Lenses Employed in the Technicolor Process of Cinematography

By H. W. Lee, Research Department of Taylor, Taylor and Hobson, Ltd.

IN colour photography it is necessary to analyse the light reflected by coloured objects into at least three spectral regions which, where there are three only, may be termed red, green and blue respectively. This is done by means of colour filters which transmit definite portions of the spectrum and absorb the rest; the three negatives are produced either successively or simultaneously. In cinematography the negatives must, of course, be made simultaneously unless the rate of movement of the film is increased threefold, to which there are grave objections. The three negatives may be made simultaneously by means of three lenses; this results in colour parallax, and the three images will never exactly superpose. Alternatively, the beam of light issuing from a single objective must be divided. This division may be made by means of superposed filters, the components of white light being successively subtracted and acting on sensitised films superposed. The objections to this are that the films and filters must be very thin if the composite 'tri-pack' and filter film is not to be too thick, and that each layer of emulsion produces a certain amount of scattering, so that the successive images are more and more diffused. Other methods of dividing the beam are by successive reflections from thin, partly-reflecting and partly-transmitting films, which may be either isolated films of collodion or films of silver on glass surfaces. The silver may be in the form of totally reflecting films partly covering the surfaces they are deposited on, a method not without objection since the areas of film must be small if there is not to be differentiation between different parts of the light beams; alternatively, the silver films may be so thin as both to reflect and transmit.

The Technicolor process is, optically speaking, a combination of two processes suggested above. *One* semi-reflecting metallic film on the diagonal plane of a glass cube is combined with a bi-pack, to which the objections of the tri-pack do not altogether apply, as the two sensitive films can be placed in contact.

The glass cube placed between the lens and the film has considerable thickness (being approximately equal to the size of field covered) and therefore produces considerable aberration. This fact was not sufficiently realised by early experimenters in colour photography, who tried to combine prism 'beam splitters' with normal lenses on the market, which of course had not been computed for use with considerable thicknesses of glass. The result was poor definition and images of unequal sizes. Technicolor, however, early realised the necessity for taking the prism into account in the design of the lens system, and in 1918, D. F. Comstock took out a patent (British patent 131,422) for several constructions, having apertures up to $f/3{\cdot}9$, for lens systems combined with prisms. In 1927, however, their prism system was simplified and the need felt for lenses of larger aperture, owing to the change in cinema technique from outdoor to studio photography. Technicolor approached Taylor, Taylor and Hobson, Ltd., who were making lenses having an aperture of $F/2$, and asked them to design a special lens for their needs. This was for two-colour work. With the change to three-colour work in 1931, a further change was needed, and, moreover, the matter of colour correction became more stringent.

It is possible to equalise the focusing position and the focal lengths for two parts of the spectrum which would, in practice, be the 'centres of gravity' of the spectrum bands passed by the two filters used, but when three colours are in question there is the difficulty that the third colour must necessarily be out of focus owing to the so-called secondary spectrum. This secondary spectrum can be reduced in certain optical systems such as telescopic objectives and photographic lenses of small aperture by the aid of special glasses; but the dispersive power of these glasses, the so-called 'telescope flints', which have partial dispersions more nearly proportional to those of crown glasses than the flints in ordinary use, is so low that, in photographic systems of large aperture and considerable field dependent entirely upon these glasses, the construction is prohibitively complicated. However, since, in the new Technicolor process, only two images are formed in a plane at right angles thereto, it is possible to allow for the slightly different focus for the green, if the foci for the red and blue coincide. These, then, were the conditions to be fulfilled; the red and blue foci must coincide, the tolerance being that the blue focus might be 0·0005 in. longer than the red as the blue negative is the rear one of the bi-pack. The green focus could be 0·003 in. shorter than the common focus for the blue and red. These conditions were for the 'standard' focal length of 50 mm. The aperture required was $F/1{\cdot}7$. As there is inevitably some loss of definition in colour processing, the definition of the lenses was to be better than that of lenses for non-colour work. Other lenses of focal length 70 mm., 100 mm. and 140 mm. were also required.

Now the 'secondary spectrum', which required an adjustment of 0·003 in. for the green on the 50 mm. lens, increases with focal length, so that it becomes 0·008 in. with the 140 mm. lens, while the 'adjustment', being made on the camera, is fixed. It thus became necessary to reduce the secondary spectrum with the longer focus lenses. Fortunately, the Parsons Optical Glass Co. (now Chance-Parsons) came to the rescue with a new glass; an experimental melting produced a glass having a reduced secondary spectrum and having the low V of 44·9 (as against 52·2 in the old 'telescopic flint'). By judicious incorporation of this glass in one or two components in the longer focus lenses, these were designed to give approximately the same difference between the green focus and the red-blue focus, as in the standard lens.

A further interesting problem arose when short focus lenses were required, because, with normal types, there is not sufficient clearance between the lens and the focal plane to accommodate the prism. Mr. J. A. Ball, of Technicolor, had tried placing a negative lens in front of an ordinary cinematographtaking lens, the distance between the two being greater than the focal length of the positive lens; thereby he decreased the focal length and at the same time displaced the nodal plane towards the focal plane, giving greater clearance.

A negative lens so placed, however, introduces considerable barrel distortion. Ball reduced this by using two negative components, each a cemented doublet, but when the problem was put to Taylor, Taylor and Hobson, Ltd. to provide a lens of aperture *F*/2 free from distortion, a complete solution was forthcoming with a negative consisting of only two simple elements. Fig. 1 shows the Taylor-Hobson lens. The same stringency as to colour correction, of course, applies to this lens.

The closeness of the limits for colour correction necessitates special precautions in manufacture. In a batch of lenses made to very close tolerances of radius and thickness and made from identical glass melts, it is rare to find the chromatic corrections identical to the Technicolor specification, owing to small variations in the composition of glass throughout the pot. The assembled lenses are first tested for focus throughout the spectrum on a collimator illuminated through a constant deviation prism. If necessary, alterations are then made, to bring the chromatic corrections right. Finally, a photographic check is made. An inclined object consisting of parallel lines is photographed through the actual colour filters used by Technicolor.

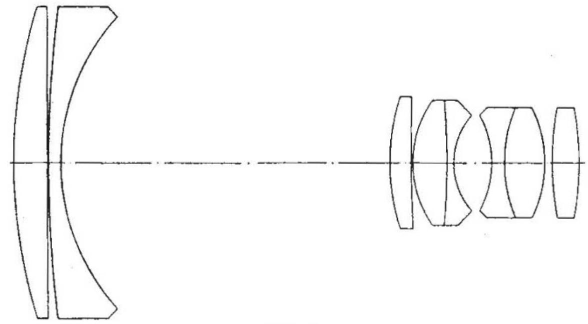

FIG. 1.

Bacteriology of the Atmosphere*

THE study of the bacteriology of the atmosphere dates back to the time of Ehrenberg, who published twenty-five papers dealing microscopically with dust and its biological concomitants in the air. The great impetus to the study was, however, the controversy over the question of spontaneous generation, with which the name of Pasteur is indelibly associated. He was not, however, the pioneer in this respect, for Gaulthier de Claubry in 1832 and Baudrimont in 1855 had already given definite experimental proof of the existence of living 'germs' in air, capable of provoking decomposition. It was the experimental genius of Pasteur which eventually settled the controversy beyond all doubt, and incidentally opened the eyes of scientific workers to the existence of a circumambient flora of unknown potentialities.

The epoch-making development of these discoveries lies in the antiseptic surgery of Lister. Researches on the sanitary quality of air multiplied exceedingly at this period, but, while much of scientific interest was revealed, the general result was to make clear that among the numerous organisms suspended in air and capable of growth, there were, as a rule, very few of pathogenic or of surgical importance. For this reason, there has been of late years a considerable waning of medical interest in the air-borne flora, to the point of positive neglect. Yet, while the above statement may be true of the surgical aspect, there is no doubt that from the physician's point of view, air-borne infection is, in certain cases, of primary importance. This is particularly true of pulmonary diseases.

Some excuse for this state of affairs may be found in the comparative dearth of knowledge about the conditions under which aerial organisms live and survive to convey infection. A few investigations have been carried out on the viability of organisms in sand or dust or suspended in water droplets; but it is still true to say, for example of the tubercle bacillus, that there is no exact knowledge of the conditions under which it can or cannot survive when floating freely in air.

If this is true of such special cases, of vital importance to man, how much more does it apply to the generality of air-borne organisms—the aeroplankton —not only of living rooms, etc., but also of the atmosphere as a whole. The biological side of oceanography has been impressively developed during this century, but the biological side of meteorology remains an unexhausted field for investigation. It has been too rashly assumed that the atmosphere cannot offer a permanent home to micro-organisms, and that those which are found there are strayed wanderers from their true homes and are either dead or in some dormant, spore form.

Investigation makes this much less certain. The number and variety of organisms found are sometimes very great, and they are in many cases not referable to types found elsewhere. Moreover, spore-bearing types are relatively rare, at least among the bacteria and the yeasts, though many fungal spores have been found. The latter have been investigated chiefly in Canada and the United States, in connexion with the spread of rust infections on crop plants, and their migrations have been traced, to some extent.

The distribution of organisms in the atmosphere is not a simple function of height, as earlier observers thought. Aeroplane surveys have made it clear that micro-organisms occur in sporadic clouds, like those of ocean plankton, which may be found at any height that has so far been investigated, that is, up to 20,000 ft. If it be true that the atmosphere does not provide permanence of vital conditions, yet it does provide undoubtedly continuity, so that there are at all times and places some portions of the atmosphere

* Substance of a Chadwick Public Lecture delivered by Prof. R. C. McLean on November 19 at the London School of Hygiene and Tropical Medicine.