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Historical and Technical Investigation of the Autochrome Process and Attempts at Re-creation

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Abstract

The autochrome was one of the first successful industrial color process. Invented by Louis Lumière at the turn of the century, patented in 1903 and produced until the fifties, on a sheet film called "Filmcolor". Very little information on this subject was found in the literature because the details of the autochrome process remained proprietary. The first part of our work consisted of collecting references, patents and historical documents. Some thorough documentation, consisting of letters, notes, and manufacture instructions was discovered in private homes (Lumière descendants or relatives, collectors) and in institutions. From these documents, we were able to gain an understanding of the thought processes that led Louis Lumière to conceptualize the autochrome. We tried to recreate it as close as possible. The reconstruction of a color screen on a glass brought us a lot of information on the complexity of the operations, and the imperfections of the fabrication. Above all, it gives useful samples for a further study on the stability.

Ninety years ago, the Lumière company patented a photographic process which would produce one of the most famous color photographic process of the beginning of this century. In spite of the price, for the plates were far more expensive than black-and-white materials then avalaible, autochromes were a resounding sucess. A few famous autochrome collections still exist like the one at the National Geographic Society in Washington or the Albert Kahn collection near Paris in Boulogne. The latter collection includes more than seventy thousand autochromes.

These color plates are fascinating. We admire their harmonious rendering of color that seems to be much more permanent than that of chromogenic processes, thought, of course, we have no reference for the original condition. At the request of the Albert Kahn Museum's curator, the CRCDG has undertaken a research project whose aim is to study the long term stability of autochrome plates and their components. I will present some historical and technical information regarding these plates, analysis of the components parts and our attempts at re-creating the process[1].

Historical and Technical Investigation

The first part of our work consisted of collecting references, patents and historical documents. Some thorough documentation, consisting of letters, notes, and manufacture instructions was discovered in private homes (Lumière descendants or relatives, collectors) and in institutions. From these documents, we were able to gain an understanding of the thought processes that led Louis Lumière to conceptualize the autochrome. The original idea of autochrome belongs to Ducos du Hauron who described the principle of using a screen made up of three fines color lines in order to produce a color slide in his book "Colors in Photography", published in 1869. In 1894, John Joly and, in 1896, James McDonough produced the first photographic color process based on this principle. It was only seven years later that the Lumière brothers patented what would be called the "autochrome".

The Lumière brothers were very interessed in producing color photography and they tried different methods during the 1890's. They spent a few years improving the Lippmann process and practicing the three color carbon process. They succeeded in bringing these two processes to a high level of perfection. This perfection was due to their technical improvements as well as the personal skill they brought to the work. They could not avoid the intrinsic defaults which made these processes impractical for a large public. At the turn of the century they started working on the screen process. A patent called simply a "new type of color" dated November 1900 reveals that they had started researching ways of making a color screen by this time. Three years later the autochrome process was patented and in 1907 the Lumières begann industrial production.

Why did they need four years between the patent and production? They had to solve various problems in the fabrication of the screen. I will discuss two of these problems today, namely those involving the starch grains and a power press used in production.

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[1] An extended paper is publish in : Les Documents Graphiques et Photographiques. Analyse et Conservation. Travaux du Centre de Recherches sur la Conservation des documents graphiques, 1991-1992. Archives Nationales-Documentation Française. Paris : 1993.

Starch grains

The patent for a "new type of color" had no direct connection to the autochrome process, but it explains how to make colored pigments by dyeing mineral substances like silicate or barium sulfate (...). It is very clear that this patent resulted from the Lumières'attempts to make colored dots for a screen pattern. This particular method was unsatisfactory.

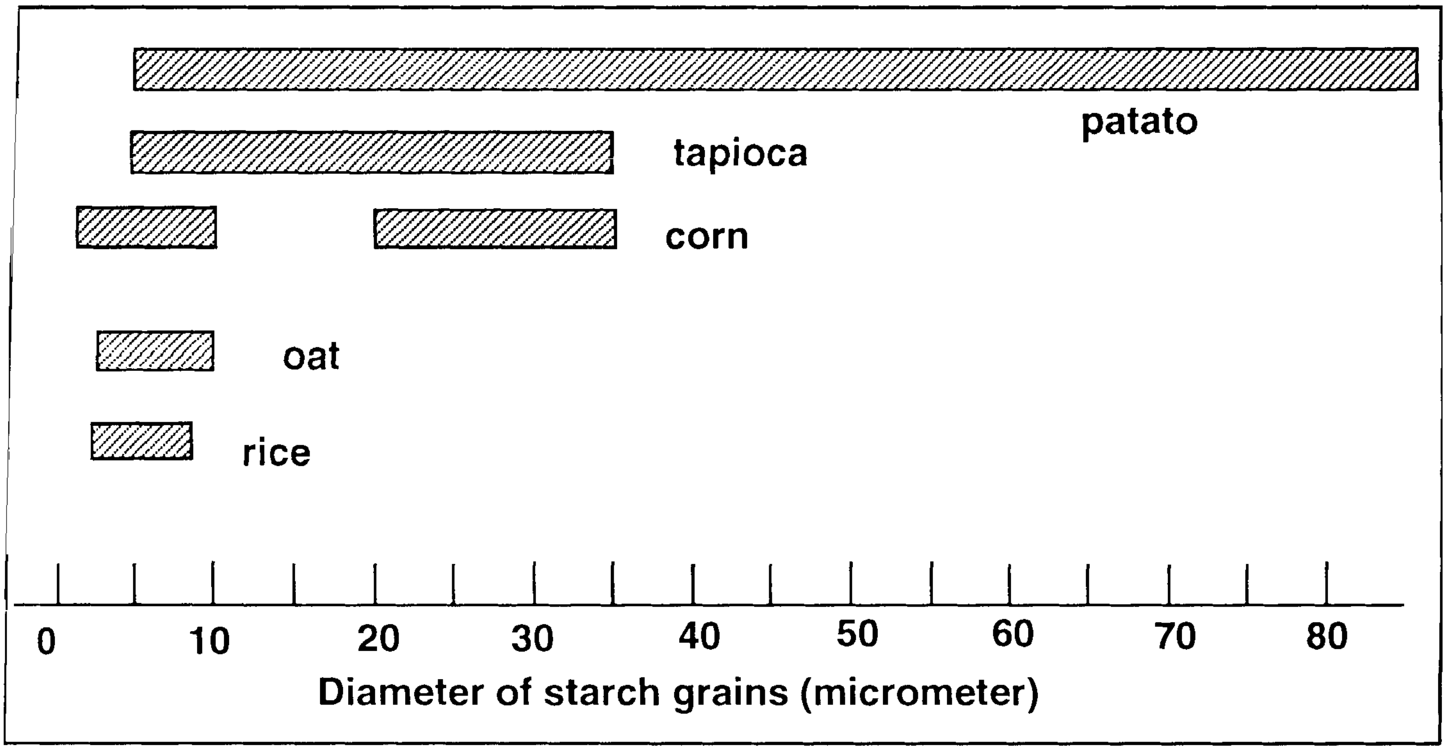
We know from reading unpublished letters that if they had adopted starch for making the screen patterns in 1903, they as yet had no idea about what type of starch to use. They wrote to starch suppliers asking information about the size of starch grains typical for various plants. They imported numerous samples from Greece, Lebanon, Vietnam and so on...More than sixteen different types of potato starch were collected from Vietnam alone. The Lumières' tested the properties of these samples for their use.

In december of 1904 potato starch was adopted for use with the new color photographic process. Louis Lumière then search for a supplier of potato starch with a fine grain size. Starch producers were very eager to work with the Lumière Company, and sent samples of their finest starch grains. Still, the grain sizes sent were too large. Even with special attention, the methods of extracting the starch in the factory setting did not allow for recovery of the finest grain sizes. Discouraged, one of the starch makers advised Louis Lumière , "do it yourself" and he sent a list of the equipment needed for extracting starch. Even in succeding for recovering the finest grains, it was necessary to keep the right range of size by eliminating the less than ten micrometers grains and the more than fifteen micrometers. Louis Lumière ordered apparatus and asked a mechanical engineer to join him in this venture. The different methods tested were unsatisfactory.

Here is an important character who would solve the problem. Mr Francisque Demure produced dextrin for Tarare fabrics, a kind of very ligth tulle made near Lyon. His dextrine factory was located across from the Lumière factory. He had probably made a deal with the Lumières : he would produce and sell fine starch grains to the Lumière factory, and would retain the coarser grains for his own use. Today, his ninety-four years old son remenbers the details very well and related them to us.

For supplying the Lumière, his father bought, an old seventeenth century watermill in the montains, in a village call Juré. He equiped it with a turbine for producing electricity and with all modern equipment. Three peoples worked there. The potato was bought to the farmer. The starch grains were separated in larges basins connected each other with a zigzag trench. The largest grains fell out of solutions in the first basins, the smallest grains in the last basins. After drying, these grains were sent by train to the Lumières. This method of separating by water, applied by Mr Demure, was very efficient. In 1910 the family Demure moved from Lyon to settle permanently in a house near the watermill. At that time the health of the young boy was bad and the pure air of the contryside should be better for him. 83 years later, he is still living there.

But why did the Lumières prefer potato starch grains? If you look at the grains diameter, you see that potatoes have the widest range of starch grain sizes when compared with rice, for example, which is much more close to the Lumières' needs in term of grain size[2].



We compared a screen made of rice starch and one made of potato starch and found that the rice starch screen is less saturated in color. We do not have any accurate explanation to explain the reason why the rice starch is less easly dyed than potato starch but we measured that the rice starch density is less than potato starch.

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[2]Wurzburg O. B. "Modified starches : properties and uses". Florida : CRC Press, Inc, Boca Raton, 1986, p.4.

The power press

An other difficulty the Lumière brothers had to overcome was the construction of a press capable of producing a pressure of five tons per square centimeter. Louis Lumière related that his discovered by chance that the transparency of an autochrome plate was increase after his nail accidentally burnished the surface of the screen. He decided to apply this treatment to all the plates in order to make the screens less dense, thereby increasing the sensivity of the plate. He tried various power presses from France and Germany but at that time the glass plates used were not flat enough to support such pressure without breaking. He built a prototype. In our preliminary study of the press he designed we thought that the pressure was applied with a thin needle like in a flatting mill. In fact the concept was much more complex. The last known model of the Lumières' press still in existence was found in a garden in Lyon and was brought to Paris last year. It was disassembled for conservation treatment and to fully understand its mechanism. These instruments seem to have been adapted from an industrial planing machine. The study of its structure provided us with a lot of information about the Lumières' method of flattening the starch grain screen, and the advantages of this technique. Louis Lumière reproduced the movment of his nail across the plate : the needlepoint swept tangentially across the surface of the plate like a windshield wiper.

After 1907, eight power presses were up and running in the Lumière factory. Measurements we made indicate that the transparency was 1.5 times higher after this treatment. Two reasons explain this phenomenon. First, the grains are made more geometrically uniform : spheres are converted into cylinders of more regular thickness, producing less diffusion of transmitted light. In addition, the pressure extends the surface of the grains and decreases the opaque space between them. The method of pressing explains the regular lines we can sometimes see on the screen.

Many other problems were solved by the Lumières such as determining the composition of suitable varnishes, making the emulsion, spectral sensitization and so on...

Analysis of autochrome plates

Another facet of our research was the physical and chemical analysis of original autochrome plates. A group of ten plates from different sources were studied. The evaluation of the number of orange, green, and violet grains in the ten plates was calculated using a video camera connected to a computer and an image processing treatment. Usually our results confirme that the green grains were in the majority but

in a few cases, the blue grains were more numerous. Visual observation of this ten screens revealed warm (pink) or cold (gray-green) hues. Under a microscope, large differences were noted for the color of the blue-violet grains. On some plates they appeared blue, on others, violet. The mean color difference between screens (ΔE* CIELAB) is much higher for the violet grains than for the others. Measurements of the density of colored grains shows also big difference between violet grains. In one of the plates the density is very low and we suspect that a degradation has occured.
Examination of a plate damaged by water reveals that in some areas where the image appears to be in good condition, the screen has deteriorated. On this plate the face of the woman looks nice. Under the microscope, however, when we compare this area to the upper left corner, the degradation becomes evident. The point here is that even with a deteriated screen, the coloured image of an autochrome can still be visually acceptable.

Chemical analysis of the screen layer was made in order to determine if the colorimetric differences could have been caused by the introduction of other dyes. The identification of the dyes will enable us in future to study their light and dark stability. Very little information on this subject was found in the literature because the details of the autochrome process remained proprietary. In 1939, thirty six years after the patent, Mr Seyewetz, the chemist of the company, revealed some dyes used for autochrome production[3]. Other clues were found in the Lumière archives and in handwritten notes in a dye dictionary in the Lumière library. So for our research, thirty five dyes were purchased, extracted from an old catalogue of dyed wool or synthetised for using as reference.

The separation of the dyes from the original plates was attempted on high performance liquid chromatography. It was necessary to neutralize ionized (acid or basic) compounds. We tryed several methods. The best separation was obtain using perchlorate salt as a counterion for the basic dyes in an acid solution for minimizing the degree of dissociation of anionic dyes[4].

Dyes such as tartrazine, erythrosine, patent blue, crystal violet, setoglaucin were identified, as well as diiodofluorescein which is probably an impuritie. Results showed very little difference in the composition of the ten plates. The observed color variation

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[3]Seyewetz A. "L'emploi des matières colorantes en photographie et en cinématographie". *Revue générale des matières colorantes*, août 1939, p.1-4.
[4]Lavédrine B., Gandolfo J.P., Susbielles J.M. "Analyse des colorants dans les autochromes" *Sauvegarde et conservation des photographies, dessins, imprimés et manuscrits*, Actes des journées internationales d'études de l'ARSAG, Paris, 30 septembre au 4 octobre 1991, pp. 91-103.

is therefore not based on the use of other dyes. Instead it can be explained by modifications in the relative proportions of the dyes or by their selective degradation.

dyes identified in autochrome screens	
C.I. number	name
-	malachite green meta-Cl
19140	tartrazine
42025	setoglaucin, malachite green ortho-Cl, bleu flexo 810
42051	patent blue
42555	crystal violet
45425:1	diiodofluorescein
45430	erythrosin
45440	rose bengal

The formulation used for dyeing the grains is as follows :
for the orange grains : rose bengale, erythrosine, tartrazine
for the green grains : patent blue and tartrazine
for the violet grains : crystal violet and setoglaucin.

The same analysis was done on Filmcolor, a modern version of autochromes on cellulose nitrate. Here, other dyes like brilliant green, rhodamine, phosphine, and thioflavin were identified

dyes identified in filmcolor screens and others samples	
C.I. number	name
19140	tartrazine
42040	**brilliant green**
42051	patent blue
42555	crystal violet
45165	**rhodamine 6G**
46045	**phosphin 2J**
49005	**thioflavin T**

At this point, we were able to make the colored starch grains necessary for carrying out our research on autochrome stability. In 1989, Watanabe and Ishikawa[5] succeeded in making an autochrome screen using a pressure sensitive polyester. We were curious to see whether it was possible to recreate a screen closer to the original plate, i.e. on glass with a selection of very fine grained starch grains, dyed with the same dyes used by the Lumières. Unfortunately, we came up against the same problems as the Lumières.

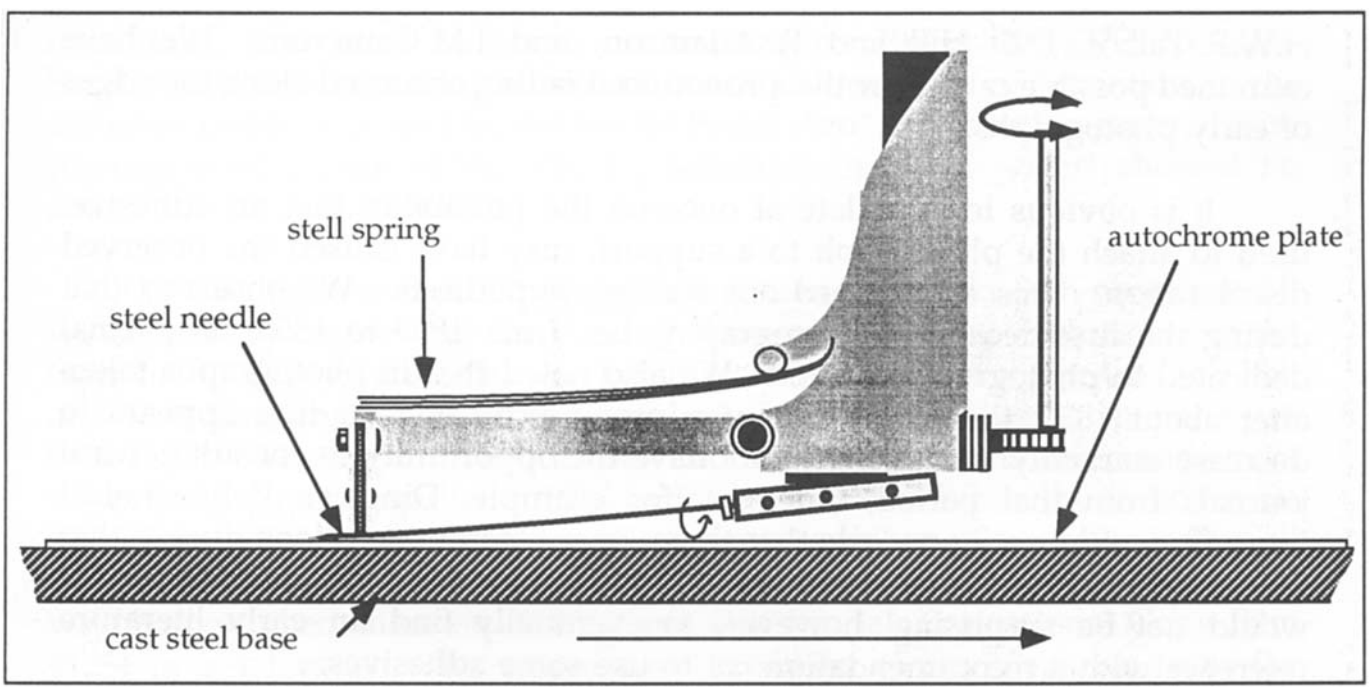
[5]Watanabe S., Ishikawa H. "Reproduction of the Autochrome Process", Report of Kyushu Sangyo University, vol 20, 1989, p.171-179.

Even now it is not easy to extract starch grains between ten and fifteen micrometers in size. We used a floating technique followed by mecanical sifting. For sifting we add three steel balls to prevent the obturation of the screen. After dyeing and then mixing the three colored grains, we coated a glass plate with a solution of latex in toluene (we tested also modern acrylic adhesives such as the Primal N 580, which gaves good results). After this layer has dried, the three colored grain mixture is poured onto it, then smoothed with a brush. The excess starch is removed and carbon black is applied to act as a filler. The screen layer is cleaned with talc on a brush and some chamois leather, then coated with a varnish. The varnish we used consists of dammar resin in ethyl acetate.

These screens were used for shooting on Ilford FP4, using reversal processing. After superimposing the screen and the transparencies, the resulting images had low saturation but are pleasing to look at. These are two samples of the plates : one with sifting grains, the other without.

This study leads us to a better understanding of the autochrome plate : its history, its composition, and its preparation. This work was carried out as a preliminary study to learn more about the light and dark stability of the autochrome screen. The final results will be published at the next ICOM meeting in Washington DC.

We would like to thank Mr J.M. Susbielles, Mr P. Génard, Mr Trarieux-Lumière, Mr J. Demure, Mrs C. Mc Cabe and N. Kennedy who helped us with this project.



Schematic representation of the autochrome power press