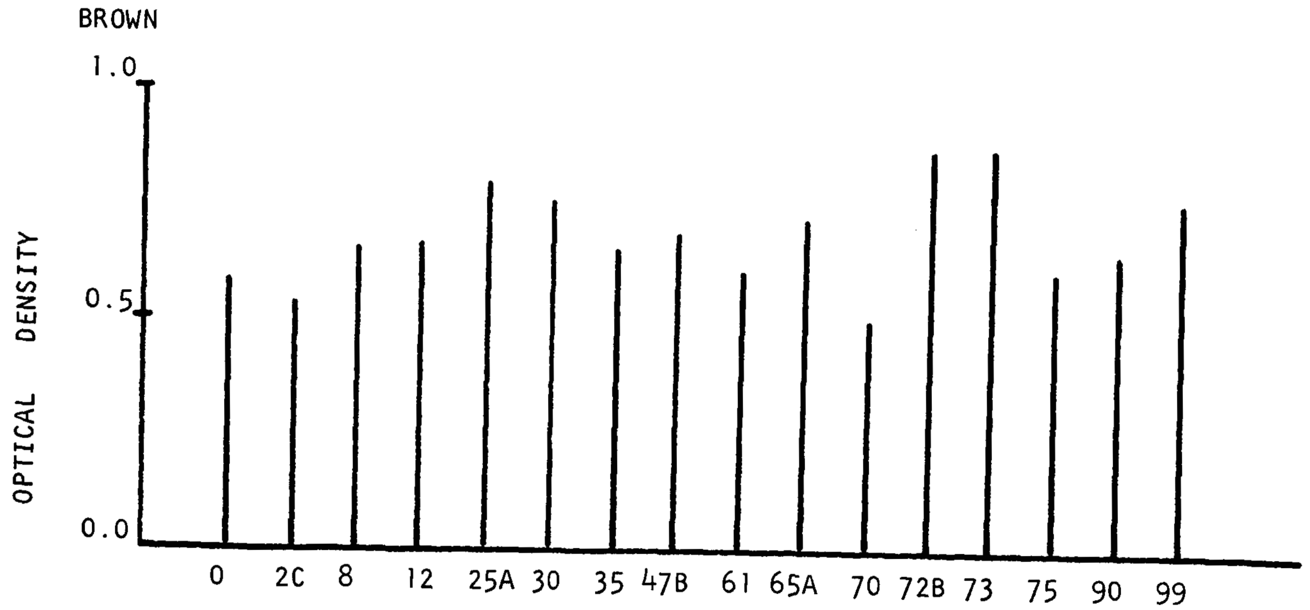
72B
73
75
90
99


BROWN
1.0
0.5
0.0
OPTICAL DENSITY
0
2C
8
12
25A
30
35
47B
61
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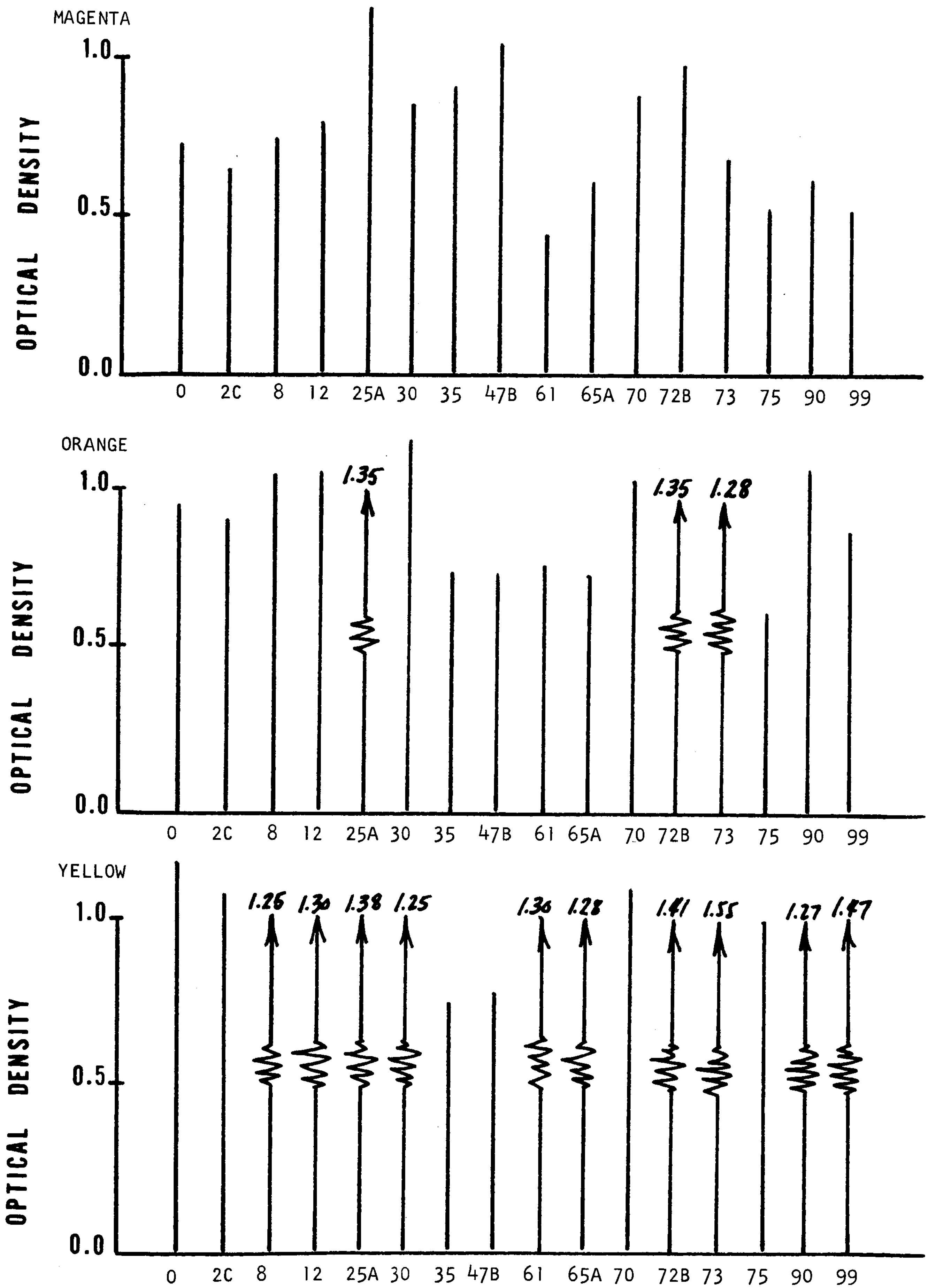
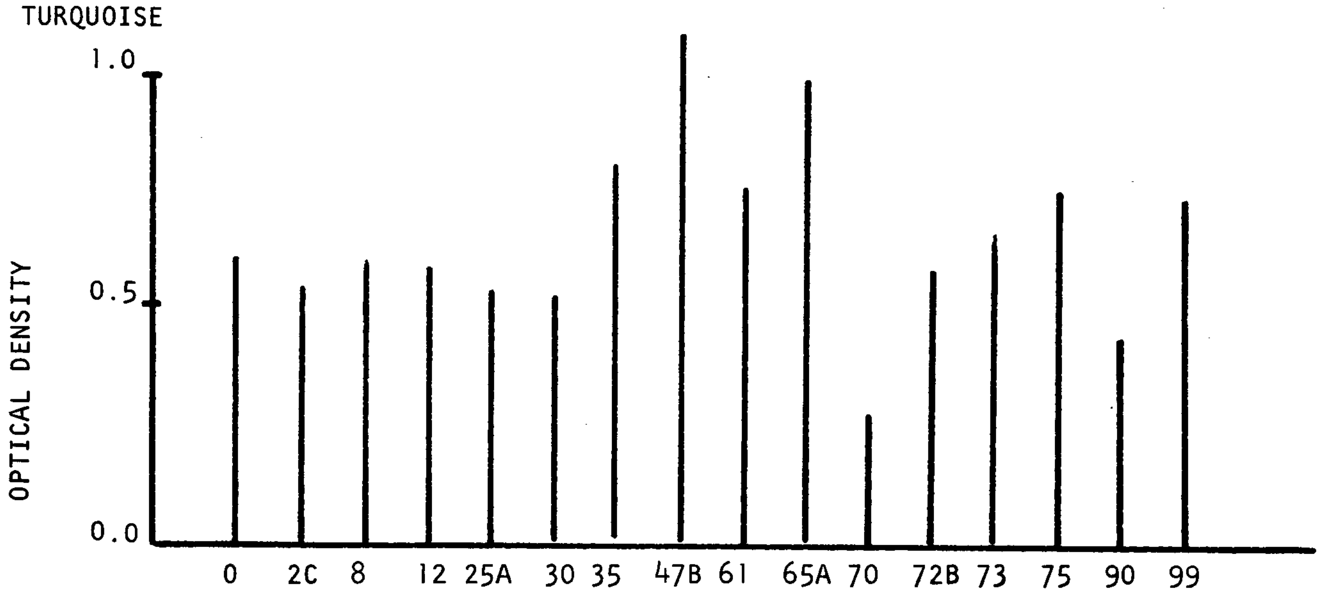
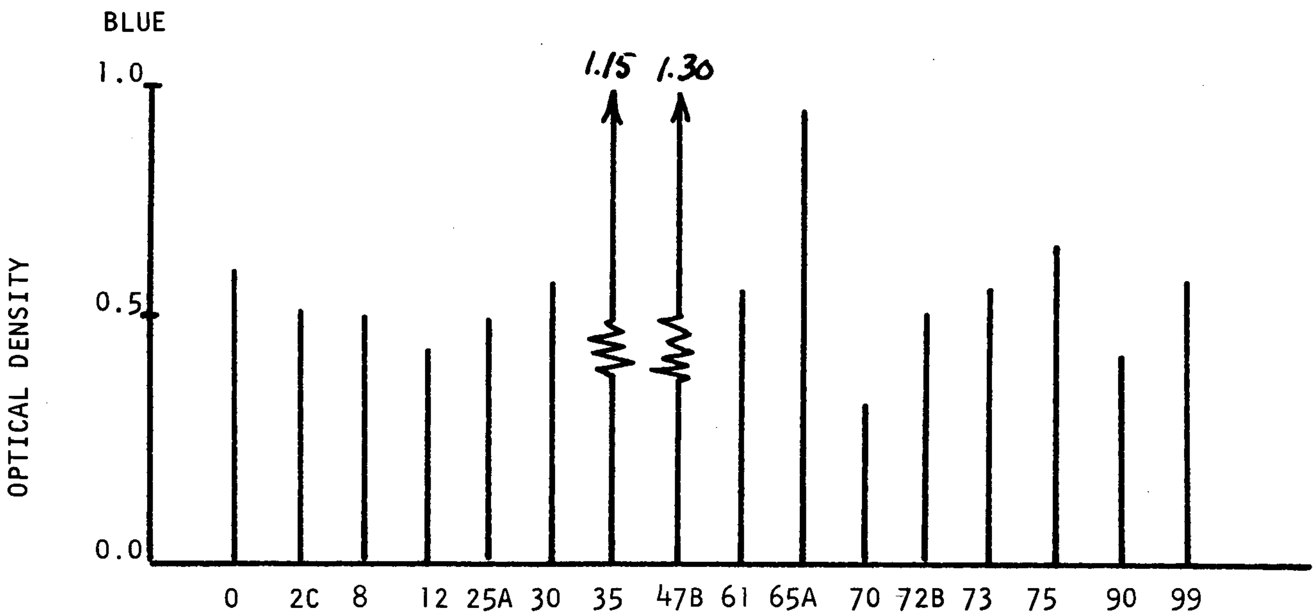
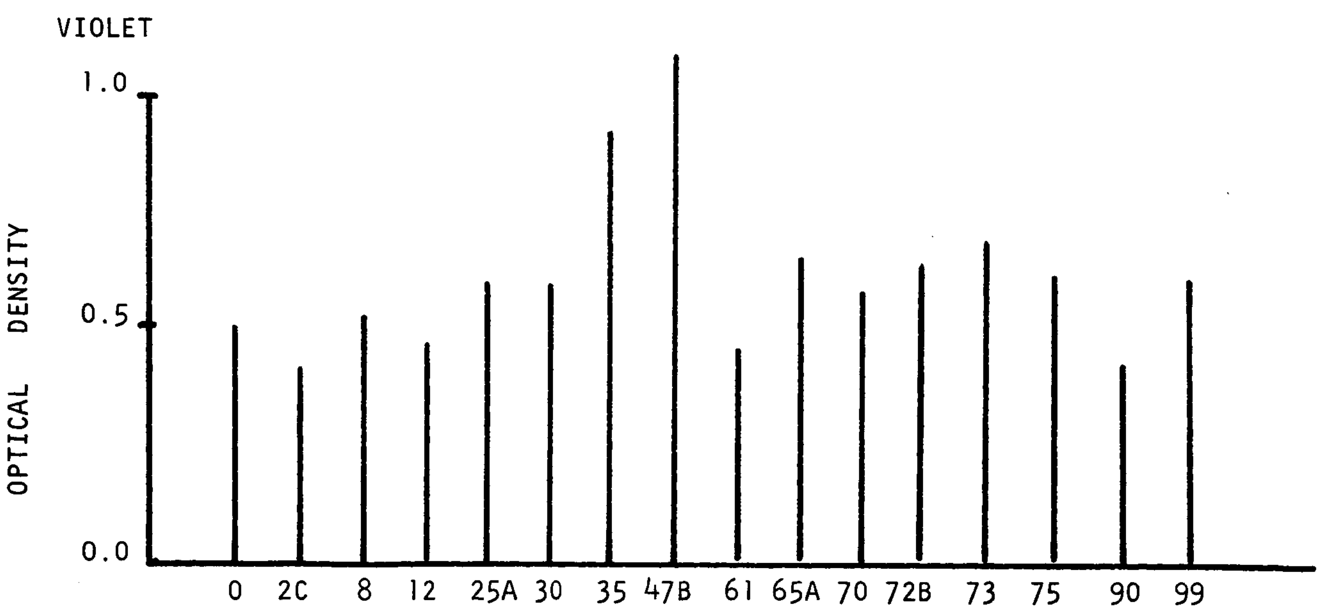
72B
73
75
90
99


MAGENTA
OPTICAL DENSITY
1.0
0.5
0.0
0 2C 8 12 25A 30 35 47B 61 65A 70 72B 73 75 90 99
ORANGE
OPTICAL DENSITY
1.0
0.5
0.0
1.35
1.35 1.28
0 2C 8 12 25A 30 35 47B 61 65A 70 72B 73 75 90 99
YELLOW
OPTICAL DENSITY
1.0
0.5
0.0
1.26 1.30 1.38 1.25
1.36 1.28
1.41 1.55
1.27 1.47
0 2C 8 12 25A 30 35 47B 61 65A 70 72B 73 75 90 99


TURQUOISE
1.0
0.5
0.0
OPTICAL DENSITY
0 2C 8 12 25A 30 35 47B 61 65A 70 72B 73 75 90 99


BLUE
1.15 1.30
1.0
0.5
0.0
OPTICAL DENSITY
0 2C 8 12 25A 30 35 47B 61 65A 70 72B 73 75 90 99


VIOLET
1.0
0.5
0.0
OPTICAL DENSITY
0 2C 8 12 25A 30 35 47B 61 65A 70 72B 73 75 90 99