PHOTOGRAPHY IN COLORS—THE THREE-COLOR METHOD.

BY A. BOSCH.

It was nearly 100 years ago that Thomas Young, with an extraordinary foresight for one of his time, advanced the theory of the three fundamental or elementary colors, based upon scientific research, and expressed the belief that the nerve apparatus of the eye possessed three kinds of fiber, each being sensitive to a fundamental color.

Indeed three primary colors, properly chosen and combined, are sufficient to reproduce the seemingly infinite combinations of nature. According to Young, it was apparent that the colored image, which could not be produced in a single exposure, was to be obtained only by combining the three correspondingly colored images. The main difficulty, however, was the proper production of these three images.

These images are now produced by means of three colored filters or screens corresponding to the three primary colors.

For the first explanation of the elementary colors we are indebted to the Scotch physicist, James Clerk-Maxwell. He it was who first experimented with three-color photography. The experiments were, however, unsuccessful, for in 1861 we possessed no color sensitizing means.

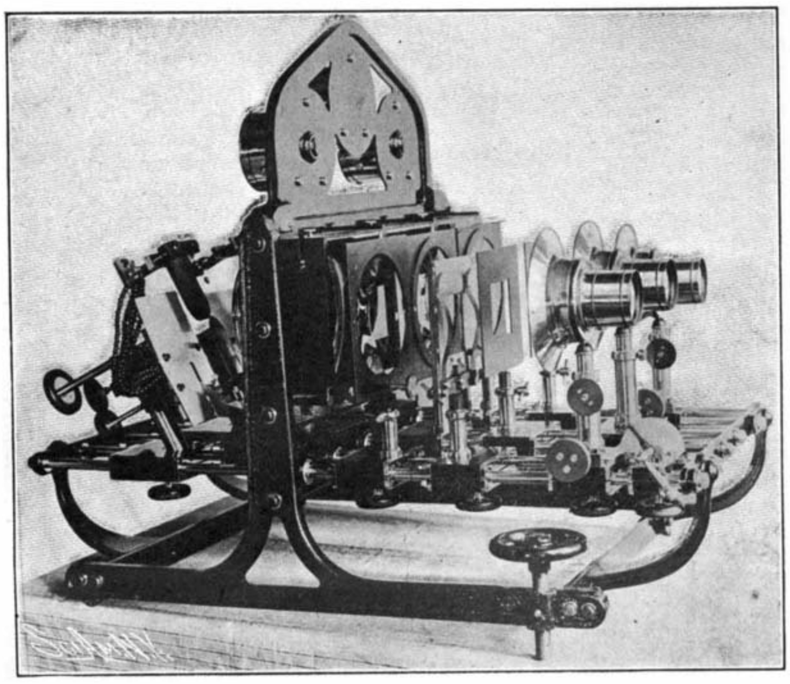

Fig. 6.—Ferd. Ernecke's Projecting Apparatus for Three-Color Slides.

The three elementary colors are red, green, and blue. If we place a colored object before the objective, then cover the lens with a red glass plate, acting as a ray filter, and expose, only the red light rays will be allowed to pass through the glass-plate filter and lens to affect the sensitive plate, the blue and green rays being absorbed. In this manner the red image is produced. By repeating the exposures and substituting the green and violet filters respectively, the three different negatives are obtained. From these three negatives, three positives are produced by copying upon transparent glass plates; and these transparencies are projected, superimposed, upon a screen so that they exactly register, with three corresponding light filters—colored glass plates or liquids. The result is a colored picture, astonishingly true to nature.

Maxwell's liquid light-filters for the projection of the different positives were comprised as follows: For red, a glass receptacle filled with thiocyanate of iron; for green, a solution of copper chloride; and for blue, a solution of copper in ammonia. After Maxwell came Ives, among others.

All these investigators worked along the same lines and obtained very satisfactory results, the only difficulty being that the exposure necessary to produce the three different negatives was too long. Moreover, the registering of the three positives upon the projecting screen was very unsatisfactory.

During the past year, however, much progress has been made in three-color photography by Prof. Dr. Miethe, superintendent of the photochemical department of the Royal Technical School of Berlin, and his assistant, Dr. Traube.

As is well known, the common photographic plate is sensitive to blue light rays only. If such a plate be exposed to the light by using a red filter, it would be hours and days before a negative would be obtained. The astounding success of Prof. Dr. Miethe was only made possible by his succeeding, in connection with Dr. Traube, in preparing plates which are just as sensitive to red and green light as to blue. In the past, such plates could be made only in a very unsatisfactory form. The time of exposure for red light rays was so long that a portrait was in most cases impossible.

With the new plates, however, this difficulty is overcome. The time of exposure necessary is reduced to the fraction of a second.

As a striking example of the possibility of this plate, the following illustration will serve: During the session of the Fifth International Congress for Applied Chemistry, held in Berlin in 1903, Prof. Miethe surprised the members of the photographic section by stating that he desired to take a photograph of the entire convention. It was about 5:30 P. M., with a rather threatening sky; there was much shaking of heads on the part of the members. The professor used but a few seconds in exposing the three-colored negatives. Imagine the surprise of the unbelievers when, upon entering the hall the following morning, they were shown a perfect picture of the convention in natural colors by means of the projection apparatus constructed especially for the occasion.

Fig. 5.—The Same Scene Photographed Through a Red, a Green, and a Blue Screen.

The method of making plates sensitive to green and red rays was first published by H. W. Vogel. It consists in dipping the plates in highly diluted solutions of different dyes. After they have dried they are ready for use.

The work of Prof. Miethe and Dr. Traube has resulted in the discovery of a certain group of coloring compounds which solve the problem in a very satisfactory manner. This group was discovered in preparing a homologous series of compounds of iodide-methyl-chinoline and chinaldine derivatives. These dye compounds are colored red or violet and show a common spectrum, the absorption spectra being all remarkably alike. With the exception of amyl-cyanine, all show two absorption lines—one in the green and the other in the yellow part of the spectrum. The following table gives the positions of the absorption lines of the different compounds:

Dye.	Main Line.	Secondary Line
Amyl cyanine	597 $\mu\mu$	—— $\mu\mu$
Methyl-iso-cyanine	558	519
Ethyl-iso-cyanine	558	517
Propyl-iso-cyanine	563	522
Hexyl-methyl-iso-cyanine	560	519
Ethyl-methyl-iso-cyanine	558	519

These compounds are all soluble both in water and alcohol. The solubility in water decreases with increasing molecular weight. Of the above-named substances, methyl-iso-cyanine possesses the most uniform sensitizing curve in the visible spectrum, extending far toward the red. The methyl and ethyl dyes are therefore well adapted to the preparation of panchromatic dry plates, and make it possible to produce plates possessing uniform sensitivity for the entire visible spectrum, the sensitivity extending into red as far as wave length 670 $\mu\ \mu$, and an appreciable increasing of the sensitivity being noticeable still further into the infra-red.

Ethyl-iso-cyanine is especially adapted to photographic purposes, particularly from the fact that the sensitizing curve does not extend too far into the red, making it possible to work by a tolerably bright red light. Furthermore, it is the most easily cleansed. The preparation is as follows, according to the method given by Spalteholz: The raw product is first cleansed temporarily by recrystallizing in alcohol. These crystals are rubbed and washed with ether and again allowed to crystallize in diluted alcohol. This operation is repeated until the crystals are free from the remaining pitchy substances, which are always formed in the operation. The least traces of these impurities will cause failures and fogging in the bath, or a coloring of the emulsions by the dyes. By virtue of the extraordinary coloring power of the iso-cyanines, a very small amount suffices to bring out the desired effect.

The maximum of panchromatic sensibility is reached by using 0.016 grammes of dye per liter of emulsion, or when the finished silver bromide plate is bathed in a dye solution of 1:50000 from one to two minutes.

A further important work which had to be carried out in order to reach the desired result was the determination of the best colors for the three light filters. Briefly described Prof. Miethe's process is as follows: For the red filter the dyes of the eosine class were found to be the best—of these "Rose Bengale" being the most serviceable for the reason that, in a somewhat concentrated solution, a very broad and sharp absorption band is

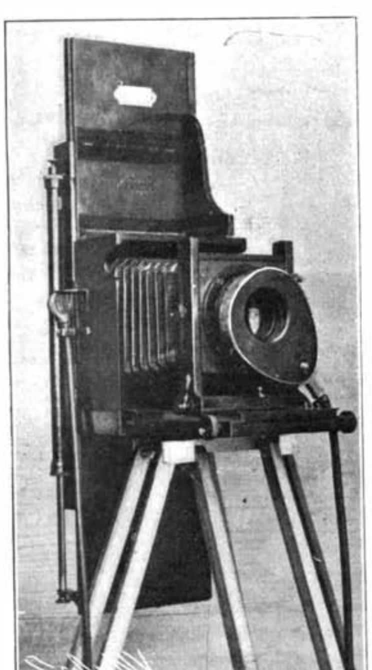

Fig. 1.—Front View of the Camera.

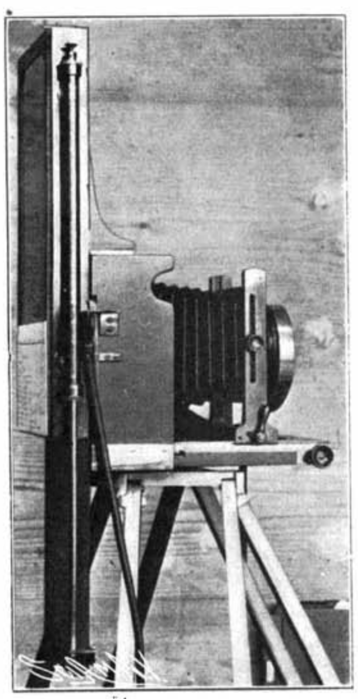

Fig. 2.—Side View of the Camera.

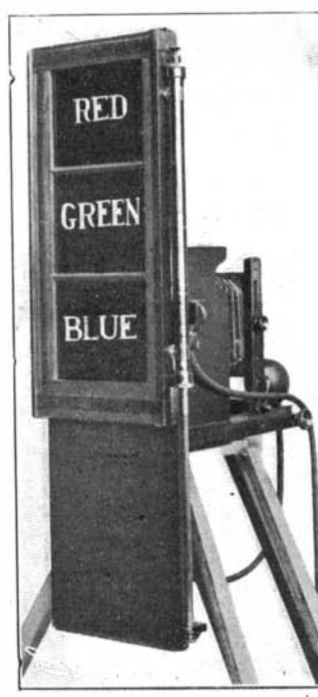

Fig. 3.—Arrangement of the Three Screens.

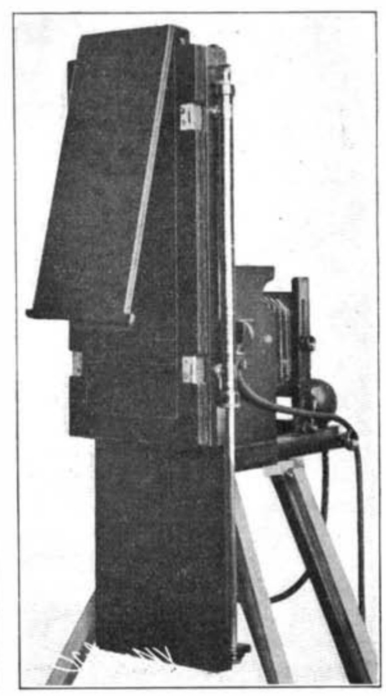

Fig. 4.—Exposing with the Blue Screen.

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shown in the green part of the spectrum. In preparing a red filter of the proper character with "Rose Bengales," the same must be combined with a filter which absorbs blue and blue-green. The film of "Rose Bengale" is to be so prepared that the filter, when dry should allow light waves down to wave length 590 $\mu\mu$ to pass through.

As medium amounts for the preparation of a red filter, 1.5 cubic centimeters of a 2 per cent solution of "Rose Bengale" in water to 18 to 20 cubic centimeters gelatine solution are taken, and 9 to 10 cubic centimeters of this mixture are then applied to 80 square centimeters plate surface.

If a plate, prepared in this manner, be combined with another tightly-fitting covering plate, which is colored with a yellow dye (best prepared with gelatine and a 4 per cent tartrazine solution) an extraordinarily quick-acting red filter is obtained, giving in every respect the desired position of absorption for the ethyl red plate. A great deal now depends upon the proper preparation of the green filter. An incorrectly toned filter causes as many poor results in the reproducing of colors as a bad exposure. The preparation of the green filter has consequently been very difficult. The adaptability of the green filter depends mainly upon the amount of violet rays which are allowed to pass through.

Suitable green filters can be prepared by using "brilliant acid green." Most green dyes tend to allow the extreme red rays to pass, which, however, is unimportant. Brilliant acid green, shade VI B, is best adapted for the ethyl red plate. To 6 cubic centimeters gelatine solution (for 80 square centimeters plate surface) add 1.6 cubic centimeter brilliant acid green (1:100), and to this solution 4 to 8 drops tartrazine solution (1:25).

By this means exclusion of the violet and the required retardation of blue rays is obtained.

The blue filter offers very little difficulty. It is necessary, at least in strong blue-green sensitive plates, to exclude only those rays lying in the green part of the spectrum. Light having at most a wave length of 480 should pass through. On the other hand, it is desirable that, in the reproduction of deep red tones of the original, the blue filter should allow the red of the spectrum to pass unhindered. The recipe for the violet dye is as follows: For 80 square centimeters plate surface, take 13 cubic centimeters gelatine solution, to which 2 cubic centimeters new victoria blue and 2 cubic centimeters methyl violet solution (1:250) are added.

The bright dye, however, demands too short a time of exposure. It is therefore better to retard the exposure. This is brought about by means of a very thin tartrazine disk, which is first so toned down that the blue filter permits a medium exposure. For the ethyl red plate an extra thin covering disk suffices for the equal exposure of red and blue. The required covering disk should contain 5 to 6 drops tartrazine solution (1:25) to about 120 cubic centimeters gelatine. From this short description of the colored filters, it is evident that it is possible to expose nearly the same length of time with the red and blue filters. The green filter, however, requires a much shorter period. A retardation of the green filter to about the same exposure is very difficult to bring about without seriously disturbing the curve of transmission. For the proper preparation of the color filters the following requirements are to be strictly observed:

1. A dark room free from dust.
2. Skill and painstaking care in handling.
3. A suitable cement or adhesive substance.
4. Careful observation of cement temperature and cautious warming of the plate after cementing.

Filters prepared in this way will last for a long time if not exposed directly for hours to the sunlight, which, however, is not probable in the usual method of working.

Prof. Miethe has a red filter which he has used just two years, making hundreds of exposures with it, in spite of which it has not changed in the least.

We come now to the description of the apparatus. This is made rather small in order to be easily carried. The best size for plates is 9 x 8 centimeters (Figs. 1, 2, 3).

As has been already mentioned, the exposure should be made as quickly as possible. Hence very fast lenses are required. The three images must also exactly register. A long focal distance is therefore necessary and an apochromatic lens. The choice of the latter, however, is rather limited, as apochromatic corrected lenses, i. e., those possessing a like focal distance for the main light rays, unfortunately do not transmit the light very rapidly. For a 9 x 8 centimeter plate a strong portrait anastigmatic lens, such as Prof. Miethe uses, of at least 180 millimeters focus is not adaptable. The camera differs very little from the usual form (Fig. 4), the main difference being that it is provided with a plate-holder (Fig. 4), whereby the three exposures can be made upon one plate of 9 x 24 centimeter dimension (Fig. 5), such plates being uniformly and easily developed. The three glass filters are brought immediately before the sensitive plate (Fig. 3). A ground glass just behind the color filters serves to focus the object properly.

The filters are firmly attached to, or set into the holder (Fig. 3). The plate-holder is then inserted in place of the ground glass. By means of a pneumatic release, the plate holder and filters are made to drop from top to bottom in the slide apparatus, passing successively before the lens (Figs. 3, 4, 5). The three accompanying photographs were made from a plate exposed in this manner. It is not possible to state the length of time necessary for exposure, this depending mainly upon the lens, the diaphragm, and the light. It is advisable to stop down as much as possible in order to facilitate registration.

As the ethyl red plate is very sensitive to red, the time of exposure for red and blue, behind properly chosen filters, can be taken from 1:1 to 1:4. The exposure for green is much less. Another point to be emphasized is that in preparing ethyl red plates, they should be dried with the utmost dispatch.

Highly sensitive dry plates are to be carefully dusted and worked in a bath containing: ethyl red, 0.1 gramme; alcohol, 300 cubic centimeters; distilled water, 5,000 cubic centimeters; ammonia, 50 cubic centimeters.

The washing must be done in absolute darkness, the plates rinsed under the water tap for 2 to 3 minutes, and then quickly dried. If the plates are long in drying they do not work well and fog easily. If, however, they be dried within 15 minutes, brilliant results can be obtained.

Prof. Miethe dries his plates in a current of air which passes between water pipes, whereby the escaping moisture from the air is quickly condensed upon the pipes. The air being now dry is slightly heated and then passes off over the plates. The plates dry in about 12 minutes. The developing and further arranging of a 9 x 24 centimeter plate with the three negatives (each 9 x 8) is the same as that of a usual plate.

THE PROJECTION APPARATUS.

Colored projections were shown for the first time by Prof. Miethe in the Urania Theater, Berlin, in the winter of 1903. The projecting apparatus used upon this occasion was built by the well-known firm of Ferdinand Ernecke, Berlin, manufacturers of precision instruments, being assisted by the scientific manager of the Urania, Dr. Donath. The apparatus consists of 3 arc lights (hand regulated) and consumes the enormous current of 200 amperes, or 45 horse power, only 10 per cent of this being transformed into light, while the other 90 per cent passes off in the form of heat, thus making it very difficult to protect the light condensers and to keep them from cracking.

These light condensers consist of 3 lenses each, and are insulated against the heat of the carbons by means of a hard glass plate. In front of the condensers are the cooling receptacles, which also act as filters for different light rays, being filled with the three respective solutions, above described for filters.

A voltmeter is provided for each lamp whereby the current and potential in each pair of carbons is carefully regulated. The lantern slides are inserted between the condensers and their projecting lenses.

The 9 x 24 centimeter plates (positives) are cut into three parts; the red, green, and blue positive being then glued on to another larger plate at equal distances from each other and corresponding to the distance between lenses.

This method permits quicker handling of the apparatus, making a focusing of the lenses for each picture unnecessary. The lenses were made by the firm of Voigtländer & Son, Braunwick, being triple-anastigmatic and exactly alike in focus, transmission of light, etc., and, of course, very expensive. Owing to the small number of lenses, very little light is lost through reflection or absorption.

The apparatus is as near perfect as the skill of the mechanic will permit. It can also be used with lamps of less current consumption (15 to 20 amperes) by substituting smaller carbons.

Longitude Difference Between Greenwich and Paris.

The investigations concerning the longitude difference between Greenwich and Paris have now been completed. The work has been of a particularly arduous and protracted nature, necessitating enormous calculations. Altogether the English and French observers have carried out 230 observations, equivalent to eighty nights' work each. Two English and two French observers have been engaged upon the task. The observations were made at Greenwich and Paris simultaneously, and in order to obtain absolutely similar results the instruments were frequently interchanged. The results of these observations have proved both the Greenwich and Paris existent meridians to be erroneous, the calculations finally working out just between the two. The discrepancy, however, is very minute, being only a small fraction of a second.

SPIER FALLS DAM AND POWER PLANT.

BY WALTER H. MAIN.

The imposing power plant which is now nearing completion at Spier Falls, which is located about ten miles above Glens Falls, in this State, has scarcely attracted the attention which its magnitude demands; for when the complete plant, as now laid out, has been installed, the ten great turbines will have an aggregate capacity of 50,000 horse power, which is equal to that of the famous electric plant as originally installed at Niagara Falls. The site of the dam was selected because of the natural advantage conferred by a fall of the Hudson River, which is well adapted at this spot to the creation of a great reservoir. The river flows between the Luzerne Mountains on the north, and Mount McGregor on the south, and the two form a valley which at this point is about half a mile in width. The underlying rock is of good quality, well adapted as a foundation for masonry, and the watershed of the Hudson above the reservoir contains about 25,000 square miles.

The dam, of which we present several illustrations, has a total length of 1,800 feet and contains 181,000 cubic yards of masonry. It is built of a fine quality of granite which was obtained from the Saratoga hills. At its deepest point it measures 156 feet from bedrock to crest, and a cross-section at this point shows a total width of base of 115 feet. The structure is virtually composed of three parts. Its northerly section, which abuts on the Warren County shore, is 820 feet in length and rises to an elevation of 80 feet. This is separated by a wing wall 10 feet in thickness from the southerly portion, which extends for 550 feet and is 90 feet in height. South of this is the canal, 420 feet in length, by which the water is led from the reservoir to the fore-bay at the back of the power house. At the fore-bay it is led by ten steel tubes, each 12 feet in diameter, to as many 54-inch turbines, which will be run under a 90-foot head. Each turbine will be direct-connected to a generator of 5,000-horse-power capacity. The ten units will be located in a handsome power house, 400 feet in length, which will be built of brick and steel, and will conform in every respect to the best modern construction and finish for large hydraulic-electric power plants. In order to secure the greatest possible head of water, the power house is located in what was formerly the bed of the river. The total cost of the plant is about $2,000,000.

The marketing of the power (a problem which in some of the larger power plants that have been constructed of late years has proved to be more serious than was anticipated) has presented no difficulties, because of the large number of important towns and manufacturing centers that are within easy reach. Within a radius of 50 miles are Glens Falls, with its shirt factories and other industries; Saratoga, with its big demand for electric lighting; Troy, which produces more collars, cuffs, and shirts than any other city in the world; Schenectady, with its great electrical and locomotive works; Watervliet, with the United States arsenal and gun factory, and Albany, the capital of the State. Throughout this section there are many hundreds of miles of interurban trolley lines, which find cheaper power in the dammed-up energy of the Hudson River, than in their own coal-fed power plants. So promising is the demand, that thirty years' contracts have been made for practically the entire output of the plant.

The provision for transmitting the power was a large undertaking in itself. A right of way for pole lines was secured, the three-phase system was installed, and mounted linemen, in relays of fifteen miles patrol every foot of the line each day. All the linemen are kept in communication with the switchboard by a private telephone line, and the loss of power due to defects of transmission is practically nothing. The power is distributed as alternating current of high voltage to sub-stations in the various cities and towns, where it is transformed and stepped-down to the particular voltage required by the consumer.

Berliner's Airship.

Emile Berliner, well known for his microphone-telephone transmitter, the gramophone, and other inventions, announces that he has devised an aeroplane. From the newspaper accounts thus far published, it seems that his contrivance is made of aluminium and tin-plate, with ribs of oak and metal tubing. The whole machine is 10 feet wide by 14 feet long.

The escalator at the 23d Street station of the Sixth Avenue elevated railroad, New York city, which has been shut down recently, has now resumed regular operation. Some time ago the motor driving the escalator was connected to take current from the third rail. It was found, however, that the voltage fluctuates over a considerably wider range than had been anticipated and the shut-down was necessary in order that alterations might be made in the motor to secure better speed regulation. During the interval that the electrical changes were in progress, the receipts of the station showed a marked falling off.