small amount is practically the same in all three combinations.

Theoretically and practically the focussing screen may be racked out to any distance, and the images remain the same size. The mirrors M^1, M^2, M^3, M^4 are of steel. Experiments recorded in text-books tell us that polished steel reflects 60 per cent. of white light, so with two reflections about 36 per cent. light ought to be reflected. With the mirrors the writer employs the reflected light falling on the plate is about 25 per cent., but no very strong conclusion can be drawn from this approximate measure, since the surfaces reflected more rays of low refrangibility than of high. A beam of white light is distinctly yellow after reflection.

The use of steel was adopted, as it is easy to work and rigid, and polishing is not difficult. Tarnish and destruction of the surface from damp is prevented by giving it a very thin coating of collodion varnish, which does not alter the reflective power appreciably, and does not distort the images. No doubt other material might be employed in the mirrors which would reflect more light, but the writer considers that steel has many advantages. After using the camera the writer finds it answers more than his expectations, and from the fact that a fairly wide angle, say of 36 deg., can be used, it is most convenient for landscape work, and the power of focussing renders it useful for portraiture or copying. The production of the three-colour negatives by one exposure instead of three makes three-colour photography a pleasure instead of an anxiety. W. de W. Abney.

THE LATEST PRACTICE OF THE LIPPMANN PROCESS.

In the last three issues of the "B.J." we have given the full text of the lengthy paper by Mr. Herbert E. Ives (son of Mr. F. E. Ives), describing the author's recent researches in and improvement of the Lippmann interference process of colour photography. As many readers will doubtless prefer to have presented to them the essential details of this paper as they affect the practice of the process, and as, further, it is desirable that this "Colour Photography" Supplement should contain a record of this contribution to the knowledge of the process, we have prepared an abstract of the paper fulfilling these conditions.

Mr. Ives set out to discover the most favourable conditions (of thickness and grain of emulsion, developer, etc.) for the reproduction of (1) pure monochromatic colours, (2) mixed colours, (3) white, and (4) natural scenes. In the course of his experiments he found that what is best for one of these is not best for others, and he further worked out a portable substitute for the mercury mirror, of particular value when using the Lippmann process in the field.

1. *Monochromatic Light.*—Since greater fineness of grain of the emulsion records more minute variations in the standing wave system, and since greater thickness of the emulsion film allows of a greater number of laminæ (thus giving reflected light of greater purity), it was to be expected that both these factors would affect the results. Recording monochromatic green light, from a mercury-vapour tube, filtered through a cell of neodymium ammonium nitrate and potass. bichromate, it was found that less silver than usually employed gave purer reflected light.

The increase was most marked between .18 and .09 gm. silver nitrate per gramme of gelatine. The formulæ used were:—

A.—Gelatine	1 gm.
Water	25 ccs.
B.—Gelatine	2 gms.
Potass. bromide	.25 gm.
Water	50 ccs.
C.—Silver nitrate	.3 gm.
Water	5 ccs.

A and B were heated to melt the gelatine, allowed to cool to 40 deg. C., C added to A, and then A to B, slowly, with stirring, the sensitiser (erythrosin) added, and the whole filtered. After flowing and setting, the plates were washed for fifteen minutes, and allowed to dry. This emulsion contains half the silver bromide usually used.

When using pyro developer, it was not found that increase of the thickness of coating beyond 1-200 mm. gave increase of purity. The pyro developer, however used, does not, however, develop the laminæ which can be shown to be formed throughout the film; it exerts a surface action, producing a band of fog, which progresses inward from the surface on prolonged development.

With other developers, however (e.g., hydroquinone), development took place with great uniformity throughout the film, without causing fog. In order to overcome the opacity of the deposit produced by this developer, the deposit was bleached with mercuric chloride, films thus obtained giving great purity of colours. Coatings up to 1-10 mm. could be used with continued increase in purity. With this modification in development and after-treatment, it would seem that purity of colour is directly dependent on film thickness.

2. *Mixed Colours.*—It was found that, in the case of colours consisting of two or more spectral lines, or of the broad bands of pigment colours, the pyro developer gave fairly good luminosity values so long as over-exposure was avoided and the grain of the emulsion not too fine; in other words, when a highly reflecting but fairly transparent deposit is produced. With over-exposure, or in the case of a more complex colour, the separate particles of the deposit fuse together, and there is a loss of luminosity. But the effect of development with pyro is to reduce all colours to one general type.

In the case of hydroquinone developer, on the other hand, it was found that, on bleaching the deposit, the more complex colours were well rendered, and more so as the thickness of the film was increased, but the loss in luminosity, compared with pyro, was marked—the resolving power is obtained at the cost of luminosity.

3. *White.*—Regarding the three theories of the production of white, (*a*) by a general diffuse deposit in an isochromatic emulsion (Lippmann), (*b*) by the formation of laminæ corresponding to red, green, and blue (Lehmann), and (*c*) by producing a mirror surface (Cajal), the author compared *a* and *c*, using Isocol as a sensitiser, on account of the even sensitiveness produced. The results confirmed *a*, but not *c*.

4. *Natural Objects.*—Little result of variations in the emulsion could be discovered. The most permanent sensitiser was found to be a mixture of pinaverdol and pinacyanol, with a screen of wool black. One thickness of coating was about 1-400 mm., which, though of small resolving power, gave satisfactory results to the eye. It should be thick enough to resolve the two maxima of purple (about the only colour of any complexity often met with), but emulsions of about 1-200 mm. thickness gave the most satisfactory results, and at $f/3.6$ in sunlight required exposures of from $1\frac{1}{2}$ to 5 minutes, according to the sensitiser. The general results entirely confirmed the practice of Lippmann. Owing to the laminæ being few and close to the surface, very slight devia-

tion from correct exposure and development cause the colours to be either too weak or diluted with white.

When obtained, the colours are extremely dependent on correct viewing conditions to appear to any advantage. The colours being formed for the most part by two or three laminæ, backed up by a diffuse deposit, great care must be taken to exclude all light, except that coming in the direction to be regularly reflected by the laminæ. Light from other directions is not sent to the eye by the laminæ, but is by the diffuse deposit, causing a drowning out of the colours with white light. By making the film excessively thin, so that the laminæ are formed, but not the deposit behind, the colours are more brilliant and less affected by conditions of illumination. Colours of any complexity, such as purple, however, suffer.

A Substitute for the Mercury Mirror.—The following is Mr. H. E. Ives' method of preparing a mirror which allows of the Lippmann plates being handled and used exactly like dry plates:—A glass plate is heavily silvered, and then flowed with a thick solution of celluloid in amyl-acetate. When this varnish is dry, the plate is placed under water; this slowly works under the coating of celluloid, lifting it from the glass, and *bringing with it the silver.* This flexible silver mirror is immediately laid, silver surface down, on a wet Lippmann plate, and allowed to dry there, a necessarily somewhat slow process. When dry, the gelatine film has the silver surface in optical contact with it. The plate may then be exposed at any time in an ordinary plate-holder. After exposure, the celluloid film is stripped from the gelatine, taking with it most of the silver, the plate developed, and after thorough washing the remains of the silver removed with a tuft of wet cotton.

This substitute works perfectly for all types of colours, and, except in the laboratory, where a convenient dark-room makes the use of the mercury mirror simple, facilitates the practical working of the process.

A difficulty which has proved rather troublesome is that some of the best sensitisers are apt to lose their effect during the slow drying. Erythrosin acts perfectly; pinacyanol and pinaverdol are apt to fail. This can probably be overcome, either by different choice of sensitisers, by so treating these that slow drying does not harm, or perhaps by finding some more porous substance than celluloid, which, acting the same in other respects, will permit of quick drying. Collodion has been tried, but has not been found to strip off the gelatine well.