The subject of the following paper is an application of the Lippmann process to the production of three-colour pictures. The method consists in using a set of three-colour negatives to make a picture composed of juxtaposed coloured lines, red, green, and blue, after the manner of the Joly colour picture, substituting, however, the laminated structure of the Lippmann film for the pigments which impart colour to the true Joly picture. By this combination of the three-colour and standing-wave processes pictures are obtained by an indirect though wholly photographic means, possessing the fidelity of the best three-colour processes with advantages peculiar to the Lippmann picture. The colours are in the picture itself, so that no viewing device is necessary to render them visible, and from the original three-colour negatives an infinite number of colour pictures can be made.

Up to the present Lippmann photographs of natural objects (as distinguished from spectra or monochromatic sources) have been
made directly in the camera. A departure from this simple and straightforward procedure of course needs ample justification. This will be found in a consideration of previous attempts to photograph mixed colours, such as those of natural objects, and the conclusions, both theoretical, and practical, to be drawn therefrom.

**Essential Conditions of the Lippmann Process.**

It has long been recognised that white spectra are easily and satisfactorily photographed by the Lippmann process, such objects as flowers, sky, stars, etc., are very difficult and rarely reproduce with great fidelity. The principal reasons therefore may be briefly summarised as follows:

1. Complete isochromatism of plates is essential. In photographing spectra with non-isochromatic plates all the colours may be made to give strong action by means of long exposure. Additional exposure of the photographically more active colours for their maximum effect is produced causes no increase of action within wide limits. In photographing natural objects recourse to long exposure to produce isochromatic action is obviously destructive of light and shade values, since these are rendered entirely by difference of exposure. The dependence of the best results on careful choosing of exposure has often been noticed.

2. To obtain a close approximation to the colour of the object photographed the laminate system must be determined, and maintained, with due regard to the conditions essential. The Lippmann film is very thin (not over 0.01 mm.) and strongly absorbing. It appears from the micro-sections made by H. Lehmann* that the laminate, owing to the scattering of the incident light and other causes, dies down much more rapidly than that predicted from calculation. The light reflected is therefore always lighter than that of the same substance. The frequent resemblance of Lippmann pictures to tinted "ambrotypes" and Daguerreotypes may be explained by this general admixture of white.

3. From experiments made by H. Lehmann* on photographing two and three colours simultaneously it appears (and theoretical study of the laminate system resulting from mixed colours confirms) that mixed colours are rendered with a loss of luminosity of the components as compared with the corresponding single photographs. This follows from this that if colours of different degrees of purity occur in an object photographed their reflective luminosities will be wrongly rendered. For instance, an area illuminated by a sodium flame and an area illuminated by a broad spectral region including red and green, while appearing the same colour to the eye, and adjusted to the same apparent brightness, would be rendered as of quite different brilliances. Certain types of colours, such as those of the red violet, and those spectra two or more maxima occur, would suffer greatly in this respect.

**The Limitations of Lippmann Photographs.**

All of these facts impose obstacles to the complete success of the original Lippmann process. A detailed study of the rendering of mixed colours and the conditions essential for the best results is now being carried on by the writer and will be published in the near future. The above conclusions on the reproduction of colours of all types, have, however, been confirmed, and the recourse to the three-colour process as the means of rendering all kinds of colours faithfully (to the eye), while employing the Lippmann film, is the practical result.

The determining reason for this step is as follows:—The Lippmann process is, as seen above, not fitted to render all types of colours faithfully. For the three-colour process all that is needed are narrow spectrum bands; these the Lippmann film is thick enough and transparent enough to give.

**Lippmann Three-Colour.**

Proceeding now to the practical details as worked out. It is, of course, necessary to have a set of three-colour negatives or colour records. Each of these must represent the amount of one of the primary colours, red, green, and blue, necessary to mix with the proper amounts of the others to counterfeit to the eye the colour of the object photographed. The three-colour records used were positives made for the Krönösk.*

The first apparatus constructed consisted of an enlarging camera by means of which an image of any one of the three-colour positives was projected on the plate; a heliostat to send a beam of sunlight through positive and projecting lens, and an opaque line screen or grating in contact with the plate, having opaque spaces twice the width of the transparent. By means of this latter, one-third of the surface of the plate could be exposed at a time. For colouring three colour screens, identical with those used in the Krönösk were used to separate red, green, and blue light, and a combined cobalt-blue and signal-green glass. These gave narrow, well separated spectrum bands, quite pure enough to give the best results. The procedure was to make three exposures in succession, between each of which the three colours was changed, the colour screen changed, and the opaque-line screen moved the width of a transparent space (one three-hundredth of an inch). The method is in all respects similar to that employed by the writer to produce diffraction colour pictures.*

It was soon found that much purer colours must be used than those furnished by the colour screens, for this reason. The spectrum band by which the plate was illuminated, reproduced, as examination of the photograph in the spectroscope showed, as a much wider one. The triplet-line pictures, therefore, instead of showing separated lines of the spectrum bands, showed an intermediate spectrum with slightly shaded spaces in the yellow and blue-green. This was confirmed by exposures with spectrum bands of varying width from a monochromatic illuminator. In all cases it was found on spectroscopic examination that these bands were rendered by broad, not sharply defined ones of from five to ten times the width of the original. The most monochromatic source then hand a sodium flame, the glass, and the plate showed in the spectroscope a fairly narrow band, although some red and green light was still visible. Colours as pure as that obtained in this way would be quite satisfactory for three-colour work. Suitable red, green, and blue line sources were not the time available, so, as the best that could be done, portions of the spectrum of about eighty A.U. width from a monochromatic illuminator were tried. The coloured light was thrown on the three-colour positive, which was then directed straight in front of the opaque-line screen and the plate, and so cast a shadow.

With this apparatus three-colour standing-wave pictures were obtained which compare favourably with the Krönösk, and have qualities rarely, if ever, seen in the ordinary Lippmann pictures. The colour and luminosity values are faithfully rendered and the peculiar metallic appearance so common in most interference pictures for the three-colour process is not present. Colours that are not directly in the camera, the ideal for which we aim, but they are faithful colour pictures produced by entirely photographic means; they are held in the hand to observe, and may be duplicated indefinitely. They do not ful... the popular conception of a colour photograph so well as Lippmann pictures taken directly in the camera, were the latter free from the unavoidable defects outlined above. They are perhaps the nearest we can come to a true colour photograph at present.

**Monochromatic Lights for the Process.**

The defects of these new three-colour interference pictures so far made are due to the inadequate means at hand when the work was done. The coloured light used was not as monochromatic as was desired. The three bright strips of colour seen when one examines the photographs with the spectroscope are as a consequence rather wide and the spaces between not quite black, hence some degradation of colour values results. It is intended as soon as possible to make pictures by means of monochromatic light furnished by sources

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* The Krönösk system is based on Maxwell's colour mixture diagram. The three negatives are made through colour screens which with the plates used give lighter results than those usually presented. To obtain the best results the three primary sensations. Those screens give the amounts of three narrow spectrum bands (near G, between E and F, between F and I) to mix to reproduce the eye the colour and luminosity values of all parts of the solar spectrum. The application of Maxwell's analysis to three-colour photography was first published by F. R. Lins in 1925.

cards, after the films are pinned on, are bent to a gentle curve with the film outside the latter is strained taut, and no solution creeps under the celluloid. It is only by this that cockling is to be feared, and not by the solution acting through the gelatine.

As regards the sensitiveness of the films thus treated as compared with those sensitised by the makers' formula, it is impossible to say definitely; but I think they are more rapid. In connection with this, it would be as well to point out that the above-mentioned semi-alcoholic sensitisier is in the proportion of 7.5 per cent. of alkali to the gelatine, whereas the makers recommend 3.3 per cent. of salt, and that the potassium, and not the ammonium, compound. Whether in the face of this it would be advisable to reduce the strength can only be determined by careful comparative experiments with a negative of known densities. This I hope to tackle shortly.

Before leaving the question of the sensitisiser, it is probably well known that a mixture of a bichromate and alcohol will not keep, so that too much should not be mixed at once.

The Temperature for Development.
Proceeding now to the question of development, I found that exposed films would develop in water at from 85 deg. to 95 deg. Fahr. It is true that they took over twenty minutes, but in no case was any difficulty met with. Personally, I have not met with any trouble from using water above 100 deg., and I think too much stress is laid by the makers on this point. The other hand, it is as well to add to the water, if the image appears opaque, some alkali, ammonia or soda, or, as I have already stated, common yellow soap acts well. These certainly permit of coaxing out an over-exposed or stubborn print.

Cementing the Constituent Prints.
This is a comparatively simple matter, yet there are pitfalls and possibilities of failure, and cases are not unknown in which the images some time after being finished have begun to separate. One correspondent suggested in the B.J. that this could be overcome by binding the edges of the print with lantern-slide binding strips; but I have seen a print begin to bubble in the middle. This separation may be caused by squeezing too roughly, and thus forcing out too much of the cementing gelatine solution. I also believe that in some cases it is due to the use of chrome alum in this solution; this I consider quite an unnecessary addition; and further, the stripping may be caused by the gelatine solution becoming chilled, and thus no proper adherence being obtained.

A Stock Cementing Solution.
I have entirely discarded the makers' formula, in the first place because I am particularly lazy and object to have to make the solution up fresh every time, and, secondly, because I think it is too bad to do a method, which at any rate gives me a solution that will keep. It is made as follows:

Gelatine .................................. 10 gms. 100 gms.
Glacial acetic acid ........................ 10 c.c. 150 min.
Distilled water .......................... 240 c.c. By c.

Allow to soak for a short time, then heat in a water bath to 150 deg. Fahr., and add slowly and with constant stirring.

Methylated spirit ......................... 750 c.c. 26 oz.

If this is carefully done, no gelatine will be thrown out, or at least, it will not remain out of solution, though just at first it may come out as milky white threads. This solution keeps well, but must be heated before use, and I just paint it freely over the print, leave the same for a few minutes till the best of the spirit has evaporated and the surface becomes tacky, and then the next image, which is allowed to drain well and begin to get surface dry, is lowered into position. If the two films are not too dry there will be no difficulty in placing them in coincidence, and in even shifting them.

There need be no fear of reticulation of the wet image by the alcohol if the latter is allowed to evaporate sufficiently. If this is not done, and the image lowered at once, then slight reticulation may make its appearance.

It is not essential, however, to use a gelatine solution; white dextrose will answer just as well, probably also any adhesive almost could be employed.

When accurate register is obtained, the two images are not squeezed together, but just ironed with a heavy flatiron that is nicely warmed—not hot—a piece of smooth, hard paper being placed over the celluloid to prevent any possible damage.

It is, of course, hardly necessary to say that before cementing the films down the rubber is carefully removed from each by gentle friction with a swab saturated with benzole, and this is done three times for each print.

Surfacing the Print.
Some objection has been raised to the half matt, half glossy appearance of the finished prints. To remove this, the old carbon worker's dodge of squeegeeing the finished print to collodionised mattopal glass may be adopted. It is probably quite unnecessary to say more than that the glass should be dusted with French chalk, excess brushed off, and then coated with any enamel collodion. When this has well set, it should be washed till all greasy marks have disappeared, then flowed over with a thin warm gelatine solution, or the above-mentioned alcoholic solution of gelatine may be used, provided more water is added and the print squeegeed down and allowed to dry, when it will peel off with a very fine matt surface. A much easier method than this would obviously be to be able to paint the surface of the film with a varnish, which should dry matt and perfectly transparent.

A few experiments have been carried out in this direction, but up to the present I have failed to obtain a perfectly satisfactory varnish—that is, one that shall not dry milky, is perfectly hard, and yet adheres well. So far the best results have been obtained with ordinary enamel collodion with the addition of xylol. A more resistant film will be obtained, I believe, with celluloid instead of pyroxylamine in the enamel collodion, but I have not yet had an opportunity to try it. The enamel collodion plus xylol gives a non-milky matt film, which is sufficiently transparent in a thin film.

E. J. Wall. F.R.P.S.

THREE- COLOUR INTERFERENCE PICTURES.
made directly in the camera. A departure from this simple and straightforward procedure of course needs ample justification. This will be found in a consideration of previous attempts to photograph mixed colours, such as those of natural objects, and the conclusions, both theoretical and practical, to be drawn therefrom.

**Essential Conditions of the Lippmann Process.**

It has long been recognised that while spectra are easily and satisfactorily photographed by the Lippmann process, such objects as still life, etc., are very difficult and rarely reproduce with great fidelity. The principal reasons therefore may be briefly summarised as follows:

1. Complete isochromatism of plates is essential.

In photographing spectra with non-isochromatic plates all the colours may be made to give strong action by mere long exposure. Additional exposure of the photographically more active colours for their maximum effect is produced causes no increase of action within wide limits. In photographing natural objects recourse to long exposure to produce isochromatic action is obviously destructive of light and shade values, since these are rendered entirely by difference of exposure. The dependence of the best results on careful choosing of exposure has often been noticed.

2. To obtain a close approximation to the colour of the object photographed the lamina system must be in the same condition as that of the lens or illuminating light. Other conditions are fulfilled.

Lippmann's film is very thin (not over 0.01 mm.) and strongly absorbing.

3. It appears from the micro-sections made by H. Lehmann that the lamina system, owing to the scattering of the incident light and other causes, discloses much more rapidly than that predicted from calculation. The light reflected is therefore always less pure than that which enters the lamina. The frequent resemblance of Lippmann pictures to tinted "ambrotypes" and Daguerreotypes may be explained by this general admixture of white.

4. From experiments made by H. Lehmann on photographing two and three colours simultaneously it appears (and theoretical study of the lamina system resulting from mixed colours confirms) that mixed colours are rendered with a loss of luminosity of the components as compared with the reproduction of the components alone.

It follows from this that if colours of different degrees of purity occur in an object photographed their respective luminosities will be wrongly rendered. For instance, an area illuminated by a sodium flame and an area illuminated by a broad spectral region including red and green, while appearing the same colour to the eye, and adjusted to the same apparent brilliancy, would be rendered as quite different brilliancies. Certain types of colours, such as those of natural objects, where those spectral two or more maxima occur, would suffer greatly in this respect.

**The Limitations of Lippmann Photographs.**

All of these facts impose obstacles to the complete success of the original Lippmann procedure. A detailed study of the rendering of mixed colours and the conditions essential for the best results is now being carried on by the writer and will be published in the near future. The above conclusions on the reproduction of colours of all types, have, however, been confirmed, and the recourse to the three-colour process as the means of rendering all kinds of colours faithfully (to the eye), while employing the Lippmann film, is the practical result.

The determining reason for this step is as follows:—The Lippmann process is, as seen above, not fitted to render all types of colours faithfully. For the three-colour process all that is needed are narrow spectrum bands: these the Lippmann film is thick enough and transparent enough to give.

**Lippmann Three-Colour.**

Proceeding now to the practical details as worked out. It is, of course, necessary to have a set of three-colour negatives or colour records. Each of these must represent the amount of one of the primary colours, red, green, and blue, necessary to mix with the proper amounts of the others to counterfeit to the eye the colour of the object photographed. The three-colour records used were positives made for the Krömskop.

The first apparatus constructed consisted of an enlarging camera by means of which an image of any one of the three-colour positives was projected on the plate; a heliostat to send a beam of sunlight through positive and projecting lens, and an opaque line screen or grating in contact with the plate, having opaque spaces twice the width of the transparent. By means of the latter, one-third of the surface of the plate could be exposed at a time. For coloured lights three colour screens, identical with those used in the Krömskop were placed in the spectrograph, milled green glass, and a combined color-transparent and blue and signal-green glass. These give narrow, well separated spectrum bands, quite pure enough to give the best results. The procedure was to make three exposures in succession, between each of which the three-colour positive was changed, the colour screen changed, and the opaque-line screen moved the width of a transparent space (one third of an inch). The method is in all respects similar to that employed by the writer to produce diffraction colour pictures.

It was soon found that much purer colours must be used than those furnished by the colour screens, for this reason. The spectrum band by which the plate was illuminated, reproduced, as examination of the photograph in the spectrograph showed, as a much wider one. The triple-line pictures, therefore, instead of showing the whole of the represented bright band, in some cases a continuous spectrum with slightly shaded spaces in the yellow and blue-green. This was confirmed by exposures with spectrum bands of varying width from a monochromatic illuminator. In all cases it was found on spectroscopic examination that these bands were rendered by broad, not sharply defined ones of from five to ten times the width of the original. The most monochromatic source then at hand a sodium flame, was reproduced, and the plate showed in the spectrograph a fairly narrow band, although some red and green light was still visible. Colours as pure as that obtained in this way would be quite satisfactory for three-colour work. Suitable red, green, and blue line sources were not at the time available, so, as the best that could be done, portions of the spectrum of about eighty A.U. width from a monochromatic illuminator were tried. The coloured light was thrown on the three-colour positive, which was then directed front of the opaque-line screen and the plate, and so cast a shadow.

With this apparatus three-colour standing-wave pictures were obtained which compare favourably with the Krömskop, and have qualities rarely, if ever, seen in the ordinary Lippmann pictures. The colour and luminosity values are faithfully rendered and the peculiar metallic appearance so common in most interference pictures is entirely absent. In addition to the negatives obtained directly in the camera, the ideal for which we aim, but they are faithful colour pictures produced by entirely photographic means; they are held in the hand to observe, and may be duplicated indefinitely. They do not fulfil the popular conception of a colour photograph so well would Lippmann pictures taken directly in the camera, were the latter free from the unavoidable defects outlined above. They are perhaps the nearest we can come to a true colour photograph at present.

**Monochromatic Lights for the Process.**

The defects of these new three-colour interference pictures so far made are due to the inadequate means at hand when the work was done. The coloured light used was not as monochromatic as was desired. The three bright strips of colour seen when one examines the photographs with the spectrograph are as a consequence rather wide and the spaces between not quite black, hence some degradation of colour values results. It is intended as soon as possible to make pictures by means of monochromatic light furnished by sources.

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1. Krömskop system is based on Maxwell's colour mixture diagram. The three negatives are made through colour screens which with the plates used give lutetia colours. A filter is added to the blue colour screens representing the three primary sensations. These screens give the amounts of three narrow spectrum bands (near G, between E and F, between F and I) to mix to reproduce to the eye both the colour and luminosity values of all parts of the solar spectrum. The application of Maxwell's analysis to three-colour photography was first published by F. E. Irwin in 1904.

COLOR PHOTOGRAPHY

C. 1902.

[Image 184x0 to 411x842]
Allow to soak for a short time, then heat in a water bath to 150 deg. Fahr., and add slowly and with constant stirring.

Methylated spirit .................. 750 c.c. ... 26 oz.
If this is carefully done, no gelatine will be thrown out, or at least, it will not remain out of solution, though just at first it may come out as milky white threads. This solution keeps well, but must be heated before use, and I just paint it freely over the print, leave the same for a few minutes till the best of the spirit has evaporated and the surface becomes tacky, and then the next image, which is allowed to drain well and begin to get surface dry, is lowered into position. If the two films are not too dry there will be no difficulty in placing them in coincidence, and in even shifting them.

There need be no fear of reticulation of the wet image by the alcohol if the latter is allowed to evaporate sufficiently. If this is not done, and the upper image lowered at once, then slight reticulation may make its appearance.

It is not essential, however, to use a gelatine solution; white dextrine will answer just as well, probably also any adhesive almost could be employed.

When accurate register is obtained, the two images are not squeegeed together, but just ironed with a heavy flaxiron that is nicely warmed—not hot—a piece of smooth, hard paper being placed over the celluloid to prevent any possible damage.

It is, of course, hardly necessary to say that before cementing the films down the rubber is carefully removed from each by gentle friction with a swab saturated with benzole, and this is done three times for each print.

**Surfacing the Print.**

Some objection has been raised to the half matt, half glossy appearance of the finished prints. To remove this, the old carbon worker’s dodge of squeegeeing the finished print to collodionised matt opal glass may be adopted. It is probably quite unnecessary to say more than that the glass should be dusted with French chalk, excess brushed off, and then coated with any enamel collodion. When this has well set, it should be washed till all greasy marks have disappeared, then flowed over with a thin warm gelatine solution, or the above-mentioned alcoholic solution of gelatine may be used, provided more water is added, and the print squeegeed down and allowed to dry, when it will peel off with a very fine matt surface. A much easier method than this would obviously be to be able to paint the surface of the film with a varnish, which should dry matt and perfectly transparent.

A few experiments have been carried out in this direction, but up to the present I have failed to obtain a perfectly satisfactory varnish—that is, one that shall not dry milky, is perfectly hard, and yet adheres well. So far the best results have been obtained with ordinary enamel collodion with the addition of xylol. A more resistant film will be obtained, I believe, with celluloid instead of pyroxyline in the enamel collodion, but I have not yet had an opportunity to try it. The enamel collodion plus xylol gives a non-milky matt film, which is sufficiently transparent in a thin film.

**E. J. Wall, F.R.P.S.**

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**Three-Colour Interference Pictures.**

[A communication from the physical laboratory of the John Hopkins University published in the "Physical Review.

The subject of the following paper is an application of the Lippmann process to the production of three-colour pictures. The method consists in using a set of three-colour negatives to make a picture composed of juxtaposed coloured lines, red, green, and blue, after the manner of the Joly colour picture, substituting, however, the laminated structure of the Lippmann film for the pigments which impart colour to the true Joly picture. By this combination of the three-colour and standing-wave processes pictures are obtained by an indirect though wholly photographic means, possessing the fidelity of the best three-colour processes with advantages peculiar to the Lippmann picture. The colours are in the picture itself, so that no viewing device is necessary to render them visible, and from the original three-colour negatives an indefinite number of colour pictures can be made.

Up to the present Lippmann photographs of natural objects (as distinguished from spectra or monochromatic sources) have been
made directly in the camera. A departure from this simple and straightforward procedure of course needs ample justification. This will be found in a consideration of previous attempts to photograph mixed colours, such as those of natural objects, and the conclusions, both theoretical, and practical, to be drawn therefrom.

**Essential Conditions of the Lippmann Process.**

It has long been recognised that white spectra are easily and satisfactorily photographed by the Lippmann process, such objects as landscapes, still life, etc., are very difficult and rarely reproduce with great fidelity. The principal reasons therefore may be briefly summarised as follows:

1. Complete isochromatism of plates is essential. In photographing spectra with non-isochromatic plates all the colours may be made to give strong action by mere long exposure. Additional exposure of the photographically more active colours for their maximum effect is produced causes no increase of action within wide limits. In photographing natural objects recourse to long exposure to produce isochromatic action is obviously destructive of light and shade values, since these are rendered entirely by difference of exposure. The dependence of the best results on careful choosing of exposure has often been noticed.

2. To obtain a close approximation to the colour of the object photographed the lamina system must be made coincident with the object and in this manner the condition is fulfilled. The Lippmann film is very thin (not over 0.1 mm.) and strongly absorbing.

3. It appears from the micro-sections made by H. Lehmann that the lamina system, owing to the scattering of the incident light and other causes, dissipated much more rapidly than that predicted from calculation. The light reflected is therefore always less pure than that finally obtained from the lamina. The frequent resemblance of Lippmann pictures to tinted "ambrotypes" and Daguerreotypes may be explained by this general admixture of white.

4. From experiments made by H. Lehmann on photographing two and three colours simultaneously it appears (and theoretical study of the lamina system resulting from mixed colours confirms) that mixed colours are rendered with a loss of luminosity of the components as compared with the corresponding single components.

It follows from this that if colours of different degrees of purity occur in an object photographed their reflective luminosities will be wrongly rendered. For instance, an area illuminated by a sodium flame and an area illuminated by a broad spectral region including red and green, while appearing the same colour to the eye, and adjusted to the same apparent brilliancy, would be rendered as quite different brilliances. Certain types of colours, such as those of the upper parts of trees whose spectra two or more maxima occur, would suffer greatly in this respect.

**The Limitations of Lippmann Photographs.**

All of these facts impose obstacles to the complete success of the original Lippmann process. A detailed study of the rendering of mixed colours and the conditions essential for the best results is now being carried on by the writer and will be published in the near future. The above conclusions on the reproduction of colours of all types, have, however, been confirmed, and the recourse to the three-colour process as the means of rendering all kinds of colours faithfully (to the eye), while employing the Lippmann film, is the practical result.

The determining reason for this step is as follows:—The Lippmann process is, as seen above, not fitted to render all types of colours faithfully. For the three-colour process all that is needed are narrow spectrum bands; these the Lippmann film is thick enough and transparent enough to give.

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The first apparatus constructed consisted of an enlarging camera by means of which an image of any one of the three-colour positives was projected on the plate; a hot-plate to send a beam of sunlight through positive and projecting lens, and an opaque line screen or grating in contact with the plate, having opaque spaces twice the width of the transparent. By means of this latter, one-third of the surface of the plate could be exposed at a time. For colouring rights three colour screens, identical with those used in the Krönskop were employed, chased on a frame, coated with blue and green and blue and green glass. These give narrow, well separated spectrum bands, quite pure enough to give the best results. The procedure was to place three exposures in succession, between each of which the three-colour positive was changed, the colour screen changed, and the opaque-line screen moved the width of a transparent space (one hundredths of an inch). The method is in all respects similar to that employed by the writer to produce direct colour pictures.

It was soon found that much purer colours must be used than those furnished by the colour screens, for this reason. The spectrum band by which the plate was illuminated, reproduced, as examination of the photograph in the spectroscope showed, as a much wider one. The triple-line pictures, therefore, instead of showing the isolated blue, red, and green, showed the entire spectrum with slightly shaded bands in the yellow and blue-green. This was confirmed by exposures with spectrum bands of varying width from a monochromatic illuminator. In all cases it was found on spectroscope examination that these bands were rendered by broad, not sharply defined ones of from five to ten times the width of the original. The most monochromatic source then at hand a sodium flame, was photographed, and the plate showed in the spectroscope a fairly narrow band, although some red and green light was still visible. Colours as pure as that obtained in this way would be quite satisfactory for three-colour work. Suitable red, green, and blue line sources were not at the time available, so, as the best that could be done, portions of the spectrum of about eighty A.U. width from a monochromatic illuminator were tried. The coloured light was thrown on the three-colour positive, which was then directly in front of the opaque-line screen and the plate, and so cast a shadow.

With this apparatus three-colour standing-wave pictures were obtained which compare favourably with the Krönskop, and have qualities rarely, if ever, seen in the ordinary Lippmann pictures. The colour and luminosity values are faithfully rendered and the peculiar metallic appearance so common in monochrome pictures is not present. It is possible to make pictures directly in the camera, the ideal for which we aim, but they are faithful colour pictures produced by entirely photographic means; they are held in the hand to observe, and may be duplicated indefinitely. They do not fulfill the popular conception of a colour photograph as would Lippmann pictures taken directly in the camera, were the latter free from the unavoidable defects outlined above. They are perhaps the nearest we can come to a true colour photograph as at present.

**Monochromatic Lights for the Process.**

The defects of these new three-colour interference pictures so far made are due to the inadequate means at hand when the work was done. The coloured light used was not as monochromatic as was desired. The three bright strips of colour seen when one examines the photographs with the spectroscope are as a consequence rather wide and the spaces between not quite black, hence some degradation of colour values results. It is intended as soon as possible to make pictures by means of monochromatic light furnished by sources.

1. [Note: This is a reference to a previously published work by the author, but the specific work is not listed in the image.]


such as the cadmium lines, and to make the triple (Joly) lines at least two hundred to the inch, so that they become practically invisible.

With these improvements the pictures should rank as one of the most perfect applications of the three-colour process.

The plates used were prepared according to the formula published by Valenta6 with the exception that it was found necessary to double the quantity of gelatine; this may, however, have been due to the kind of gelatine used.7 The pictures were mounted under a prism according to the usual method. To destroy all extra reflec-


tions possible the back of the glass and the lower surface of the prism were ground with emery before the application of asphaltum varnish to the one and Canada balsam to the other. It was further found advantageous to substitute gum styrax ($n = 1.58$) for Canada balsam in mounting the prism. By this the surface reflection from the film is less than with the balsam, and in addition (if the lower side of the prism is ground) a slight diffusion of light results so that the picture is visible through a wider angle, and the reflected image of the source of light (such as a gas flame) no longer well enough defined to be disturbing.

Herbert E. Ives.