A HANDBOOK OF PHOTOGRAPHY IN COLOURS.

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MARION & Co.,
22 & 23, SOHO SQUARE, LONDON, W.
1900

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LIPPMANN'S PROCESS OF INTERFERENCE HELIOCHROMY.

The great question of colour photography in which a sensitive surface could be exposed in the camera in the ordinary manner and the impression thus obtained be made to show the colouring in all its brilliancy of the objects photographed, is one which has received the attention of scientists for years past.

Edmond Becquerel, in 1840, was probably the nearest to reach the desired goal, as he actually obtained coloured images directly in the camera. The colours, however, were not perfect, and owing to the nature of the substance on which they were formed could not be fixed, therefore could only be examined in a subdued or non-actinic light.

In the early part of the year 1891 Professor Gabriel Lippmann, a French physicist, announced that he had been able to produce direct in the camera photographs showing the spectrum in the true colours and that the results were absolutely permanent. Startling as this statement appeared at the time the

experiments have since been confirmed by others, and the writer has obtained by the method heliochromes in which the colours are remarkable for their brilliancy and clearness.

Lippmann appears to have worked out this process from a purely theoretical standpoint based upon the well-known phenomenon of interference of light, examples of which we have in mother of pearl, opal, and upon which the beautiful colours of a soap bubble depend and the colours of all thin films are due; and it is interesting as being an example of one of those instances in which theoretical reasoning based upon well-known scientific facts has led to the working out of a successful process.

Before proceeding to the practical part of our subject it will be necessary to explain to some extent interference of light and to show how it has been applied in the production of the results.

The generally accepted theory of light is that it, like sound, is the result of wave motion, and the medium for its transmission has been given the name of ether.

Now these ethereal waves are not all alike, but vary in their lengths and amplitudes:—Let A B Fig. 1 represent the direction of a ray of light the ether

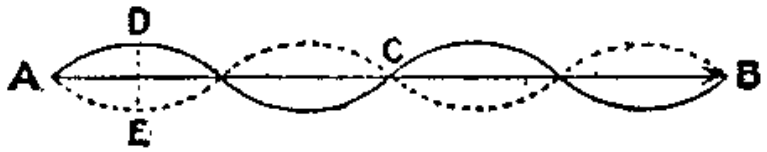

Fig. 1.

particles vibrating to and fro at right angles to the direction of propagation giving rise to the wave

motion as shown. A C would be a wave length, D E the amplitude of vibration, or distance traversed by the vibrating particles in passing from one extreme position to the opposite.

If now another ray of light of the same periodicity and the same phase of vibration start from a point a whole wave length in front of the first one will intensify the other and we shall get more light; in other words the ether particles acquire a greater amplitude. Fig. 2 (a).

Fig. 2 (a).

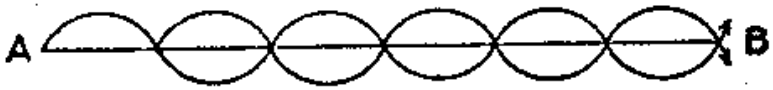

Fig. 2 (b).

Let, however, the second ray (in opposite phase) start from a point half a wave length in front of the the first then one will neutralize the other, owing to the crests of one system being opposed to the troughs of the other and interference would result and consequently absence of light. Fig. 2 (b). It follows, therefore, that interference will occur when one system differs from another by an odd number of semi-undulations the same as holds good in the case of sound waves.

Zenker's theory: Stationary or stagnant waves.

A wave is said to be stationary when its form changes alternately from that of a crest to that of a hollow, but does not to the eye exhibit any progressive movement. Waves of this nature can readily be produced by the superposition of direct and reflected waves on a stretched cord. For this purpose we may make use of a long vulcanized rubber tube filled with sand having one end firmly fixed at a convenient height. If the free end be quickly shaken a wave is produced which travels along the tube to the end and is there reflected and returns to the hand. By carefully timing the impulses given to the tube by the hand, a series of waves of the same length may be made to follow each other regularly, but the length of each half wave must be an aliquot part of that of the tube such as $\frac{1}{2}$, $\frac{1}{4}$, &c. When the tube vibrates as a whole, the length of the wave generated will be equal to twice that of the tube, because the wave is continually reflected at one fixed end and at the hand. To produce a wave on the tube which shall be equal in length to that of the tube itself it is necessary to shake the tube as fast again as when required to make it vibrate in the ordinary way. The effect of causing two half wave lengths exactly to extend along the tube is, that the direct and reflected waves will completely interfere with one another at the middle point along the tube. For as the direct wave leaves the hand a reflected wave from the fixed or opposite end will be travelling forward in opposite phase and the consequence is that corresponding points in the two waves meet in opposite phase at the middle of the

tube at the same moment and as the vibrations would be equal in each direction the one would neutralize the other and there would be no movement as shown by the direction of the small arrows in Fig. 3.

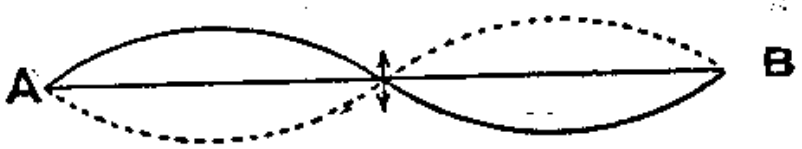

FIG. 3.

The appearance of the tube to the eye is that of its two halves vibrating independently of each other, the middle point being at rest. The point where there is no perceptible motion is known as a node and the vibrating parts ventral segments.

It will now be self evident that where we get no movement or no light no chemical action can take place, while between these parts or at the position of the ventral segments we should have chemical action and therefore deposit upon development, consequently we should have a series of layers or particles of silver separated by alternate blank spaces and so obtain a record within the film of the different vibrations.

We are now in a position to follow the reasoning that has been adduced to account for the production of these photographs in colours and to understand the manner in which theoretical knowledge has been turned to practical account.

In a photograph taken in the ordinary way the deposit after development is present in the film as a continuous one, but in order to fulfil the conditions necessary in the subject under consideration it is

essential that this continuity be broken up so as to produce points of interference. We have seen that this can be brought about by the super-position of direct and reflected waves, and in taking these photographs a metallic mirror in the shape of mercury is in contact with the sensitive surface during the exposure in the camera, and this mirror is for the purpose of reflecting the incident light back upon itself and so giving rise to interference within the film, with the result that although vibration takes place, the effects of propagation are stopped, and instead of having propagated waves we get stationary waves, which rise and fall each in its own place and so leave a record of their own forms, the largest movement leaving the strongest impression, and where there is no movement no impression would be left. So that there is formed a series of planes parallel with the surface of the mirror in which the light is alternately at a maximum and a minimum intensity. On development of such a plate we should have a series of strata corresponding to these maxima and minima in which the deposit is alternately present and absent.

On viewing photographs taken under these conditions by means of white light falling upon them at a certain angle, the deposit in the film gives rise to interference, with the result that the constituents of white light which were active in forming the image are reflected to the eye of the observer.

To more clearly understand the subject let us consider for a moment the doctrine of colour. Colour is not an inherent quality in a body. It arises from the treatment on the part of the body of the incident light which falls upon it. Colour is due to the extinction of some of the constituents of the white

light within the body, the remainder which return to the eye imparting to the body the colour which it appears.

In a soap film we have an excellent example of the manner in which interference colours are produced. Its thickness is found to be comparable to a wave of light, and as it gradually thins by gravity, part of the film becomes of a thickness that the reflection from the back surface is half a wave length behind that reflected from the front, and one of the constituents of the white light would be destroyed at such place, and the colour seen by the eye would be the result of the remaining components of white light.

Comparing this with our interference colour photographs, supposing the blue constituent of white light to undergo reflection within the film at points situate half the wave length of the blue behind one another, the blue would be annihilated at these places and the remainder which would reach the eye would be the components of white less the blue. We have, therefore, a demonstration that the colours reflected from the film are not caused by any conversion of white light into coloured light but by the abstraction "due to interference" of certain colours from the components of white light.

The various hues of colour can also be explained on the theory of partial interference only having taken place in parts :—Thus crimson and purple are the result of a mixture of red and blue and the less the proportion of blue present the more will the red be felt, so that we should have tints ranging from purple to crimson according to the proportions in which they are mixed.

That moisture also plays an important part in

the rendering of these heliochromes is evident from the change in colour produced by exposure to air. The writer has an example in which a certain part of the image is of a golden yellow, but on leaving it exposed to the air it assumes a coppery hue. The probable explanation is that the film takes up moisture when the distance apart of the laminæ becomes greater and reflects light of a greater wave length so that more red is felt. That such is the case appears to be borne out by the fact that on warming the film the image again appears of a golden yellow colour and if the heating be carried too far it becomes of a greenish yellow.

In experimenting with this process, among several peculiarities noticed was one in particular which appeared to be directly connected with the successful rendering of the colours and as it suggests the possibility (at least) of another explanation to account for the production of these heliochromes, we feel justified in advancing it, more especially as the same thing has already been suggested by Ives.*

In a large number of photographs by this process it rarely happens that the colours are seen the same from either side and indeed with some of the writer's most successful results no colours whatever were visible from the glass side. Now it would appear that if the colours are simply due to interference of light reflected from deposited silver in a series of planes that the colours should be seen from either side, although is has been stated by Dr. Neuhauss** that these heliochromes are of two kinds—one in which

*British Journal of Photography, December 15th, 1893.

**Eders Jahrbuch, page 186, 1895.

the colours can be seen from either side, the other from the film side only. Another peculiarity of these heliochromes is that when viewed by ordinary reflection they resemble a positive, although the image is negative by transmitted light.

The conclusions to be drawn from this appear to indicate that these heliochromes can be produced by means of a single interference film of varying thickness backed up by different amounts of deposited silver. And that this interference film is the result of partial reversal brought about by the prolonged exposure in the camera.

Against this hypothesis, however, must be placed the recent experiments of Dr. Neuhauss in which he states that having prepared sections and taken photo-micrographs of them he found Zenker's thin laminæ were actually present and that the distance of the laminæ represented in the photo-micrographs corresponded exactly with the calculated distance of Zenker's laminæ for the particular region of the spectrum taken. This then would appear to be conclusive proof of the correctness of Lippmann's theory. Still although there appears to be little doubt that the colours are due to interference the conflicting nature of the results that are often obtained tend to show that they are not in harmony with the theory as originally put forth and that some further explanation is necessary.

Having now given the theory as explained by Lippmann to account for the production of these heliochromes, together with our own observations in experimenting, we will proceed to describe in detail the practical working of the process.

Apparatus.

The only piece of apparatus required beyond that which every photographer already possesses, is the special dark slide containing the mercury chamber. An illustration of the slide is shown at Fig. 4 open. In appearance it resembles the ordinary book form type, with the exception that in the place usually occupied by the second shutter is a fixture that forms the back of the mercury chamber (B).

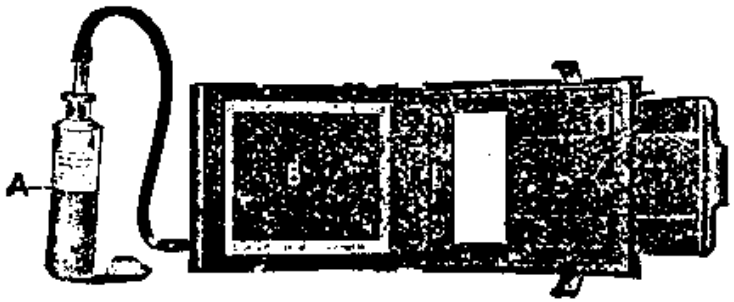

FIG. 4.

To use this apparatus the sensitive plate with its film side downwards is placed in this half of the slide resting upon a narrow rabbet of chamois leather. Twelve steel springs keep the plate firmly pressed against the leather and so prevent leakage of the mercury. The bottle (A) containing the mercury is, when everything is ready, held in such a position as will allow of the contents flowing down the rubber tube and into the space formed between the film and back of slide. It will be seen that the inlet is at the bottom of the slide so that the mercury on entering will rise in an uninterrupted wave over the surface of

the film but should any stoppage occur, markings on the finished picture will be the inevitable result.

The mercury is prevented from returning by having a metal clip on the rubber tube or keeping the bottle above the level of that in the slide. A small valve (not shown in illustration) allows the displaced air to escape and an indicator shows when the slide is full.

As the use of the mercury is to form a perfect reflecting surface in contact with the film during its exposure in the camera, it is necessary that it should be kept bright and clean. Having a decided objection to any chemical treatment, the writer "using pure mercury" has always resorted to running it through a paper cone "having a small orifice at its apex" or a small separating funnel; and finds this method to be satisfactory.

Lenses.

From the extreme slowness of the emulsion used in this process it becomes very necessary to employ lenses transmitting a large amount of light and capable of working well with a large aperture and having the shortest focus possible, and any of those which fulfil these conditions appear to answer in practice. Lippmann and others have mentioned the following as being suitable: Anastigmat Zeiss 6·3, double anastigmat Goerz 7·7, and also Voigtländers Collinear 6·3. And the writer has used a Ross rapid symmetrical and also a Petzval type of portrait lens of 6 inches equivalent focus employing the full aperture in each case, and has obtained excellent results, the images covering a surface on the quarter plate of about two inches square.

Preparation of Emulsion.

When we come to consider that the colours of these photographs are said to be the result of the reflection from the different laminæ or strata within the film of the particular constituents of the white light which were active in forming them, and that the narrowest of these strata is not more than half the length of the shortest wave visible to our eyes, it is evident that the sensitive film must be of the finest possible nature with an entire absence of any visible granularity. In fact the film must be a transparent one.

In order to fulfil this condition Lippmann first of all used the albumen process as being one lending itself more particularly to the preparation of emulsions free from any visible grain.

In 1892 Messrs. Lumière, of Lyons, showed results which were greatly superior in brilliancy and beauty of colouring, and which had been produced upon gelatino-bromide plates, prepared by a formulæ which they published in 1893.

The method adopted in Lumière's process to ensure the sensitive salt being in the finest possible state of division, consists in mixing the silver nitrate and potassium bromide in water containing the gelatine, and of employing a weak solution of these, and also keeping the temperature as low as possible during the process of mixing.

Under these conditions an emulsion is formed which is remarkable in appearance, being almost perfectly transparent, and plates coated with it at most only show the faintest opalescence.

By this modification one of the greatest drawbacks

to the successful working of the process with gelatine plates was removed and a means placed at our disposal which in careful hands is capable of yielding good results.

We now give the formulæ for the preparation of the emulsion as recommended by their respective authors :—

Lumiere's formulæ.

A

Water (distilled)	400 cc. or 14 ozs.
Gelatine	20 grams or 308·6 grains

B

Water (distilled)	25 cc. or 7 drachms
Potassium bromide	3·5 grams or 54 grains

C

Water (distilled)	25 cc. or 7 drachms
Silver nitrate (recrystallized)	5 grams or 77·15 grains

The gelatine is placed to swell in the 400 cc. of water, the silver nitrate and potassium bromide are each dissolved in 25 cc. of water, all three are then heated on a water bath to a temperature of 35° Centigrade or 95° Fahrenheit. The gelatine being dissolved, the solution is divided into two parts, to one of which is added B, to the other C. The two solutions are then mixed by pouring the one containing the silver nitrate into that of the potassium bromide, stirring well the while. If the operation has been carefully performed there will now result an emulsion of silver bromide in gelatine which is transparent and of a golden colour.

A modification of the above method by which a

greater degree of sensitiveness is obtained (but at the risk of red fog) consists in dissolving the silver nitrate in the water in which the gelatine is swelled, thus :—

A

Water (distilled)	200 cc. or 7 ozs.
Gelatine	10 grams or 154·3 grains
Potassium bromide	3·5 „ „ 54· „

B

Water (distilled)	200 cc. or 7 ozs.
Gelatine	10 grams or 154·3 grains
Silver nitrate (recrystallized)	5 „ „ 77·15 „

The operations with regard to mixing, temperature, etc., are the same as before.

The writer, as the result of a number of experiments, was led to adopt the following formulæ :—

A

Water (distilled)	225 cc. or 7 ozs. 7 drachms
Gelatine (Nelson's No. 1)	5 grams or 77·15 grains
Potassium Bromide	2·1 „ „ 32·4 „

B

Water (distilled)	225 cc. or 7 ozs. 7 drachms
Gelatine (Nelson's No. 1)	5 grams or 77·15 grains
Silver nitrate (recrystallized)	3 „ „ 46·29 „

Each having been brought to a temperature of 35° C (95° F.) B is added to A with continual stirring.

Valenta's Formulæ.

A

Water (distilled)	300 cc. or 10½ oz.
Gelatine	10 grams or 154·3 grains
Silver Nitrate	6 „ „ 92·58 „

B

Water (distilled)	300 cc. or 10½ oz.
Gelatine	20 grams or 308·6 grains
Potassium Bromide	5 „ „ 77·15 „

Each having been brought to 35° C (95° F.) A is added to B gradually.

With the Lippmann process it is a *sine qua non* that the plates should be orthochromatic.

To this end 2 cc. or about ½ drachm of the following is stirred into every 100 cc. or 3½ ozs. of emulsion.

Alcoholic solution of cyanine (1·500) 4 cc. or 1 drachm
„ „ erythrosine (1·500) 2 cc. or ½ „

The emulsion is then filtered through glass wool, pure cotton wool, hemp, or No. 1 Swedish filter paper, and the plates coated without delay. The glasses which should be patent plate and which must have been made chemically clean by immersing them in nitric acid and water (1 to 10), washing and rubbing over them a weak solution of caustic soda or potash and a little methylated spirit, and after washing under the tap, rinsing in distilled water, and setting up to dry on clean blotting paper, are warmed, and the filtered emulsion poured over in the manner of collodion, the excess being returned to the filter.

The coated plate is now placed on a levelled glass or marble slab to set ; when set, each plate is immersed for a minute in alcohol and washed for fifteen minutes in water, drained, and dried.

Plates that have been prepared with the plain emulsion may also be rendered colour sensitive by

dipping, although perhaps the results are not quite so good as when the emulsion itself has been treated.

To proceed in this manner immerse the plates for two minutes in the following :—

Water (distilled) - - - 100 cc. or 3½ ozs.
Alcoholic solution of cyanine (1·500) 4 cc or 1 drachm

Or a similar solution of erythrsione or a mixture of the two.

The cyanine confers a maximum sensitiveness from D to C, erythrosine from E to D of the spectrum.

Quite recently the following method of preparation of the emulsion has been given by Professor Lippmann and differs somewhat from the foregoing :—

Lippmann's formulæ.

Water (distilled) - - - - 100 cc. or 3½ ozs.
Gelatine - - - - 4 grams or 61·72 grains
Potassium bromide - ·53 „ „ 8·1 „

For orthochromatizing add about 6 cc. or 1½ drachms of an alcoholic solution of cyanine (1·500) and 3 cc. or 45 minims of an alcoholic solution of chinoline red (1·500).

Having mixed the above at a temperature of 35° C· (95° F.) and in red light add ·75 grams or 11·5 grains of dry powdered silver nitrate and stir until dissolved. Filter through glass wool and coat plates as before. Allow the emulsion to set, place each plate in alcohol then wash for half an hour, drain and dry. The plates in this condition would keep a long time.

Owing to the disadvantages attending the washing of the plates themselves, any method which would obviate this, and at the same time allow of the necessary fineness of grain being obtained would be a distinct gain. Valenta with his formulæ recommends pouring the emulsion in a fine stream into 1 litre (35·22 ozs.) of alcohol 90 °/₀, cutting up and washing for a short time in running water, re-dissolving and coating plates as usual. Although a considerable amount of success attended a trial of this method the plates could not be said to be as transparent as those prepared by the original plan.

It is usually recommended to whirl the plates after coating, experiment, however, shows that this is not only unnecessary but is harmful, as not only are the colours less brilliant, but the general sensitiveness of the plate is reduced by so doing.

Increasing sensitiveness of plates.

Several methods having been given by which the general sensitiveness of these plates may be increased, the following by Professor Lippmann is perhaps one of the best :—

Lippmann's method.

Alcohol (absolute) - - - 100 cc. or 3½ ozs.
Silver nitrate - - - ·5 gram or 7·7 grains
Acetic acid (glacial) - - - ·5 cc. or 7 minims

The dried plates are immersed in this for about a minute, whirled, and again dried, and must be used as soon after as possible as they will not keep.

Lumiere's method.

Water (distilled) - - - -	200 cc. or 7 ozs.
Silver nitrate - - -	1 gram or 15·43 grains
Acetic acid (glacial) - -	1 cc. or 15 minims

The plates are immersed for two minutes in the above and dried.

To the same end Valenta recommends the addition of 1 gram (15.43 grains) of sodium sulphite to every 300 cc. (10½ ozs.) of emulsion and subsequent heating to 38° C. (100° F) for a short time.

The writer working in the same direction but with the desire to take advantage of the use of silver eoside as a sensitizer for mixed colours prepared this substance in the form of a powder and added ·2 gram (3 grains) to 100 cc. (3½ ozs) of emulsion. This method was found to greatly increase the general sensitiveness, plates exposed behind a Warnerke sensitometer for five minutes to a sixteen candle-power incandescent lamp showing the number nineteen distinctly on development, against the number nine with the same emulsion without the addition of the dye and silver compound. Further trials have confirmed this, as well as the excellence of the substance as a colour sensitizer.

Exposure of the plate.

There is no doubt that the most suitable object from a theoretical point on which to experiment would be the spectrum, and at Fig. 5 is shown a photograph of the apparatus as arranged for this purpose. A is

a small arc lamp, B a condensing lens placed so that the light is focussed on to the slit of the spectroscope, C (a direct vision one) attached to a camera.

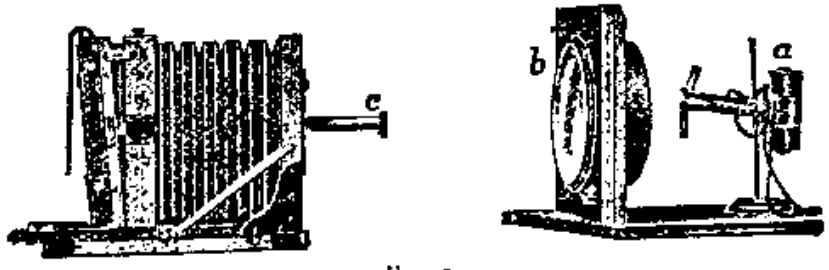

Fig. 5.

The writer, however, for certain reasons preferred experimenting on objects by means of reflected light, and for this purpose made up a test subject composed of brightly coloured ribbons arranged in form o. a star.

It was found that working in the open air and illuminating the object by sunlight and employing a portrait lens of six inches focus with full aperture, "the size of image formed being two-thirds that of the original" that the exposure required to produce good results (using plates that had not been treated with a chemical sensitizer to increase their sensitiveness) varied from fifteen to twenty minutes.

One thing most noticeable was the importance of the objects being brilliantly illuminated and although there is a certain latitude in the exposure it appears to be much less than in ordinary cases.

Exposure meters seem of very little use, and careful experiment noting all the conditions under which the photographs are taken, appear to be the only safe guide in practice. However, in taking a

sun-lit landscape including moderately close objects and using a Zeiss 6·3 lens and employing the most sensitive plates, the exposure would be about two minutes. Exposures made with and without light filters to exclude the ultra-violet rays produced results which were not distinguishable one from another; therefore, the use of a screen for this purpose would appear to be unnecessary. What is more particularly required seems be a plate which is equally sensitive throughout the entire spectrum rather than one whose sensitiveness is greatest to the most luminous portion.

Before placing the prepared plate in the dark slide it must be carefully dusted with a soft brush and when in position the outer surface cleaned from any deposit there may be upon it. The mercury is now introduced slowly but without any stoppage, and when this can be performed in the dark room, it is advisable to draw out the shutter and watch the inflow of it and if any air bells form on a part of the plate on which the image will fall the whole operation must be repeated until they are absent.

On removing the exposed plate from the slide, a broad soft camel hair brush must be lightly passed over it several times in order to remove any adhering mercury on the film and which would result in streaks and markings of a metallic lustre on the finished picture. Dr. Neuhauss* recommends dipping the brush in alcohol as being more effective for this purpose. The plate is now ready for development.

Developing.

Owing to their extreme slowness, a large amount of light can be employed in the dark room with

*Eder's Jahrbuch, 1898.

safety in the development of these plates. In our own practice a sixteen candle power incandescent lamp covered with one thickness of Canary medium is used.

The developer may be any of those usually employed:—Pyro, Amidol, Metol, Eikonogen, etc., although perhaps the best for the purpose is the Pyro-ammonia originally recommended by Lumière, thus:—

Lumière's formulæ.

No. 1.

Pyrogallol	1 gram or 15·43 grains
Water (distilled)	100 cc. or 3½ ozs.

No. 2.

Potassium bromide	10 grams or 154·3 grains
Water	100 cc. or 3½ ozs.

No. 3.

Ammonia ·960 at 18° c., practically a 10 °/₀ solution.

For use take:—

No. 1	10 cc. or	2½ drachms
No. 2	15 ,,	3¾ ,,
No. 3	5 ,,	75 minims
Water	70 ,,	2½ ozs.

Valenta's formulæ.

A

Pyrogallol	4 grams or 61·72 grains
Water (distilled)	400 cc. or 14 ozs.
Nitric acid	6 drops

B

Potassium bromide	10 grams or 154·3 grains
Water (distilled)	400 cc. or 14 ozs.
Ammonium sulphite	12 grams or 185·16 grains
Ammonia ·91	14 cc. or 3½ drachms

For use take two to three parts of B and one part of A and twelve to fourteen parts of water.

From recent experiments, either of the two following formulæ can be recommended as giving good results and as that of the pyro is made from the ten per cent. solutions in every day use it is perhaps more convenient :—

Pyro developer.

Pyrogallol (10 °/₀ solution)	5 minims
Potassium bromide (10 °/₀ solution)	1 drachm
Water	1 oz.
Ammonia (10 °/₀ solution)	10 minims

Amidol developer.

Amidol	2·5 grains
Sodium sulphite	36 ,,
Potassium bromide	2 ,,
Water	1 oz.

The development of these plates takes place rapidly and is usually complete in about one minute, but their behaviour during the process is peculiar and one soon gets to know by their appearance whether or not the exposure has been correct and that the colours will be visible on drying. At first nothing unusual is apparent but a point is soon reached where there is distinct evidence of reversal

"over the whole or part of the image" and it is at this stage where the greatest judgment on the part of the operator is required.

That this phenomenon must be present has been noticed with all the successful results, and in its absence, although the deposit forming the image may have been considerable, the colours have either been wanting entirely, or very weak.

Further than this, it can only be said that development should be discontinued soon after this appearance is manifest and the image by transmitted light appearing as a reddish brown stain of good depth.

Plates whose sensitiveness has been increased by the use of silver nitrate have a great tendency to show surface fog if the development is forced in the slightest but fixing in the cyanide solution will remove this; the best course, however, is to give sufficient exposure in order that development may be complete in about the time indicated.

Fixing.

After rinsing from the developer, the image may be fixed by means of either sodium thiosulphate (hypo) or potassium cyanide. Lippmann recommends hypo of the following strength :—

Sodium thiosulphate (hypo)	150 grams or 4·6 ozs.
Water	1000 cc. or 35·22 ,,

The fixing takes place very rapidly.

M. M. Lumière and Valenta recommend potassium cyanide of the following strength and say that the colours are more brilliant when it is employed.

Potassium cyanide	5 grams or 77·1 grains
Water	100 cc. or 3½ ozs.

Owing to the great tendency of this to attack the finely divided silver composing the image the plate must not be left in the solution longer than from ten to twenty seconds and then well washed in running water for half an hour.

On drying the colours will appear, but should they not be as brilliant as desired this may be increased by careful intensification, and Lippmann states that it seems to be more advantageous to develop little and intensify with mercury and amidol.

Intensifying.

To intensify a Lippmann photograph we proceed as in the case of an ordinary negative, only using a more dilute solution of mercuric chloride of about the following strength :—

Mercuric chloride	2 grains
Potassium bromide	2 ,,
Water	1 oz.

If the plate has already been dried it must be placed for about five minutes in clean water and then immersed in the above solution until the film is bleached, it is then well rinsed, and an ordinary amidol developer is flowed over until the film is blackened through, or a solution of sodium sulphite of the following strength may be employed :—

Sodium sulphite	1 oz.
Water	10 ,,

The plate is then washed and again dried.

The writer having been very successful with physical intensification employs the following formulæ for the purpose :—

Pyrogallol	2 grains
Citric acid	3 ,,
Water (distilled)	1 oz.

To which is added immediately before use a few drops of a ten grain solution of silver nitrate. This solution is flowed over the plate held in the hand and the result carefully watched and when the increase of density, which must not be great, is judged to be sufficient the plate is washed, and placed for a few seconds in the cyanide fixing solution, well washed and again dried. By this treatment if the action has not been allowed to proceed too far the colours will appear much brighter and unaltered in tint.

If success has attended the various operations it now only remains to examine the photograph as a Daguerreotype is viewed when the colours of the object photographed will be plainly visible. That is to say the eye must be in the direction of the regularly reflected ray ; if you look from another point you see only a colourless image.

A much greater degree of brilliancy and transparency is imparted to these heliochromes and at the same time disturbing surface reflections eliminated " by cementing a shallow prism to them by means of Canada balsam. A piece of black glass or a coating of black varnish should also be applied to the back of the plate and they are then complete.

In the absence of daylight for viewing these heliochromes, they should be seen by light transmitted through a sheet of opal glass in front of a lamp, or that reflected from an opal shade. In order, however, to show them to best advantage, they should be thrown by opaque projection on to a screen, using a megascope or aphengescope lantern. But in this case it becomes necessary to employ a powerful electric arc light to project them with satisfactory brilliancy even up to a small size.

Omission must not be made of the recent experiments of Dr. Neuhauss* the results of which show that heliochromes of the spectrum are much more easily obtained on albumen plates than on gelatine and that it is only necessary to coat a glass plate with pure albumen and when dry sensitize in the silver nitrate bath, and then treat with the colour sensitizers.

After exposure the plates are developed with pyro-ammonium carbonate and potassium bromide, the development taking place as slowly as possible. Unfortunately, however, these plates do not appear to be suitable to the reproduction of mixed colours.

Experiments also are not wanting to show that these heliochromes can be produced without the use of silver salts at all, Lippmann having shown results obtained with bichromated gelatine, and St. Florent is said to have been successful with ferric chloride and gelatine.

In conclusion we can only say that whatever

*Eder's Jahrbuch, 1898.

future developments there may be, the process itself is a most fascinating one, and it is hoped that the information here given may induce others to experiment with it and to those already engaged the matter may be found useful for reference.

Printed by Geo. Newton & Co., 63, Queen Victoria Street, London, E.C.