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A method for hue circle production using a dichroic color head, 35mm animation camera, luminance meter, and 35mm color reversal film

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A METHOD FOR HUE CIRCLE PRODUCTION USING A DICHROIC COLOR HEAD, 35mm ANIMATION CAMERA, LUMINANCE METER, AND 35mm COLOR REVERSAL FILM

by

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THESIS

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A METHOD FOR HUE CIRCLE PRODUCTION

USING

A DICHROIC COLOR HEAD, 35mm ANIMATION CAMERA,

LUMINANCE METER, AND 35mm COLOR REVERSAL FILM

1.0.0 Glossary

Brightness - the unmeasurable subjective visual sensation caused by the intensity of light. See Luminance. (White, Zakia, Lorenz, 1976)

Dichroism - the capacity of a substance to display two-thirds of the spectrum when subjected to a light source containing the entire spectrum. (Nadler, 1978)

Hue - the characteristic of a color permitting description as yellowish, reddish, bluish, greenish, etc. The presence of hue differentiates chromatic from achromatic colors. (Ostwald, 1969)

Luminance - the measurable intensity of light. See Brightness. (White, Zakia, Lorenz, 1976)

Threshold - the point at which difference in hue is first perceived. (Ostwald, 1969)

Transparency - a frame of processed 35mm color reversal film that has been mounted in a slide binder for viewing in a slide projector.

2.0.0 The Problem

The dichroic color head, 35mm animation camera, luminance meter, and 35mm color reversal film, in combination, can produce and record an array of hues. This system has a number of controls capable of numerous combinations of settings with which to produce the hues. Selecting a hue and then finding the specific combination of settings which will produce the hue in the projected transparency, poses a problem.

3.0.0 The Proposed Solution

A solution is to develop a reference base from which hues can be produced predictably and accurately. The reference base will be expressed by a hue circle on 35mm color reversal film using the equipment system described in 2.0.0.

A circle was chosen for the configuration of hues because there is no natural terminal point in the hue series. Beginning the series with any hue, and following the hue series sequence will return one to the beginning hue, i.e., beginning with yellow, the hue series sequence is orange, red, purple, blue, blue-green, green, yellow-green, and back to yellow. This characteristic of the hue series is best represented by placing the hues in a circle.

The hue circle and its method of production must exhibit the following qualities:

a. The hue circle will represent the visible hues of the spectrum.

b. The collective hues of the circle will represent a given range of brightnesses.

c. Each hue of the hue circle will be accurately producible by the given equipment system and film.

d. The hue circle and the method of its production will provide a foundation from which hues related to, but not physically produced in this study, can be predictably produced.

4.0.0 The Equipment System and Film

The dichroic color head, 35mm animation camera, luminance meter, and 35mm color reversal film are primarily used in the

production of 35mm multicolor transparencies. Therefore, the development of the hue circle presented in this paper will apply to multicolor transparency production using the same equipment assemblage and film.

4.1.0 Operational Description of the Equipment System and Film

Following is a listing and description of the equipment and film according to specific make, model and/or type. The functional application of each piece of equipment to the production of the hue circle is discussed. Descriptions pertain only to those functions used to produce the hues of the circle. Descriptions are also based on normal applications and use of the equipment listed with which the reader is assumed to be familiar. It must also be assumed that the reader has a basic knowledge of photography.

4.1.1 The Dichroic Color Head

The dichroic color head is the source of light, and, thus, of hue generation in the equipment system used. Specifically, I used a Beseler Dichro 23dga color head. The Beseler color head contains three dichroic filters which divide the 3200°K quartz-halogen light source into the three subtractive primary colors, cyan, magenta, and yellow. Each filter is exposed to the 3200°K light source by turning a dial, and each dial is divided into one-hundred and sixty increments. With the light source on, turning a dial towards 160 exposes a progressively greater amount of that filter to the light source. The light source contains the wave

lengths of the visible spectrum. When the 3200°K light is passed through a dichroic filter, one-third of the spectral wave lengths are subtracted from the light and the remaining two-thirds of the wave lengths are passed through the filter. The two-thirds of the passed spectral wave lengths compose the hue of light specific to the filter being exposed to the light source. Since the 3200°K light can be partially or totally filtered by use of the dials, the amount of the spectral wave lengths subtracted from the light is reciprocally proportional as the dial is turned towards 160, i.e., turning the cyan dial towards 160 subtracts a greater amount of red wave lengths from the light source and causes the projected light to appear more cyan in hue.

The three subtractive primary colors, when mixed in proper proportions, will produce any hue of the visible spectrum. (Time/Life, 1970) Varying hues are projected by dialing filter increment combinations in varying amounts. By altering the filter increment combinations, the entire range of hues of the spectrum can be produced.

4.1.2 The 35mm Animation Camera

A Forox single column 35mm animation camera equipped with a 55mm Nikkor lens was used to photograph the light emitted from the color head. The technical capabilities of the Forox camera fulfill the requirements for multicolor transparency production. Capabilities of the Forox making it applicable to hue circle production are: 35mm film

capacity, wide control of shutter speed, accurate film movement registration, and physical stability of both camera body and photographic field.

The Forox camera was used in conjunction with an animation compound equipped with a glass platen and beneath this an opening covered with a pane of white flash glass.

4.1.3 The Luminance Meter

Luminance level readings were made with a Spectra Combi II luminance meter using only the following method of metering in the production of the hue circle; with ASA set to film specifications and meter set in reflected light reading mode, the meter was placed flat, centered on the platen glass with the reflected light aperature facing down, and the reading taken.

4.1.4 The 35mm Color Reversal Film

Kodak's 35mm Ektachrome 50 EPY color reversal film was used to record photographically the hues generated by the dichroic color head. Ektachrome 50 EPY is suitable to the hue circle production when used with the aforementioned equipment for two reasons; Ektachrome 50 EPY is color balanced for $3200^{\circ}K$ light (color head light source is $3200^{\circ}K$), and Ektachrome 50 EPY has a well balanced color sensitivity for recording the entire spectrum.

4.2.0 The Physical Arrangement of the Equipment

The entire equipment system was housed in a room which

could be sealed off from all light except the light of the color head.

Particular attention was given to the placement of the color head in relation to the camera. After centering the animation compound beneath the camera's lens, the color head was placed on the floor beneath the camera and centered below the opening in the animation compound.

The light from the color head was projected onto the bottom surface of the white flash glass in the opening of the animation compound. The central area of the projected light on the white flash glass appeared brighter. A meter reading (4.1.3) of both the central and peripheral areas of projected light indicated a higher luminance level at the center of the glass. When filters were added to the light, hue mixing in the central area appeared less uniform than at the periphery.

To equalize both luminance and hue mixing of the projected light, an additional pane of white flash glass was placed directly on the end of the color head from which the light was projected. As a result, the hue appeared better mixed, but the high luminosity remained at the center. By tilting the color head, the area of high luminosity was projected at a tangent to the photographic field removing the "hot" spot. Subsequent metering of the central and peripheral areas of projected light on the white flash glass confirmed a more even luminance level.

5.0.0 Methods of Hue Circle Production

5.1.0 Brightness of Hues

When a yellow is placed next to a blue, an observer will describe the yellow hue as brighter than the blue. (Ostwald, 1969) The quality of brightness is evident in hues produced with paints, inks, dyes, and other related substances. A test was made to determine if hues produced with filtered light have the same quality of brightness.

5.1.1 Determining Brightness of Hues

Using the information presented in 5.1.0 as a foundation for the test, the color head filtration dials were set to produce a yellow hue, viz., the yellow dial at 160 and the cyan and magenta dials at 0. A meter reading was taken of the light producing the yellow hue. The dials were then set to produce a blue light with the dials at cyan 160, magenta 160, and yellow 0. This blue light was metered, and the readings compared; yellow had a luminance reading of f11▼' ' f16 @ 1sec. Blue read at f2.8 ▼ ' f4 @ 1sec. The difference in luminance between f11▼' ' f16 @ 1sec. and f2.8 ▼ ' f4 @ 1sec. is nearly four stops; indicating yellow to be higher in luminance, hence brighter than blue when produced with filtered light.

The test was repeated to find whether red and green, when produced by filtered light, would have luminance readings between the readings for yellow and blue, and therefore have a brightness between yellow and blue as do red and green when produced by methods other than filtered light.

The dial settings for red were cyan 0, magenta 160, yellow 160; for green cyan 160, magenta 0, yellow 75. Resultant readings were f8 ▼ · f11 @ 1sec. for red, and f8▼· · f11 @ 1sec. for green.

The four meter readings for yellow, blue, red, and green were then plotted on a single scale of f-stops:

```
          Blue              Green  Red Yellow
      f2.8 ▼ · 4 · · 5.6 · · 8▼▼ · 11▼· · 16 @ 1sec.
```

The four readings on the same scale show the luminance level relationships of the four hues tested for luminance and brightness; yellow has the highest luminance and blue the lowest with the luminance of red and green between that of yellow and blue. This test demonstrates that hues produced by filtered light have the same quality of brightness as do hues produced by other means.

5.1.2 Control of Hue Brightness

The luminance measured by the luminance meter is directly related to the visual sensation of brightness. Thus, the intensity of brightness in the hue when viewed in the projected transparency may be controlled by measuring the luminance of the hues produced by the color head and then adjusting the f-stop and shutter speed to photograph the hue. Opening the lens aperature and/or decreasing the shutter speed increase the brightness of the photographed hue as more light is permitted to reach the film. On the contrary, closing the aperature and/or increasing the shutter speed will decrease

the brightness of a photographed hue.

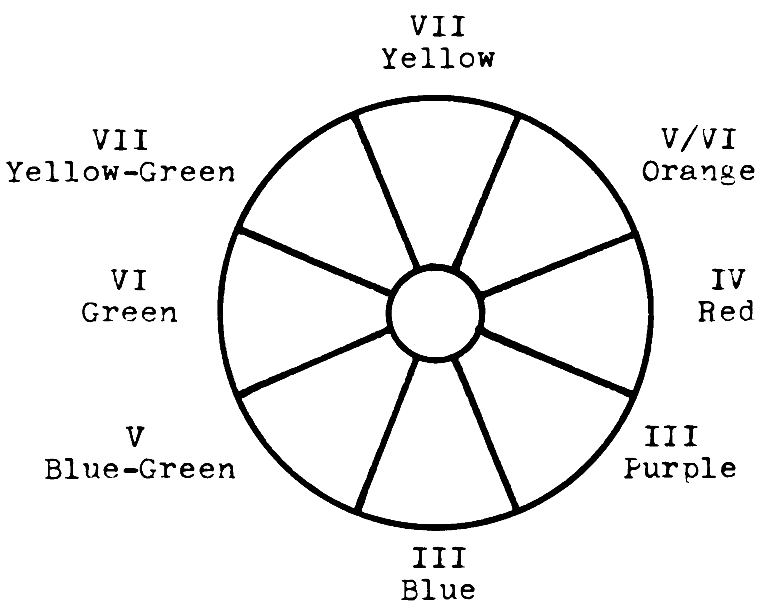
Before the hues could be arranged according to brightness, the Kodak Ektachrome 50 EPY film had to be tested to determine the range of f-stops the film could record. This test was based on the fact that most panchromatic films record an average of ten stops beginning with black and ending with white. This relates to the zone system developed by Ansel Adams in which each of the ten steps of luminance are one f-stop apart. Each zone is indicated by a Roman numeral, I for black, and X for white.

To find the recording range of f-stops for the Ektachrome 50 EPY film, a meter reading was taken of the 3200K° light from the color head with all filter dials set at 0. This meter reading indicated the exposure setting for zone V, and the remaining settings were calculated to be as follows:
f32@.25 (I), f22@.25 (II), f16@.25 (III), f11@.25 (IV), f8@.25 (V), f5.6@.25 (VI), f4@.25 (VII), f4@.5 (VIII),
f4@1sec. (IX), f4@2sec. (X)

Transparency 1 shows the results of the above exposure settings. Ektachrome 50 EPY film will record a range of ten f-stops, but there is less of a visible difference between zones I and II, and between zones IX and X than is evident between zones II through IX.

In the design of the hue circle, the results of the previous tests were applied. Kodak Ektachrome 50 EPY film has shown a noticeable contrast difference in zones II to IX. Zones II and X were designated the ends of the brightness

range, black and white respectively. Since black results from the absence of light, and therefore absence of hue, and white is the presence of light and all hues, zones II and IX cannot represent a single hue. The hue circle's range of brightnesses must, therefore, be contained within the range of zones III to VIII. The placement of the zone designations of the hues was at the discretion of the designer. However, the sequence still demonstrates the natural tendency of the hues' brightnesses to become less bright as the hues progress from yellow to blue on both sides of the hue circle. The placement of the zone designations relative to the primary and secondary hues is shown in the following diagram:



5.2.0 Production of Hues

5.2.1 Procedure for Primary Hue Production

Filter dials were set so that the projected light visually resembled the secondary hue preceding the primary hue being produced, i.e., for producing yellow, a yellow-green hue was produced with the color head. (The sequence of hues on the hue circle begins with yellow at the top and moves clockwise through orange, red, purple, blue, blue-green, green, and yellow-green.) Visual evaluation of the secondary hue was made by observing the light as it was projected through the white flash and platen glass. The light was metered and the exposure setting adjusted to correspond to the zone assigned to the primary hue (5.1.2) to be produced.

Consecutive exposures were made, each time subtracting fifteen increments of the filter predominantly influencing the primary hue, i.e., in producing yellow, fifteen increments of the cyan filter were subtracted with each exposure. When the influencing filter reached 0, or no longer showed a visible effect on the primary hue, the filter influencing the primary hue towards the following secondary hue was added by fifteen increments with each exposure until the projected light visually resembled the following secondary. With each subtraction or addition of fifteen increments, the resultant light was metered and the exposure setting adjusted to maintain the zone assigned to the primary hue then being produced.

Finally, the transparencies were projected and evaluated visually. Yellow showed no visible influence of green or red; red showed no effect of yellow or blue; blue no influence of red or green; and green no effect from blue or yellow. The combinations of filter increments used to produce the transparencies of the four primary hues were:

Yellow: cyan 0, magenta 30, yellow 160
Red: cyan 15, magenta 135, yellow 145
Blue: cyan 160, magenta 130, yellow 0
Green: cyan 160, magenta 0, yellow 75

(Transparency 2)

5.2.2 Procedure for Secondary Hue Production

The color head filter dials were set to create the primary hue preceding the secondry hue to be produced. Filter increment combinations for the primary hues produced in 5.2.1 were used as the dial settings. Fifteen increments of the filter(s) influencing the primary towards the secondary hue were added with each consecutive exposure. Filtration was added or subtracted (depending on the filter increment combination of the primary hue following the secondary hue being produced) until the filter increment combination of the following primary hue was reached, i.e., to begin the production of orange, the dials were set at cyan 0, magenta 30, and yellow 160. Addition of magenta caused the yellow to appear more orange; therefore, fifteen increments of magenta were added with each consecutive exposure. Magenta

was added until the filter increment number equaled 135, at which time, fifteen increments of cyan were added and fifteen increments of yellow subtracted equaling the increment combination for red. This procedure was repeated to produce the increment combinations of the remaining secondary hues.

Secondary hues were chosen which exhibited an equal mixing of adjacent primaries. The filter increment combinations used to produce the secondary hue transparencies were:

Orange: cyan 0, magenta 75, yellow 160

Purple: cyan 90, magenta 160, yellow 75

Blue-Green: cyan 160, magenta 15, yellow 15

Yellow-Green: cyan 100, magenta 0, yellow 120

(Transparency 3)

5.2.3 Procedure for Interstitial Hue Production

Interstitial hues of the hue circle are those existing between the primary and secondary hues. Theoretically, between any two hues a third hue can be inserted that is an equal mixture of the two adjacent hues. This means that the potential range of hue variation in the spectrum is infinite. The hue circle produced by the methods presented in this paper is to be composed of separately definable hues, and be representative of the spectrum.

The final determination of how many interstitial hues can be produced is controlled by the observer's threshold for determining change in hue and the limit of hue producing capability of the equipment system and film. Based on the

fact that the spectral area least discernible to the eye is between blue and green (Ostwald, 1969), the following test was performed to find the number of interstitial hues the equipment system could produce that the eye could discern.

Using the increments for primary blue (5.2.1) as the starting point, a series of exposures were made subtracting ten increments of magenta with each exposure. The reduction of magenta advanced the hue of the light towards blue-green. When the increment combination reached that of blue-green, yellow filtration was added in increments of ten until the increment combination for green was reached.

The least noticeable change in hue occurred over the filter increment combinations: cyan 160, magenta 50, yellow 0; cyan 160, magenta 40, yellow 0; cyan 160, magenta 30, yellow 0; cyan 160, magenta 20, yellow 0. (Transparencies 4,5,6,7)

The filter increment combinations causing the least noticeable hue change were then related to the increment combinations that produced primary blue and secondary blue-green:

Blue:	cyan 160,	magenta 130,	yellow 0	
	cyan 160,	magenta 50,	yellow 0	area of least change
	cyan 160,	magenta 40,	yellow 0	
	cyan 160,	magenta 30,	yellow 0	
	cyan 160,	magenta 20,	yellow 0	
Blue-Green:	cyan 160,	magenta 15,	yellow 15	

Observe that the magenta difference between blue and blue-green is 115 increments. Thus, since 30 increments of magenta are required to cause a noticeable change in the test, two

separately definable interstitial hues can be inserted between blue and blue-green. I concluded that if this is true of the least discernible area of the hue circle, then two interstitial hues could also be produced between the remaining primary and secondary hues.

Location of each interstitial hue was made by finding the differences between the filter increment numbers for primary and subsequent secondary hues and dividing the difference by three. In the case of increasing units, the resultant figure was added; for decreasing units the figure was subtracted, e.g.,

Yellow:	cyan 0,	magenta 30,	yellow 160
Orange:	cyan 0,	magenta 75,	yellow 160
Difference:	0	45	0

$$45 \div 3 = 15$$

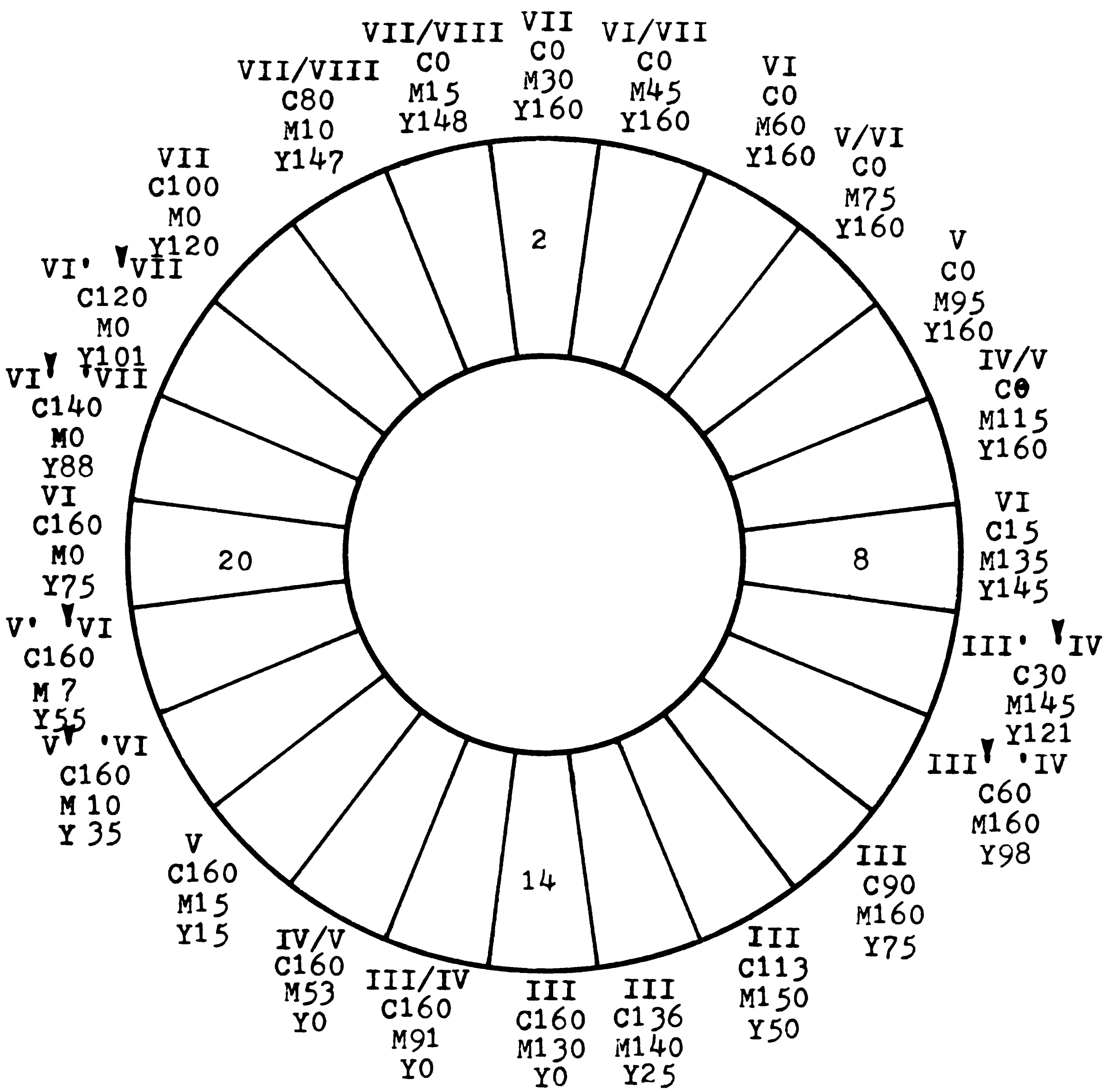
Beginning with primary yellow, add 15 increments of magenta to the increment combinations;

Yellow:	cyan 0,	magenta 30,	yellow 160
Interstitial 3:	cyan 0,	magenta 45,	yellow 160
Interstitial 4:	cyan 0,	magenta 60,	yellow 160
Orange:	cyan 0,	magenta 75,	yellow 160

After calculating the increment combinations for each of the remaining interstitial hues, these were set on the color head dials, the light metered,and the exposure for each interstitial hue set evenly between the zonal values assigned to the adjacent primary and secondary hues. The primary, secondary, and interstitial hues were then photographed. (Transparency 8)

The following diagram shows the increment combinations, and zone placements of the twenty-four hues of the hue circle derived from the procedures described in 5.0.0 through 5.2.3. Primary yellow is placed at the top of the hue circle and is numbered 2. Primary red is number 8, blue number 14, and green number 20.

C = Cyan, M = Magenta, Y = Yellow



6.0.0 Conclusion

The methods described to produce the hue circle are applicable to multicolor transparency production. For example, hues produced in the hue circle as well as additional potential hues may be accurately produced and duplicated using the methods presented.

Control of brightness allows specific control in producing multicolor transparencies directly translatable to a black and white medium. Hues may also be made to appear as advancing or receding within the transparency by controlling the brightness. Thus, three dimensional visual effects may be achieved.

Most importantly, the hue circle production methods offer the designer a controllable and accurate method of hue selection and production for multicolor transparencies.

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