by a weak aspheric plate located in the aperture-stop, the off-axis aberrations introduced by the plate are all of the seventh and higher orders, and so may be expected to be very small.

In the actual design of the system, fuller particulars of which we hope to publish elsewhere, we proceed somewhat differently, choosing the concentric meniscus so as to minimize the on-axis aberrations as a whole, and the aspheric plate to give axial stigmatism. The effect of this procedure is to balance out some of the seventh and higher order off-axis errors by a suitable combination of small amounts of lower order errors.

To correct the colour-error of the meniscus, a doublet plate is used (see diagram), its glasses having the same mean refractive index but different dispersions. The off-axis colour-effects of the plate interface turn out to be harmless.

In this way, an $f/1{\cdot}2$ system is obtained which, working over a 30° diameter field, sends 97 per cent of the light of each image into a confusion circle less than 21″ of arc in angular diameter. The remaining 3 per cent of light has, of course, no appreciable effect on the resolution, but it can be eliminated if desired by adding a pair of extra stops S_1, S_2, equal in aperture to the aspheric surface, at a distance of one tenth of this aperture on either side of it. The result is a system of nominal aperture $f/1{\cdot}2$ and effective aperture $f/1{\cdot}5$, nearly free from edge-vignetting, the error-spreads of which over a 30°-diameter field are less than 21″ of arc, that is to say, only a small fraction of those of the classical Schmidt camera, or of the meniscus system with spherical surfaces.

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[1] *Nature*, **155**, 798 (1945).

[2] Maksutov, D. D., *J. Opt. Soc. Amer.*, **34**, 270 (1944). Mention should also be made of a system by D. Gabor (Brit. Pat. 544,694; 1940), based on the same idea and employing an annular aperture.

Anti-Reflexion Films Evaporated on Glass

DURING the past decade, much progress has been made on the production, by the evaporation method, of anti-reflexion films on glass surfaces. Up to date, the metallic fluorides have proved the most successful as evaporating materials. Many of these fluorides have been tested, and now magnesium fluoride is probably favoured most.

At first, workers engaged themselves with the proper methods of cleaning the glass surfaces before being placed in the bell jar. Then the subjection of the surfaces to glow discharges, during the evacuation of the bell jar, was examined as a means of completing the cleaning process. When the films were deposited, baking at various temperatures in an air oven was tested, and finally evaporation on to glass surfaces, maintained at high temperatures (200–300° C.), was carried out. Dr. D. A. Lyon, United States Naval Gun Factory, was, I believe, the first to evaporate magnesium fluoride on to hot glass surfaces.

I have carried out research on the production of anti-reflexion films by the evaporation method. In the case of magnesium fluoride, a number of samples have been tested. These samples were prepared in three ways, namely, by the action of hydrofluoric acid on (1) magnesium chloride, (2) magnesium carbonate, (3) magnesium oxide. The samples prepared from magnesium oxide had a considerable amount of magnesium oxide in the final product, but this seemed to affect the films very little. It has been found necessary to dehydrate carefully all magnesium fluoride preparations. It was found that hydrates stored in glass bottles for more than three months gave inferior films.

The method of evaporation involves the use of a molybdenum boat and baffle. The material is preheated until it begins to vaporize freely in the vacuum before the surfaces are coated. During the preheating the baffle protects the surfaces. The tests applied to the films are those recommended in the U.S. Army Specification No. 51-70-4A of January 28, 1944.

A study has been made of the effects of baking in the case of glass coated with magnesium fluoride film. It has been found that:

(*a*) It is most advisable to bake the glass at a temperature of 250° C., approximately, for about thirty minutes in the vacuum before coating. This preheating improves the glass surface by expelling adsorbed gases and vapours and by removing traces of fatty acids, etc. It has been noticed that films deposited on cold glass surfaces, which were first baked and then allowed to cool to room temperature, did not craze when afterwards baked in an air oven at temperatures as high as 375° C. If the glass is not baked before coating, there is a tendency to craze and peel.

(*b*) If the surface is allowed to cool to 200° C. or below before coating, then it will be necessary to bake the film afterwards in an air oven for several hours at a temperature of about 250° C. to render it sufficiently perfect to pass all the above tests.

(*c*) If the surface is maintained at a temperature of 250° C. or more (tested up to 350° C.) during evaporation, then no further baking is required after evaporation.

(*d*) If one quarter wave-length magnesium fluoride films are evaporated on cold glass surfaces, then the reflectances of these coated surfaces are reduced considerably by baking in an air oven at 250° C. for a number of hours. If the surfaces are baked at 375° C. the reductions are greater, especially where the very dense flint glasses are concerned. These reductions range from 20 to 40 per cent. For example, for crown glass ($n = 1{\cdot}52$) the reflectance was reduced, by baking at 375° C., from 1·40 to 1·10 per cent approximately, while for Chance optical glass ($n = 1{\cdot}806$) the reduction was from 0·23 to 0·14 per cent, approximately. These figures correspond to a reduction in the estimated film refractive index of 1·39 to 1·37 in the case of the crown glass, and 1·405 to 1·39 in the case of the flint glass.

As compared with magnesium fluoride films, it has been found that calcium fluoride films react very differently to baking. As in the case of magnesium fluoride, it is advisable to bake the glass to about 250° C. in the vacuum prior to coating. The following reactions have been found:

(*a*) If a crown glass surface is allowed to cool so that it is at a temperature of 100° C. or less during coating, then the resulting film will have a reflectance which gives an estimated refractive index as low as 1·26 approximately. This film is very soft, and, when baked in an air oven at 250–300° C. for several hours, increases slightly in reflectance and hardness.

(*b*) If the surface is at a temperature of 120° C. about, during evaporation, the film has a somewhat larger reflectance. This film is soft.

(*c*) If the surface is at a temperature of 230–250° C. approximately, the resulting film is fairly hard, but will not quite withstand the rubbing test indicated in the U.S. Army specifications.

(*d*) If the surface is at a temperature of 280–300° C., the resulting film is very hard and will withstand all the tests. The estimated refractive index is 1·40 approximately. When the glass surface is at a temperature of 330° C., during evaporation, the reflectance corresponds to a refractive index of 1·42 approximately.

(*e*) When a number of glass surfaces, placed at equal distances from the evaporating boat, and maintained at different temperatures, varying from room temperature up to 350° C., are coated with calcium fluoride, the resulting films have all approximately the same optical thickness.

(*f*) Using iron $K\alpha$ radiation and a special focusing camera, powder photographs of calcium fluoride films, having an optical thickness of $\frac{1}{4}\lambda(5500)$, were obtained. From these photographs it was evident that (1) the films were made up of very small crystals in random orientation, (2) these small crystals had the same cubic structure as the parent substance, (3) the structure and random orientation persisted independently of the temperature or the nature of the glass surface.

It appears, from (*f*) above, that the change in reflectance of the film-coated glass is probably due to a change in density of the films according to one of the mixture rules[1]. It also appears that, according to (*e*) above, the film thickness is inversely proportional to its refractive index.

In the case of magnesium fluoride films, the estimated refractive index increases with the refractive index of the glass. For example, a film deposited on a crown glass surface will have a refractive index of 1·39, whereas the value for a flint glass surface ($n = 1{\cdot}65$) will be about 1·41. This does not occur to any extent in the case of calcium fluoride, and in no case is the estimated refractive index of a calcium fluoride film greater than the refractive index of a single crystal of calcium fluoride.

I have produced very strong films, with an estimated refractive index of 1·35 approximately, by using a mixture of cryolite and calcium fluoride (1 : 1 or 1 : 2 by molecular weight). These films are very much like "gearksutite" films[2], but are more soluble in water. The "gearksutite" films are very satisfactory, but pure anhydrous aluminium fluoride is necessary in their production. This fluoride is difficult to prepare except in very limited quantities.

A more complete account of the investigations on the above-mentioned and other films will be published elsewhere.

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[1] Heller, W., *Phys. Rev.*, **68**, 5 (1945).

[2] R.C.A. Commonwealth of Australia Patent No. 7010/42.

Current Density at the Cathode Spot of the Mercury Arc

LAST July, I observed that the cathode 'spot' of the transient arc obtained by discharging a condenser through a vacuum tube with mercury cathode took the form (a few microseconds after initiation) of a number of very small spots. The current density of emission appeared at least 100,000 amp. per sq. cm., however prolonged the discharge and however nearly the characteristics of the discharge approached those of a 'normal' arc. These results were obtained from low-power photomicrographs (up to × 25) using a Kerr cell shutter giving an exposure of one microsecond.

This suggested taking similar photographs of a more normal arc. Recent photographs of the cathode of a 50 amp. and 120 amp. D.C. arc 1/200 sec. after initiation show the cathode spots do in fact still have a similar structure. They show that for the 120 amp. arc there are generally four to eight main groups of about four or five minute spots. The number of groups is smaller for the 50 amp. arc. If the electronic emission comes chiefly from these minute spots, then the current density is nearer 100,000 amp. per sq. cm. than the usually accepted value of about 4,000 amp. per sq. cm.[1-4]. Exposures of 24 microsec. show that the minute spots generally seem to move within the envelope of the group. Hence only the groups might be observed with an ordinary camera. Lord[5] has presumably observed such groups with the Kodak high-speed camera, and states that for a 1,150 amp. arc the cathode spot sometimes divides into 75 parts.

It is hoped to publish a full report of these investigations in due course.

I would like to thank Sir George Thomson for continued encouragement and advice. Since October 1945 I have been working as a Beit Fellow in his Department at the Imperial College of Science and Technology.

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Dec. 6.

[1] Hull, *Elec. Eng.*, **53**, 1435 (1934).

[2] Loeb, "Fundamental Processes of Electrical Discharge in Gases", 629 (John Wiley, 1939).

[3] Smith, *Phys. Rev.*, **62**, 48 (1942).

[4] Teago and Gill, "Mercury Arcs", 12 (Methuen, 1936).

[5] Lord, *Electronics*, 11 (May 1936).