*Use of Polaroid Filters on Kelsh Plotters**

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ABSTRACT: *This paper reviews the basic operation of projector-type photogrammetric plotters using the color anaglyph principle and mentions the use of polarizing filters as alternate to dichromatic filters. This review is followed by a discussion of the phenomena of polarization of light by filters and by reflection from surfaces of certain materials.*

A résumé on the development and use of polaroid for Kelsh plotters is then presented, touching on (a) type of polaroid filters used for Kelsh plotters, means of attachment, and orientation; (b) description and availability of polaroid viewing glasses; and (c) specifications for satisfactory performance and availability of materials for the required special platen surface which consists of anodized aluminum. The paper then presents a summary of results of actual use of polaroid filters and anodized aluminum platen surface as used with Kelsh plotters in the Intermountain Region of the U. S. Forest Service, Ogden, Utah.

I. INTRODUCTION

THE Kelsh plotter, and other photogrammetric plotters of the projector type, commonly utilize the color anaglyph principle. Projection with filters of two colors permits use of black and white aerial photographs for three dimensional study and for making photogrammetric measurements. Two projectors are employed concurrently to project a pair of photographs that have stereoscopic coverage. Glass plate transparencies of the photographic stereo pair are set in the projectors, each of which is equipped with a color filter mounted between the light source and the diapositive. The colors of the filters in the projectors are complementary to each other. These colors, usually red and blue-green, correspond to the colors of the two lenses in viewing eyeglasses worn by the plotter operator. Images of terrain features that appear in both photographs are projected simultaneously to the plane surface of a disk called the "platen", which is mounted on a movable tracing table. The platen surface used for color anaglyph projection is a smooth, flat, white, non-glare disk of plastic material. As images are focussed on this surface, the action of the color filters in the projectors and viewing glasses allows the operator's left and right eyes to see only those images projected from the left and right projectors, respectively. Thus, the operator sees the model stereoscopically.

This paper describes a substitute for the complementary colored filters now used in anaglyphic projection. This alternate approach utilizes the principle of polarized light.

II. POLARIZED LIGHT

According to the wave theory, light consists of electro-magnetic vibrations transverse to the direction of propagation. In ordinary unpolarized light, these vibrations are thought to be in all directions perpendicular to the light ray. Considering each ray of light as a line in space, the number of planes containing this line is infinite. If one of these planes is stipulated as the plane of polarization and all the light vibrations are modified so as to be parallel to this plane, the light is said to be plane-polarized. When ordinary light passes through a polarizing filter, only the vibrations or components thereof that are parallel to the plane of polarization are allowed to pass through. Obviously, the amount of light is reduced by no less than 50% through being completely plane-polarized.

If light so polarized then encounters a second filter oriented in the same plane as the first, it passes through essentially undiminished. However, if the second filter is rotated 90° about an axis parallel to the direction of

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propagation, none of the polarized light can pass through.

There are some transparent minerals occurring in nature that are capable of polarizing light. Also, compounds having this property have been manufactured artificially. A synthetic material called "polaroid", commercially produced on a plastic film base by Polaroid Corporation, is very efficient as polarizing filter material.

Another property of light in this regard is that polarization to varying degrees is produced when light is reflected from the surfaces of some materials. Many substances, such as road pavement, water, plastics, paint pigment, etc., polarize light when it is reflected from their surfaces, provided the substances are non-metallic. For this reason, polaroid eyeglasses are often utilized to reduce the glare of reflected light. Furthermore, when polarized light strikes such surfaces and is reflected, its polarization is altered to a greater or lesser degree depending on the nature of the surface and angles of incidence and reflection.

Conversely, polarization of light is affected little, if any, by reflection from a metallic surface. This optical property of metals becomes the means by which polarized light can be utilized for the Kelsh plotter and others of the projector type when a properly treated metallic surface is provided for the platen.

III. Development of Use of Polaroid for Kelsh Plotters in U. S. Forest Service, Region 4

During 1962, innovations were developed in U.S. Forest Service, Region 4 for using polarized light in Kelsh plotters in lieu of color anaglyphic projection. Three basic elements constitute the materials necessary to accomplish this. They are:

A. Polaroid filters for the Kelsh projectors.
B. Polaroid viewing eyeglasses.
C. Special platen surface.

Polaroid filters were mounted in the projectors of the Kelsh plotter after removing the color filters. Polaroid viewing eyeglasses, with the planes of polarization of the two lenses at 90° to each other, were substituted for the color anaglyph viewing glasses. The polaroid filters on the left and right projectors of the Kelsh plotter were oriented so that their planes of polarization conformed to those of the left and right lenses, respectively, of the eyeglasses. In place of the standard white platen disk of plastic material, a platen surface was used which did not destroy or alter polarization of the light coming from the projectors and reflected from the platen to the eyes of the operator. This enabled the operator to see with his left eye only the images projected from the left projector and with his right eye those coming from the right projector to give him a stereoscopic model on the platen. The three components of this process are further described below:

A. Polaroid Filters

Plastic film polaroid filter material of 0.01 inch thickness was obtained from Polaroid Corporation. With the color filters removed from the Kelsh projectors, an initial trial was made with 12″×12″ polaroid sheets oriented in their respective proper positions and simply laid over the photographic diapositives mounted in the Kelsh. With this arrangement, the positions of the filters did not change when the tracing table and light source moved. Results observed were considered satisfactory. Subsequently, the 12″×12″ sheets were removed and $2\frac{1}{2}''\times 2\frac{1}{2}''$ polaroid filters were placed between the light source and diapositives by attaching them to the lamps in place of the color filters. The latter arrangement gave equally satisfactory results, with the advantage of using much less filter material. Clip-on filter holders were fabricated from thin sheet metal, which provided a positive and rapid means of adjusting the orientation of the polarizing filters.

B. Polaroid Eyeglasses

Commercially produced polaroid viewing glasses of good quality, and good polarizing efficiency are available.

In commercial polaroid glasses designed for stereo viewing, the planes of polarization of the two lenses are at 90° to each other, and each makes a 45° angle with the plane of symmetry of the pair. Viewing glasses can easily be hand-farbricated from sheet polaroid.

C. Special Platen Surface—Anodized Aluminum

It should be emphasized that the key item in the use of polarized light with projector type plotters is the platen surface. The white platen of plastic substance ordinarily used for color anaglyphic projection is completely unsatisfactory with polaroid filters. This is because it is non-metallic and destroys the orientation of the plane of polarization of the light coming from the projectors.

Several types of metallic surfaces were tried before a satisfactory material was found. Various samples of aluminum paint, polished metal, and unpolished metal failed to yield good results. In order to perform satisfactorily, the surface must have the following properties:

1. It must not destroy or alter the plane of polarization of light reflected from its surface. This requires that the surface be metallic.
2. It must be perfectly uniform in texture, free from any patterns or marks that would interfere with distinctness of projected images.
3. It must have a matte finish in order to provide a good projection surface. Polished or shiny surfaces behave like a mirror and projected images are not discernible thereon.
4. It must be colorless, and must have good light reflecting quality as close as possible to that of a white surface.

A material that meets these specifications to a high degree and provides a usable platen surface is anodized aluminum. This is obtained by applying the anodizing process to a polished aluminum plane surface, free from marks, scratches or other defects.

Metal finishing firms use this process commercially to produce paint-grip and corrosion resistant surfaces on various aluminum products.

Aluminum anodizing consists essentially of the following steps:

1. The surface is first cleaned chemically to remove oxide and other impurities.
2. The aluminum object is connected as the anode in an electrical D.C. circuit and immersed in a 15% sulphuric acid solution at a temperature of 70°F.
3. D.C. voltage is applied (about 15 volts) for thirty minutes to produce a current of 20 amperes per square foot passing through the surface. This current causes a uniform, controlled deposit of aluminum oxide 3 to 5 ten thousandths of an inch thick on the aluminum surface.
4. The aluminum is washed and then immersed in boiling water containing a chemical that seals the pores in the aluminum oxide coating.

Possibly other metals and other surfacing processes may exist that would give as good or better surface for use as a platen. However, this is the best we know of at present.

As actually used in the test mentioned above, a mirror-shiny, aluminum sheet, free from surface defects, was obtained and anodized. A circular disk $3\frac{1}{4}$ inches in diameter conforming to the size of a standard platen was cut from the sheet. A small aperture was drilled in the center of the disk by a jeweller to provide the opening for passage of light to produce the floating dot.

IV. Observations and Comments

Where anaglyphic, projection is used in photogrammetric instruments of the projector type, it is obviously impossible to work with color photographs. Probably the greatest single advantage offered by polaroid filters and viewing glasses with an anodized aluminum platen is that this method opens up the opportunity to utilize color photography in projector type plotters. This makes available for such plotters the greatly improved presentation of detail and interpretive qualities of color photography over black and white. Results of an actual test with color photography were considered very satisfactory.

Since September 1962, polaroid and anodized aluminum have been used regularly in Kelsh plotter work in U. S. Forest Service, Region 4 as an alternate to anaglyphic projection. Several Kelsh plotter operators have used both types of projection in routine project work with black and white photography, and have made comparisons between the two. These operators have generally expressed the opinion that polaroid with anodized aluminum is entirely comparable to anaglyphic projection. Some operators prefer one type and some the other. The Photogrammetric Section in U.S. Forest Serivce, Region 4, has issued instructions allowing their Kelsh operators to use either type of projection as they may prefer.

The following observations regarding polaroid and anodized aluminum have been furnished by Mr. J. B. Stewart who directs Kelsh plotter activities in Forest Service, Region 4, and who participated in this development:

A. Within the "neat model", or working area of the model, there is more equal light distribution than with anaglyphic projection.
B. The floating dot appears the same with either eye. With anaglyphic projection, the red dot usually appears larger, while the blue dot appears brighter.
C. This method seems to make available more usable light in the shadow areas of photos, permitting perception of some detail in these areas.

   With anaglyphic projection, shadow areas often appear completely black with no detail.
D. The angle of orientation of the filters is

critical, requiring considerable care in adjusting the filter holders.

E. For optimum stereo perception, the Kelsh operator must keep his head oriented so that the plane of the eyeglasses is approximately parallel to the long axis of the Kelsh table. With a little experience, the operator becomes accustomed to this requirement. Rotation of the head up to about 10 degrees does not seriously interfere with stereo viewing.

F. Clearing of the Kelsh model requires a little more time than with anaglyphic projection. This may be improved with experience.

G. Polaroid and anodized aluminum can be interchanged with anaglyphic projection equipment in a few minutes without changing the model setup.

Special measurements made on a Kelsh plotter with polaroid and anodized aluminum and with anaglyphic projection have yielded quantitative data for comparison as to elevation reading accuracy and intensities of projected light. These consist of the following:

ELEVATION READINGS

In a Kelsh model setup, 11 points well distributed throughout the model area were arbitrarily selected for reading terrain elevations. Two operators made independent sets of elevation readings on these points. Each operator made two sets of readings, one set with anaglyphic filters and the other set with polaroid and anodized aluminum. The results appear in Table I.

LIGHT INTENSITY

Points numbered 1 through 15 and arranged within the model area as shown in Figure I were marked on a sheet on the Kelsh table. A light measuring device was fastened to the platen on the tracing table and calibrated with a foot candle meter. Designating the two Kelsh projectors as Projector No. 1 and Projector No. 2, the test procedure is described by the following steps:

1. A stereo model was set in the Kelsh plotter, one glass plate diapositive of each aerial photograph of the stereo pair being mounted in each projector.
2. A standard Kelsh blue-green filter was placed in Projector No. 1 and a standard red filter in Projector No. 2. Light intensity settings of the two projectors were adjusted for stero viewing at an arbitrary point. These intensity settings were then not changed throughout the remainder of the test. It so happened

TABLE I

KELSH PLOTTER ELEVATION READINGS WITH POLAROID FILTERS AND WITH DICHROMATIC FILTERS

Photo Scale 1:6000
Map Scale 1:1200

Point No.	*J. B. Stewart, Operator*			*Robert Fuechsel, Operator*		
	Elevations Read in Feet		*Difference in Feet*	*Elevations Read in Feet*		*Difference in Feet*
	Color Filters	*Polaroid Filters*		*Color Filters*	*Polaroid Filters*	
1	4,724.5	4,724.5	0	4,725.0	4,725.0	0
2	4,712.0	4,713.0	+1.0	4,713.5	4,714.0	+0.5
3	4,510.5	4,511.0	+1.0	4,512.0	4,513.0	+1.0
4	4,738.0	4,738.5	+0.5	4,739.5	4,739.5	0
5	4,443.0	4,444.0	+1.0	4,444.0	4,445.0	+1.0
6	4,510.0	4,510.0	0	4,511.0	4,511.0	0
7	4,330.0	4,330.0	0	4,330.5	4,331.0	+0.5
8	4,658.0	4,659.0	+1.0	4,659.5	4,658.5	−1.0
9	4,340.5	4,341.5	+1.0	4,341.5	4,342.0	+0.5
10	4,611.0	4,612.0	+1.0	4,614.5	4,614.5	0
11	4,481.0	4,482.0	+1.0	4,483.5	4,484.0	+0.5

Readings were to the nearest 0.5 foot. There was no index adjustment made either for the change in operators or for the change of viewing surface from standard Kelsh platen to anodized aluminum viewing surface.

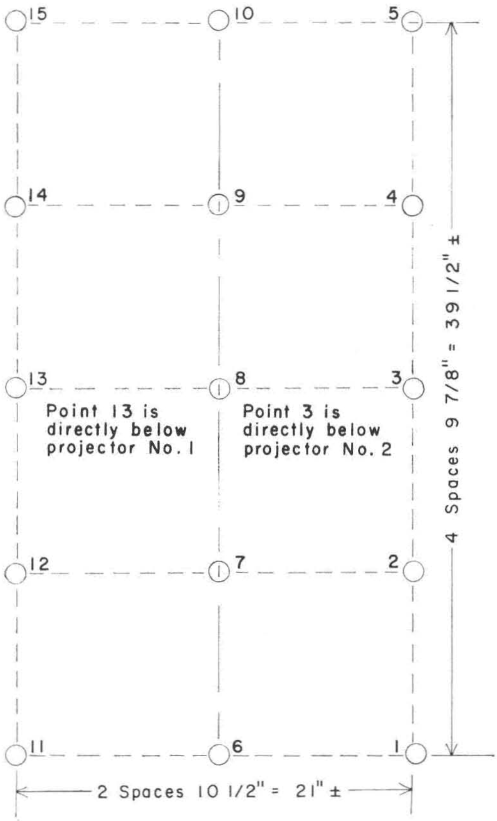

FIG. 1. Arrangement of Points on Kelsh Plotter Table for Light Intensity Test.

that the intensity setting of Projector No. 1 was considerably higher than that of Projector No. 2.

3. Projector No. 2 was turned off. Light intensity readings were taken at points Nos. 1 through 15, measuring only the light from Projector No. 1 with a blue-green filter.
4. Projector No. 2 was turned on and Projector No. 1 turned off. Light intensity readings were taken at points Nos. 1 through 15 measuring only the light from Projector No. 2 with a red filter.
5. The color filters were removed from both projectors and polaroid filters installed.
6. With Projector No. 2 off, readings were taken at the 15 points using only light from Projector No. 1 with a polaroid filter.
7. With Projector No. 1 off, readings were taken at the 15 points using only light from Projector No. 2 with a polaroid filter.
8. The photographic diapositives were removed from the Kelsh projectors and $\frac{1}{4}$ inch thick, clear glass plates placed therein.
9. Steps Nos. 2 through 7 above were repeated with only the clear glass plates in the projectors instead of the aerial photo transparencies.

Data obtained by these readings are given in Table II and Table III.

TABLE II

INTENSITY MEASUREMENTS OF LIGHT PROJECTED THROUGH *Photographic Diapositives*

Point No.	*Light Intensity on Platen—Foot Candles*					
	Projector No. 1—Light Set High			*Projector No. 2—Light Set Low*		
	A *Blue-green Filter*	*B* *Polaroid Filter*	*B/A*	*C* *Red Filter*	*D* *Polaroid Filter*	*D/C*
1	0.33	0.25	0.76	0.08	0.25	3.13
2	0.25	0.45	1.80	0.45	0.58	1.29
3	0.45	0.50	1.11	0.50	0.75	1.50
4	0.38	0.50	1.32	0.25	0.50	2.00
5	0.23	0.25	1.09	0.13	0.20	1.54
6	0.40	0.75	1.87	0.05	0.13	2.60
7	0.40	0.68	1.70	0.25	0.40	1.60
8	0.55	0.75	1.36	0.50	0.63	1.26
9	0.43	0.58	1.35	0.08	0.38	4.75
10	0.20	0.38	1.90	0.08	0.10	1.25
11	0.13	0.38	2.92	0.03	0.13	4.35
12	0.45	0.65	1.44	0.13	0.13	1.00
13	1.00	1.50	1.50	0.25	0.45	1.80
14	0.45	0.55	1.22	0.13	0.25	1.92
15	0.33	0.25	0.76	0.13	0.18	1.38

TABLE III

INTENSITY MEASUREMENTS OF LIGHT PROJECTED THROUGH *Transparent Glass Plates*

Point No.	*Light Intensity on Platen—Foot Candles*					
	Projector No. 1—Light Set High			*Projector No. 2—Light Set Low*		
	A *Blue-Green Filter*	*B* *Polaroid Filter*	*B/A*	*C* *Red Filter*	*D* *Polaroid Filter*	*D/C*
1	1.30	2.25	1.73	1.13	1.75	1.55
2	1.93	3.00	1.55	2.23	3.50	1.57
3	2.00	3.00	1.50	2.75	4.08	1.48
4	1.75	2.50	1.43	2.20	3.18	1.45
5	1.13	1.53	1.35	1.38	1.95	1.41
6	1.93	3.75	1.94	1.00	1.43	1.43
7	2.95	5.45	1.85	1.75	2.75	1.57
8	3.38	5.75	1.70	2.13	3.45	1.62
9	2.63	4.45	1.69	1.60	2.80	1.75
10	1.48	2.58	1.74	1.10	1.93	1.75
11	1.88	3.50	1.86	0.58	0.75	1.29
12	3.38	6.25	1.85	0.95	1.58	1.66
13	4.13	7.30	1.77	1.25	1.95	1.56
14	3.28	5.58	1.70	1.10	1.83	1.66
15	1.25	2.55	2.04	0.70	1.43	2.04

The equipment used in this test was not highly precise and the data shown are only roughly approximate. At very low readings, estimated interpolations between divisions on the meter scale undoubtedly caused rather high percentages of error. Nevertheless, for light intensities of over $\frac{1}{2}$ foot candle, the data are considered sufficiently reliable to indicate a fair comparison between color and polaroid filters.

In general, this test showed that considerably more usable light is made available on the platen with polaroid filters than with color filters.

Determination of Weights of Parallax Observations for Numerical Relative Orientation

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(*Abstract is on the next page*).

INTRODUCTION

THE consideration of weighted parallax observations in determining the relative orientation of a photogrammetric model has not so far been undertaken by the photogrammetrists very seriously. Only some stray work has been done in this respect. The author is aware of the method of Jerie[1] which is aimed at giving a com-