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Additive Color Process: Dufaycolor

The additive color process, simply put, incorporates a direct light source of each of the three primary colors (red, green and blue), usually pure light through filters. When combined at varying luminosity they produce secondary colors (yellow, magenta and cyan) or white when projected at equal intensity.[1] Of the several additive color processes developed for motion pictures in the early 20th century, Dufaycolor was the only process which overcame the hurdles of requiring specialized equipment. While not being completely flawless, Dufaycolor very nearly became a leading color process in the British film industry.

Frenchman Louis Dufay, who was a photographer by trade, invented the process that would become known as Dufaycolor. His original Dufay color process was called Diopticolor, and was marketed under the name Dioptochrome in 1908.[2] Though there had been other attempts at such a structure, Dufay's invention was the first additive color method to successfully utilize a "fine mosaic of microscopic filters" on a glass plate.[3] Dufay discovered that a basic geometric pattern for his filter "reduced the grainy appearance due to the 'clumping' of colour elements when a random colour filter dot system was employed."[4] The first incarnation of Dioptichrome, however, was sold as two separate screen processes: two glass plates, one contained the mosaic

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[1] Hirsch, Robert, "Exploring Colour Photography: A Complete Guide", Wikipedia.org, 2004 <http://en.wikipedia.org/wiki/Additive_color#cite_note-1> (2 October 2010).
[2] Vaughan, Fiona, "Dufaycolor: materials, techniques and deterioration," Cranberra: AICCM, Vol. 31 (Australia: AICCM, 2008): 56.
[3] Coe, Brian, The History of Movie Photography. (Westfield: Eastview Editions, 1981) 124.
[4] Newham, Grahame, "9.5MM Dufaycolor." Grahame N's Web Pages, 2004, <http://www.pathefilm.freeserve.co.uk/95flmart/95dufay.htm> (2 November 2010).

and the other contained the panchromatic plate.[5] By 1910, Dufay had figured out how to merge the emulsion and mosaic pattern on to one glass plate.[6]

The use of a mosaic pattern is the only additive color process that did not require any additional lenses or filters to view the color effects.[7] The mosaic was set between the base and emulsion, and its original pattern was made up of blue lines interspersed with red and green squares.[8] The film was exposed through the base and then through the mosaic, with one exposure capable of making three separate color records simultaneously on a singular emulsion coated surface.[9] In 1917, Dufay set up a company he named Versicolor for the express purpose of exploring the possibilities of transforming his successful photographic mosaic process into a fully functioning motion picture process.[10]

The Versicolor process used a celluloid acetate base, and the mosaic was manufactured with "warm rollers imprinting fine parallel lines into the celluloid sheet. Red, blue, yellow, violet lines were added onto the film base."[11] Though coming very close, Dufay was never able to fully resolve the issue of the filter pattern being too obtrusive to viewers close to the screen when the film was projected.[12] By the mid 1920's he was no longer financially capable of continuing the development of his color process.[13] During this period, Dufay had been working on the Versicolor development with Thomas Thorne Baker. Baker had been reporting Dufay's progress to a well known British paper-processing company named Spicer Limited, and his reports spoke

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[5] Vaughan, 56.
[6] Vaughan, 56.
[7] Coe, 124.
[8] Brown, Simon, "Dufaycolor- The Spectacle of Reality and British National Cinema," Centre for Film and Television Studies, 2002 < http://www.bftv.ac.uk/projects/dufaycolor.htm> (10 October 2010).
[9] Coe, 125.
[10] Brown.
[11] Vaughan, 56.
[12] Coe, 125.
[13] Brown.

favorably about what was being accomplished.[14] Spicer Ltd. officially purchased Dufaycolor in 1925, and between 1927-1930 a large number of patents were granted under Spicer-Dufay.[15] In 1926 testing began under the supervision of T. Thorne Baker to perfect Dufaycolor as a motion picture color process. The research project was shrouded in secrecy, and nothing was presented publicly until 1931.[16]

Spicer-Dufay representative Baker presented Dufaycolor with its patented *reseau* (the new official term for the mosaic pattern) to the Royal Society in Britain in March 1931, and shortly afterward to the British Kinematograph Society in September 1931.[17] The presentations were met with great enthusiasm, but all the kinks were not yet worked out. The Spicer studies had revealed that the color order of the reseau was very important. Originally there were blue lines with red and green squares between, but the higher visual contrast of the blue line made the reseau much more visible when magnified for projection.[18] By 1932 the newly developed 35mm format boasted an improved reseau with a solid red line with blue and green squares, the order of which reduced the visibility greatly when magnified or projected.[19]

The process of creating the reseau involved multiple bleaching and chemical bath steps, as well as dyeing. Dufaycolor still photography film and moving image film were produced in much the same way, though the reseau on the moving image film is more compact as it needs to be magnified to a larger degree. Initially the reseau had 15 lines to the millimeter, by the time of

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[14] Brown.
[15] Klein, Adrian, Colour Cinematography, (London: Chapman & Hall, Ltd, 1936) 137.
[16] Brown.
[17] Brown.
[18] Dunn, Carlton, "Color Photography - Dufaycolor", Natural Color Processes, 1938 <http://www.oldandsold.com/articles21/color-photography-10.shtml> (10 October 2010).
[19] Coe, 125.

its 1931 presentation it had 20 lines to the millimeter, and by 1935 they were able to achieve 23 lines to the millimeter.[20]

The basic structure of Dufaycolor film can be broken down into four parts: 1. a cellulose acetate base 2. the reseau 3. protective varnish 4. gelatin emulsion.[21] In the manufacturing process, the clear non-inflammable film base was coated with a layer of blue dyed collodion. A specialized rotary printing press printed parallel lines (500 lines to the inch) with a specially developed ink that resisted any reaction to further dye or bleach.[22] The film was then run over a bleaching bath of alkaline alcohol which removed the blue dye that had not been imprinted with the resistant ink, leaving parallel blue and bleached out lines.[23] After the remaining resistant ink was rinsed off the film was dyed green, the bleached lines being the only parts affected, leaving the film striped in blue and green.[24] At a right angle to the blue and green lines, a new set of ink resistant lines were printed, then the film was passed through a second bleaching bath.[25] At this stage there were bleached out lines with green and blue squares in between. Once again, remaining resistant ink was rinsed off and red dye was then applied to the film, affecting only the bleached out lines and completing the reseau color screen scheme.[26] A protective varnish was then added to insulate the reseau from the sensitive emulsion comprised of silver bromide and silver iodide, which was then coated over the reseau.[27]

As with Dufay's Dioptochrome process, light needed to be projected through the base of the film, which passed through the reseau and imprinted the color information on the light

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[20] Dunn.
[21] Vaughan, 56.
[22] Dufaycolor, Inc, The Dufaycolor Manual: Of Interest to Advanced Amateurs, Professional Photographers, and Printers, (New York: Dufaycolor, Inc, 1938) 2.
[23] Klein, 136.
[24] Dufaycolor Inc, 2.
[25] Dufaycolor Inc, 2.
[26] Dufaycolor Inc, 2.
[27] Vaughan, 56.

sensitive emulsion. The light source had to contend not only with the thicker base, but the reseau which actually absorbed nearly 2/3 of available light.[28] This light demand resulted in a dimmer picture onscreen, as well as some sound loss. The full level of brightness achieved was still 1/3 that of a black and white film exhibited in the same conditions.[29] Unfortunately, if the reseau had been manufactured any thinner, the depth of color in the film would have been reduced.[30]

When projected, Dufaycolor still had the problem of the reseau being visible from the first six rows of an average sized theater. It was found that if projected at 24 fps this helped reduce the appearance.[31] While it is true that the issue of needing specialized equipment was solved, and that goes a long way in the industry, the nature of the film required it to be threaded differently. The emulsion had to face away from the projector lens, making the emulsion a fraction of an inch further away from the main light source.[32] Any sort of additional education to projectionists who were already comfortable with a certain way of projecting[33] created a major disadvantage. Despite Dufaycolor's technological innovations, requiring camera operators to re-calibrate their projectors and optical sound systems[34] in order to accommodate what must have seemed to them as just another color film attempt, had to have hurt its chances at industry wide acceptance, even despite the convenience of not needing filters or a specialized projector.

The presentations of Dufaycolor in 1931 were successful, but soon the dim picture began to draw some criticism. This was not a major alarm initially, as Dufaycolor was still in the development phases. Beginning with a distribution and marketing agreement in 1932, a British company name Ilford Ltd. began investing in the further development of Dufaycolor as 35mm

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[28] Lobban, Grant. "Dufaycolor V Cinecolor." Cinema Technology 15.1 (2002) 32.
[29] Coe, 126.
[30] Coe, 126.
[31] Klein, 136.
[32] Brown.
[33] Harrison, Dr. G.B, "Dufaycolor," Proceedings of the British Kinematograph Society 1935, 33 (1935): 4.
[34] Brown.

professional film stock.[35] Dufaycolor made an earnest effort to advertise its relative cheapness as a professional film stock. While its processing and development costs were more expensive than black and white film, Dufaycolor was still much cheaper than Technicolor.[36]

The issue of color and loss of light was the major drawback for Dufaycolor within the motion picture industry. In terms of actual filming, Dufaycolor did great in natural light, requiring very little adjustment of the camera, and a simple gelatin filter.[37] The initial demonstrations were filmed in natural light, which explains their relative success in comparison with studio work that came after. In artificial light major problems ensued. Due to the nature of the reseau, the film needed one and a half times the usual amount of light, not to mention the lighting sources absolutely could not be mixed.[38] Basic studio lighting provided by either tungsten or carbon arc lights caused color balance problems.[39] The primary colors in the reseau had to be balanced upon filming in order to be balanced in the printing stage. Improper light balance would cause one color to be stimulated more than another, and correcting this in the printing process was very difficult.[40] The gelatin filter took care of this issue easily for natural light shoots, and Dufaycolor even supplied this filter free of charge to its clients.[41] They exercised similar courtesy in trying to resolve the interior shoot lighting issue by commissioning Mole Richardson Ltd to create a lighting set-up which patrons could purchase or even directly hire from Mole Richardson.[42] While very helpful in terms of customer relations, this drawback on top of extra processing costs did not help make Dufaycolor popular in the industry.

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[35] Enticknap, Leo, Moving Image Technology: from zoetrope to digital, (London, New York: Wallflower Press, 2005) 84.
[36] Dunn.
[37] Brown.
[38] Brown.
[39] Enticknap, 85.
[40] Brown.
[41] Brown.
[42] Brown.

The first studio film that used Dufaycolor was British musical *Radio Parade* in 1934, but only in one musical sequence.[43] Reviews complained the color was "not up to the highest standards."[44] The only full feature length film that used Dufaycolor exclusively was *Sons of the Sea* in 1939, by some accounts a "naïve" "war propaganda" film.[45] If color correction were easier to achieve when processing the film, lighting issues may have been forgivable. The nature of the reseau made it almost impossible to improve color issues because under or over exposure impacted the tone value as well as color reproduction.[46] Minute color correction, on say, one frame could be achieved, but on multiple frames it became overly complicated as different shots with different lighting required different levels of compensation, consuming too much time and money.[47] Adding to the processing cost as well was the need to print the sound track negative onto ordinary film stock to produce a positive that was then printed onto the Dufaycolor reversal film, in order to have the sound track print emulsion to emulsion.[48] Ilford Ltd developed a printing method to make positive projection prints from positive originals for its 35mm stock, in an effort to accommodate the motion picture industry.[49]

Because of its easy fix in natural light, Dufaycolor did well in the amateur and documentary film market.[50] Pathé distributed Dufaycolor in special "H" film chargers in 9.5 mm gauge, which was the only color film in that size until Kodachrome manufactured one in the 1950s.[51] Dufaycolor 16mm film stock was presented the same year as the reseau improved

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[43] Lobban, 33.
[44] Coe, 125.
[45] Enticknap, 85.
[46] Harrison, 3.
[47] Harrison, 3.
[48] Harrison, 3.
[49] Newham, Grahame, "9.5MM Dufaycolor," Grahame N's Web Pages, 2004, <http://www.pathefilm.freeserve.co.uk/95flmart/95dufay.htm> (2 November 2010).
[50] Enticknap, 84.
[51] Newham.

35mm format in 1934 with great success.[52] In the spring of 1936, Kodachrome 8mm was released in the U.S., which was a set-back for 9.5mm film in Europe.[53] Kodachrome had also released a 16mm color reversal format only a month prior.

In 1937, new incarnation Dufay-Chromex released improved 16mm and 35mm formats.[54] They managed to reduce the density of the reseau just enough to improve the transmission of light without too much loss of color depth.[55] In particular, they had achieved the ability to reduce "35 mm Dufaycolor prints onto 16mm."[56] That same year, Dufay-Chromex unleashed the first negative-positive process, made possible through "the creation of special developing and printing techniques."[57] Now the film could be given a "single development" to produce a color negative in which the colors and tone range were both reversed in complimentary colors to what was originally captured.[58] The new negative-positive process was used successfully in capturing the widely seen King George VI Coronation celebration.[59] Ultimately, Dufay-Chromex produced about eighty short-films using Dufaycolor, the coronation being the most high-profile.[60] Other filmmakers made use of Dufaycolor with short documentaries and travelogues, and it was even utilized in experimental films.[61]

Despite all of the technological issues mentioned earlier, Dufaycolor still had a fighting chance of becoming a viable motion picture industry color film option. It competed with many color processes in the British film industry. Cinecolor, a two color process that had a soundtrack and blue-green image on one side, and an orange-red image on the opposite side, providing "an

[52] Brown.
[53] Newham.
[54] Coe, 125.
[55] Lobban, 33.
[56] Brown.
[57] Coe, 125.
[58] Coe, 125.
[59] Coe, 125.
[60] Lobban, 33.
[61] Brown.

adequate if restricted range of colors" was a primary opponent.[62] Another major competitor was Gasparcolor, a subtractive color process utilizing a three color multi-layer.[63] While Cinecolor's downfall was brought on primarily by the onset of WWII, which also greatly impacted Dufaycolor, Gasparcolor was very expensive to print, turning users over to Technicolor "dye-transfer" prints[64], and it was not well-suited to live action because the film was not sensitive enough to properly capture live movement.[65] Dufaycolor achieved a coup over Gasparcolor when Major Adrian Klein, the most influential expert in color cinematography at the time, left the latter company for the former.[66] Dufaycolor always maintained its unique accomplishment of being the only additive color process to have color filters built into the film.

Active research and development for solutions to Dufaycolor's drawbacks were always underway, and although initial forays into commercial films were not as successful as documentary shorts, complete failure was never seen on the horizon. The onset of World War II required that all labs be put toward important government work.[67] Dufaycolor as a motion picture film process was officially over by 1950, and the company focused production on black & white and color roll film for still photography, even trying to expand the market to Italy (unsuccessfully).[68] Despite a brief revival in the amateur photography market, Dufay-Chromex was liquidated in 1952.[69]

In terms of preservation, it is doubtless that Dufaycolor film requires an especially unique method to deal with the complexity of the reseau. Efforts to locate material on the specifics of

[62] Lobban, 32.
[63] Lobban, 32.
[64] Lobban, 34.
[65] Lobban, 34.
[66] Brown.
[67] Brown.
[68] Brown.
[69] Enticknap, 85.

this process proved painfully difficult. It is universal practice to store color film in cold temperatures, but what about the reseau? Leo Enticknap provides a theory in his publication about the complexities of dealing with the reseau, and how lack of knowledge of the reseau will affect the preservation of Dufaycolor in future generations. His "hypothetical example" entails the possibility of someone digitally removing the reseau pattern in the belief that it was a mistake in the printing process.[70] A very brief sentence on a website for aviation photographer W. Owen Dinsdale (http://www.tardis.myzen.co.uk/Aeropix/Home.html) states that a major difficulty in trying to restore Dufaycolor prints is that the reseau makes the image rather dense, in turn making it difficult to scan.

The state of the art preservation laboratory PresTech in London, England holds very detailed information on restoring Dufaycolor as its founder, João de Oliveira, was made an Honorary Fellow of the British Kinematograph Society in 2007 not only for his immense contributions to film restoration in general, but specifically "for his work in developing a new method for the restoration of…Dufaycolor Film."[71] Any further elaboration on this very intriguing information states only that Oliveira invented "unique restoration techniques for obsolete film types and gauges" including a "restoration and duplication system for Dufaycolor using digital processes."[72] Oliveira's own company website does not delve into detail, and evidence of any sort of publication of this breakthrough method is so far unobtainable. An email sent to PresTech Laboratories was met with no response to date.

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[70] Enticknap, 229.
[71] PresTech Film Laboratories, "Company", <http://www.prestech.biz/company.html> (15 November 2010).
[72] Iles, Tony, "BKSTS 75th Anniversary Awards," Image Technology: BKSTS The Moving Image Society, 89.1 (2007): 42.