Defence Science Journal, Vol. 1, No. 1, July 1949, pp. 10-16 © 1949, DESIDOC

INFLUENCE OF TROPICAL ATMOSPHERIC CONDITIONS ON 'BLOOMED' OPTICAL INSTRUMENTS.

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Introduction.

1. When light passes from one transparent medium to another, having an index of refraction different from the former, part of the light is transmitted through the second medium and part of it is reflected back at the boundary surface between the two media (Fresnel's reflection). It is well known that, for the case of normal incidence for light passing from air to glass, the fraction of the incident light reflected back at the interface or the 'reflectance' R of the surface is given by the following equation due to Fresnel :

$$R=\frac{(\mu-1)^2}{(\mu+1)^2}$$

μ is the refractive index of glass. Thus, in the case of light passing through a glass plate or lens bounded by two surfaces, about 4 per cent. of the incident light is reflected back at each interface, or the total loss in intensity due to reflection at the two boundary surfaces amounts to nearly 8 per cent. of the incident light. The case of normal incidence mentioned here approximately represents the conditions of vision through an optical instrument (e.g., a telescope), and the reflection of light at the glass/air interfaces of the optical components of such an instrument adversely affects its performance in two ways. Firstly, when a number of optical components are present in a system, the sum total of the intensity of light lost by reflection at the numerous glass/air boundary surfaces represents a considerable proportion of the light incident on the system ; for instance, in an instrument like a pair of prismatic binoculars having ten glass/air surfaces, the loss in intensity due to reflection amounts to as much as 40 to 45 per cent. of the light incident on the surface of the object glass. Because of the more or less logarithmic response of the eye to illumination, losses as great as the above or even greater may not materially affect vision under average daylight conditions of illumination, but they are bound to be of serious consequence under poor or twilight conditions when instruments like 'tank' telescopes and 'night' (or navy pattern) binoculars are required to be mostly employed. Secondly, the light thus reflected from the glass/air surfaces gets re-reflected or scattered from the internal surfaces of the instrument, and this extraneous light partially illuminates the field of view, thereby resulting in loss of contrast and definition of the image formed by the instrument.

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Fig. 10

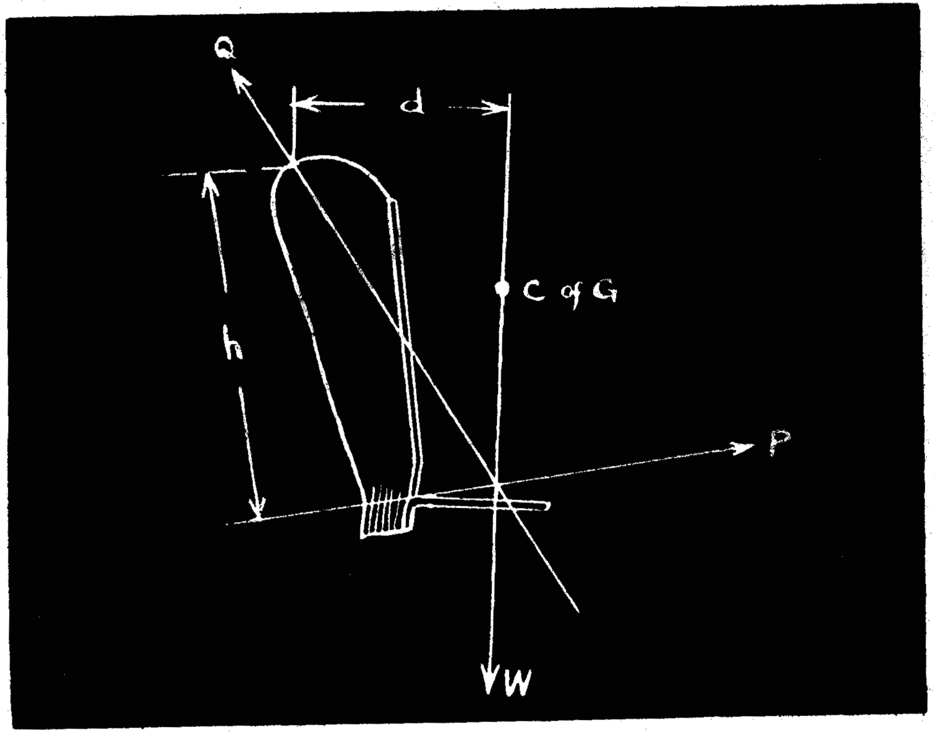

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Fig. 11

2. It is generally known that should such rapid transition from air to glass be eliminated by the interposition of an intermediate medium having a refractive index which is the geometric mean of the indices of refraction for air and glass $(\sqrt{\mu_a \mu_g})$ and of a thickness equal to $\frac{1}{4}\lambda$ (or an odd integral multiple of quarter wave-length for radiation in the brightest part of the visible spectrum, say 5550 Å), then reflection from the glass/air surface can be completely eliminated by destructive interference for light of this wave-length and to a less extent for radiation of neighbouring wave lengths. If, therefore, a film of the above nature and thickness could be deposited on the surfaces of the optical component concerned, it would not only result in eliminating light losses due to reflection, but would also result in a corresponding increase in the brightness of the image formed. It is, of course, preferable that the thickness of the film should be a quarter wave-length rather than an odd multiple of $\frac{1}{4}\lambda$, as, in the latter case, although the reflectance would still be zero at the wave-length of correction, it would be greater for neighbouring wave-lengths.

3. Although the outlines of the theory of non-reflectance films were worked out by Lord Rayleigh[1] more than half a century ago, the development of a suitable technique to deposit on glass surfaces fairly stable films that would stand normal wear and tear during use and repair of instruments is of comparatively recent origin and was originally developed by Strong[2] and Cartwright and Terner[3]. The only satisfactory films that have so far been produced are by the high vacuum volatilization process, which consists in evaporating on to the glass surface metalic salts (mostly fluorides) of low refractive index under high vacuum conditions of the order of 10^{-5} mm. The two materials most commonly used at present for the formation of non-reflecting films on glass by the above process are cryolite (sodium aluminium flouride) and magnesium flouride. While magnesium fluoride forms very hard films and is eminently suitable for the denser glasses, cryolite is a good compromise for the whole range of optical glasses and can be made quite hard enough to withstand unavoidable handling.

4. A centrifugal method of deposition of these bloomed films has been developed in Germany during the last war and is claimed to give very hard and stable films of a silicon skeleton network of mean refractive index of 1.28. In this process, a final solution made up from separate solutions of sodium or potassium silicate and hydrochloric acid, together with a suitable wetting agent, is dropped on to the glass surface revolving at 3000 r.p.m. and the experimental conditions are carefully controlled so as to obtain a film of the requisite thickness.

5. It is perhaps not so widely known that the term 'blooming' is applied to the process of deposition of non-reflecting films on optical glass surfaces.

6. If, in view of the considerations outlined in the first part of this Introduction, blooming of the surfaces of optical components

1. Lord Rayleigh. Scientific Papers, Vol. 1, P. 461 ; Vol. 6, P. 71.
2. Jour. Opt. Soc. Am., Vol. 26, P. 73 (1936).
3. Phys. Rev., Vol. 35, P. 391 (1939).

is to be introduced as a regular treatment for some or all of the optical instruments used in the armed services, it is of interest to know how the bloomed surfaces react to the action of fogging, filming and fungus from which most of the instruments used in humid tropical climates are known to suffer and rapidly deteriorate on exposure. With this end in view, two pairs of prismatic binoculars with bloomed optics and two other pairs with unbloomed optical components were subjected to weathering trials during a full yearly cycle of atmospheric changes in Bengal.

Experimental Details.

7. The trials described hereunder were undertaken in collaboration with the Admiralty Research Laboratory, Teddington, by whom the instruments required for the trials were obtained through the Ministry of Supply, U.K. and supplied to the Directorate of Armaments in India. The instruments were the standard pattern army prismatic binoculars manufactured by Messrs. Taylor, Taylor & Hobson, properly sealed airtight to start with and provided with rubber sealing rings in the eye-pieces and desiccating nipples on the coverplates. The binoculars were initially cleaned, assembled, adjusted, desiccated and sealed in the United Kingdom and passed the initial sealing test of 2 lb./sq. in. for 5 minutes without leakage.

8. The four pairs of binoculars under trial (two pairs with bloomed and two pairs with unbloomed optical surfaces) were, for the duration of the trial, placed in the open, protected from direct sun and rain by a wooden cover. A hygrograph and thermograph were also kept under the same cover to maintain a continuous record of the humidity and temperature values during the entire period of the trial. The instruments were left exposed under these conditions through a full annual cycle of seasonal changes of atmospheric conditions in Calcutta from the end of August 1943 to the close of August 1944.

9. At the start of the trial, the right hand eye piece (ocular with graticule) of each binocular was set to the zero reading on the dioptre scale and allowed to remain in that position until the end of the test. The left hand eye piece of each binocular, on the other hand, was focussed fully outwards each morning at sun up and screwed fully home each evening at sun down. This procedure was designed to study the effect of breathing, if any, of the instrument due to imperfect sealing.

10. All the binoculars under trial were regularly examined for clarity of vision and other effects at weekly intervals until the conclusion of the trial, and the following gives a summary of the results obtained during the trial.

Results.

11. Throughout the test period, the field of view as seen through the 'bloomed' instruments was distinctly brighter than that viewed through the untreated binoculars; this, as is obvious, is due to the improved light transmission due to blooming of the surfaces of the optical components of the former.

12. Fogging and consequent lack of clearness of field of view of all the instruments under trial varied with the humidity changes in the atmosphere, the depth of fogging increasing with increase in humidity and vice versa. Thus, the field was quite clear and well defined during most of the dry season from October to April while it had a more or less fogged appearance during tthe monsoon season or periods of high humidity; in fact, condensation of water droplets could be clearly observed all over the surface of the graticule during the mid-monsoon period.

13. As between the left and right halves of each pair of binoculars, the right ocular was, in general, found to have been fogged and filmed to a relatively larger extent than the left half.

14. Comparing the 'bloomed' instruments with the 'unbloomed' ones, it was observed that the degree of filming and consequent deterioration of the optical surfaces was less pronounced in the case of instruments fitted with 'bloomed' optics.

15. During the relatively dry periods of the year, the prism surfaces in all the instruments presented a finely pitted appearance, the extent of 'pitting' being, however, comparatively less in the case of 'bloomed' binoculars.

16. None of the interior surfaces of any of the binoculars under trials showed any signs of corrosion during the whole period, although the exposed surface of all the cover plate screws on the outside were found to have rusted heavily during the later stages of the trial.

17. There was no formation of fungus on the surfaces of the optical components of any of the binoculars under trial.

Discussion.

18. At about the same period as the above trials were in progress or a little later, a number of 'bloomed' binoculars was included in a large scale 'anti-fungus and anti-filming trial' with optical instruments carried out in West Africa by Campbell[4]. His observations, as a result of these trials, may be summarized as follows:

(a) Blooming does not offer any advantage in preventing fungus growth in binoculars, although the growth in 'bloomed' instruments is on the whole less excessive than in 'unbloomed' instruments;

(b) There is some evidence to indicate that 'blooming' of flint inner components actually encourages the growth of fungus on this type of glass;

(c) Fungus growth usually destroys the blooming in its immediate vicinity;

(d) Fogging readily takes place on magnesium fluoride 'bloomed' surfaces and has a dissolving action on the fluoride film; when the moisture dries off, it leaves behind a number of fine points at which the 'blooming' has been dissolved.

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4. Major Campbell's 'Report on the Development of Fungus, Fogging and Filming in Optical Instruments under Tropic Conditions and Possible Control'. (War Office—Dec. 1944).

19. Comparing the observations recorded by Campbell with those obtained in the trial described in the present paper, it will be seen that while there was perceptible growth of fungus in the binoculars used for his trials by Campbell, there was not any record in the latter case. This can only be attributed to the inefficient sealing of the binoculars in the former case which facilitated the entry of fungus spores with resultant growth of fungus under the jungle conditions of exposure to which these instruments were subject during the course of the trial. That the sealing of these binoculars had broken down during the exposure period was shown by the leakage test subsequently carried out. In the case of the present trials, however, the binoculars were initially cleaned, desiccated and well-sealed under proper conditions of assembly, and although there is evidence to show that, during the course of the trial period, the sealing of the instruments was not as perfect as the one would like it to be and breathing and consequent fogging of the instruments did occur, yet no growth of fungus took place in any of them. The absence of fungus in these binoculars, in spite of the favourable conditions existing for its formation and growth, can only mean that the leaks in the instruments could have been of such a small magnitude as not to facilitate the entry of spores into the interior. Unfortunately, no leak tests on the instruments could be carried out before they were returned to the United Kingdom.

20. That fungus, if allowed to grow on a bloomed surface, would destroy the blooming in its vicinity is easily understood, as the local condensation of moisture which usually takes place in the neighbourhood of fungal hyphae results in a slow dissolving action on the extremely thin fluoride film on the surface; and further, any subsequent cleaning of the surface to remove the fungus would naturally result in the destruction of the bloomed film at the place.

21. The variation in the extent of fogging of the optics of the binoculars under trial with changes in humidity and temperature of the surrounding atmosphere as recorded in para. 3.2 gives a positive indication of the presence of breathing of the instruments. This could only occur through minute leaks in the sealed joints which permitted the ingress of water vapour from the outside to the interior during periods of high humidity, and vice versa. That the leaks in the instruments were at least partly through the focussing screw threads of the eyepieces is borne out by the fact that the degree of fogging was generally greater in the right half on the binocular than in the left half; the right eyepiece was, throughout the trial period, set to the zero reading on the dioptre collar whereas the left eyepiece was everyday screwed fully home at sun down thereby providing a better seal during periods of high humidity due to the rubber sealing ring on top being brought into action. There was, therefore, less or no leakage through the eyepiece focussing screw threads in the left half of the binoculars. Thus there were no signs of corrosion of the interior surfaces even at the close of the twelve month exposure period indicates that leaks through the instruments, although present, could at no stage have been excessive. This is also supported by the fact that there was no formation of fungus in any of the binoculars.

22. The observations recorded in sub-paras. 3.4 and 3.5 with respect to the degree of filming in bloomed and unbloomed binoculars are somewhat in conflict with the results obtained by Campbell in his West African trials. The extent of fogging and filming observed in any of the present instruments was at no time so great as to completely obscure vision through them or even moderately affect it, while a good percentage of the binoculars (over 40 per cent.) used by Campbell were heavily filmed after an exposure period of 15 weeks. This again can be ascribed to the comparatively better sealing of the former binoculars. Further, the effect of fogging and moisture in producing a finely pitted appearance of the interior surfaces of the optics, particularly those of the prisms, was observed not only in the case of 'bloomed' instruments as was recorded in Campbell's trials, but was also noticed to an equal degree and even more in the case of the 'unbloomed' or control instruments. This cannot, therefore, be said to be the peculiar action of moisture on the fluoride film of the bloomed surface as explained by Campbell, but is rather due to the action of moisture on the particular variety of flint glass used for the manufacture of binocular prisms; moisture appears to have an appreciable degree of solvent action on this flint glass. The fact that the extent of pitted appearance of the surfaces was comparatively less with bloomed instruments goes to indicate that blooming, if any affords a sort of partial protection against the deleterious action of moisture on glass.

23. The results of the comparative weathering trials carried out on bloomed and unbloomed (or normal) binoculars as described in the foregoing pages do not support the view held in some quarters at one time that bloomed optical surfaces would be more liable to fungal attack than untreated surfaces, nor do they support the opinion expressed that blooming results in a greater affinity for moisture with consequently more rapid deterioration of the optical glass surfaces. On the other hand, the considerably improved transmission of light that results on blooming is a definite and very important advantage, particularly so in the case of certain types of optical instruments used by the armed services; and if this property is to be profitably made use of for the maximum period of useful life without at the same time increasing the cost of upkeep of an instrument out of all proportion to the advantage gained, it is imperative that adequate steps should be taken to prevent fouling and fungus growth. This can be achieved, as is well known, by assembling the instrument under scrupulously clean conditions, completely desiccating the interior and finally sealing it hermetically. An instrument hermetically sealed under such conditions

would remain serviceable in its original condition for a long time, but perfect sealing of optical instruments, particularly those equipped with focussing eye-pieces, is very difficult with the existing design of the vast majority of them. Experimental techniques have been recently developed towards achieving this desideratum with most of the service optical instruments during their subsequent repair and overhaul, but what should be aimed at, if the advantages of blooming are to be fully realised in such cases, is to alter the existing designs of the instruments in the light of the vast experience gained in the recent past so as to make them capable of being rendered absolutely airtight by hermetical sealing. This appears to be the final solution not only towards making a more general use of the advantages to be secured by blooming, but also most ills met with during the upkeeper and maintenance of optical instruments in general; and all efforts should be directed at achieving it.