Fungus in optical instruments.

Many old optical instruments have fungus growth on a glass surface. Fungus does not look like haze but has an appearance like hairs or tendrils branching from a center. While the fungus can be removed by cleaning, it frequently has etched the glass, since fungi secrete enzymes and acids to chemically alter their environment so they can absorb nutrients. This etching requires repolishing, which if done unprofessionally will ruin the instrument. It is not possible to tell if the glass is etched until the fungus is cleaned. Maintenance of optical instruments involves prevention of future fungus problems, especially if located in damp regions.

To sum up the lengthy documentation below:

--WWII research programs on fungus in optical instruments (Turner, below) used sodium ethylmercurithiosalicylate, now known as Thimerosal and widely used consumer medical products. When mixed in paint used inside the binocular, this was found effective at preventing fungus. It is not known if Thimerosal is so used today.

--Hydrogen peroxide, or bleach, can be used to kill fungus.

--Leitz documents describe a fungus treatment of 94% distilled water, 4% clear ammonia (for cleansing) and 2% hydrogen peroxide (to kill fungus).

--Carl Zeiss Oberkochen, dept. KuDi, sells: Fungus Cleaning Agent "Fungusreiniger NEU". Dilute with ethyl alchohol, leave on glass for one hour or more, then clean. Not poisonous but avoid contact with skin. 100ml bottle, INR 0117.362 500ml bottle, INR 0117.361 1000ml bottle, INR 0117.360

--Notes on treatment & prevention are found at the end of this text.

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1. Turner, J.S., et al. Tropic-Proofing of Optical Instruments by a Fungicide. Nature 158 (Oct. 5, 1946) 469-473.

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3. Fay, J.W.J. Comments. Nature 158 (Oct. 5, 1946) 474.

4. Saxena, B.B.L., S.S. Nigam, & S.R. Sengupta. Fungal Attack of Optical Instruments & Its Prevention. Indian Journal of Technology 1 (1963) 283-286.

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7. Howard, Richard. The Role of Botanists During World War II in the Pacific Theatre. page 100. Macleod, Roy, ed. Science and the Pacific War: science and survival in the Pacific 1939-1945. Dordrecht: Kluwer, 2000.

8. Notes on fungus from military, commercial, camera, & optical sources.

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Tropic-Proofing of Optical Instruments by a Fungicide.

J.S. Turner, E.I. McLennan, J.S. Rogers, & E. Matthaei. University of Melbourne.

Nature 158 (Oct. 5, 1946) 469-473.

It is remarkable that the problem of the deterioration of optical instruments by fungi has remained so long without thorough investigation. Until 1939 very few people seem to have realized that fungi can grow actively on or over the internal optics of binoculars, cameras, etc., exposed to warm and humid conditions. The trouble became acute, however, in Australia when military units went into action in New Guinea.

Not only were the facilities for storage of instruments extremely primitive in the early stages of this campaign (1), but, as has since been shown, parts Of New Guinea are climatically the worst possible Places for fungal troubles. In a short time, the fungal infection of instruments designed for temperate regions became a major problem. Optical instrument workshops, adequately equipped and staffed for normal repair work, found themselves entirely unable to cope with the flood of fungus-infected instruments which descended upon them. Many types of instruments lasted only for four to eight weeks before infection; and, very often, new

instruments awaiting issue in depots were found to be deteriorating rapidly on the shelves because of fungal attack. In fact, instruments in store were affected more often than those in use, and the trouble was greatest where they were housed in leather cases and stored in wooden boxes.

Accordingly, in 1943, the Australian Scientific Instrument and Optical Panel (an advisory panel to the Ordnance Production Directorate of the Ministry of Munitions, Australia) set up a special subcommittee, which carried out research on this problem and which has issued interim reports from October 29, 1943, up to the present time. (2) Considerable research was carried out during the same period in both the United States (3) and Great Britain. (4) In this report we shall summarize the results of the Australian work, which led to a reasonably effective method of tropic-proofing optical instruments.

The fungi which grow in optical instruments belong to the groups Phycomycetes, Ascomycetes and Fungi Imperfecti. The following species were frequently isolated from instruments which had been in New Guinea: Penicillium spinulosum, Thom.; P. commune, Thom.; P. citrinum, Thom.; Aspergillus niger, Van Tiegh.; Trichoderma viride, Pers. ex-Fr.; Mucor racemosus, Fres.; and M. ramannianus, A. Moeller. So far, Monilia crassa has not been isolated from Australian instruments, although Dr. W. G. Hutchinson (5) of the United States, found this to be a common species in the Panama zone, and it has also been recorded as frequent in West Africa by Major I. G. Campbell. (6)

The fungal spores germinate on the moist surface of the glass lenses or prisms or, more frequently, on particles of dust, luting wax, cork and other organic debris. The mycelium spreads thence over the whole surface of the clean optical glass. The moulds are particularly troublesome when they grow on graticules, but they are also capable of obscuring lenses and prisms. The fine hyphal threads in contact with the glass surfaces are often surrounded by minute condensed water droplets or by droplets of alkali-soluble substances liberated from the glass itself. If the mycelium remains for many months in contact with the glass, it is capable of etching a pattern into it. More commonly, when removed, the mycelium. leaves only a slight stain resembling an oil film which can be removed by cerium oxide polishing.

The committee concentrated at first on methods for civilian binoculars which were to be issued to the Australian Services. It was early decided that it would be futile to attempt to desiccate these instruments or to ensure that they were optically clean and sterile when dispatched. A search was made, therefore, for a suitable volatile fungicide which could be placed in the instrument during its first reservicing and fitting with graticules. The requirements of the fungicide were: (a) toxicity to all possible contaminants, (b) action at a distance (that is, volatility) for the substance could not be placed directly on the optics, (c) stability in moist air and to a temperature of at least 60 degrees C., (d) persistence of action over some months or, preferably, years, (e) lack of power to corrode metals, especially brass, steel, and aluminium alloys, (f) non-toxicity to man, (g) mite repellent (because mites have been shown to enter optical instruments carrying fungal spores with them), (h) availability in war-time.

As might be expected, very few of the known fungicides passed even the first of these tests. The initial laboratory experiment was designed to select a fungicide with the properties noted in (a) and (b) above. For this purpose the substance under test was incorporated in luting wax and a drop of this was melted on to a microscope slide. This was then inverted and a hanging-drop culture of mixed spores from optical instruments was set up around the wax.

The following known fungicides were shown to be ineffective under these conditions for some or all of the moulds concerned: 'Ceresan', 'Agrosan', 'Shirlan', 8-hydroxy-quinoline, penta-brom-phenol, tetramethyl thiuram disulphide, tri-brom-phenol, azo-chloranide, clove oil, copper naphthenate, phenyl mercuric acetate, tri-oxy-methylene, methyl alcohol and thymol. Many other fungicides were not tested here, following adverse reports on their properties from other workers, for example, naphthalene, paraformaldehyde. Thymol was the most promising, but further experiments with it were discontinued when it was found that an organic mercurial completely suppressed the germination of all the species with which we were concerned. This substance was sodium ethylmercurithiosalicylate, referred to here as 'M.T.S.'. It had been produced in Australia on a large laboratory scale by Prof. V. M. Trikojus and his associates of the Universities of Sydney and later of Melbourne. It was in use by the Australian Army Medical Corps for the preservation of blood. Prof. Trikojus suggested its trial for tropic proofing, and very, extensive tests have shown it to be the best fungicide so far investigated by us for this particular purpose.

At first, the M.T.S. was incorporated only into luting waxes, but later it was mixed with a black lacquer, which was used to cover the interior metal surfaces of optical instruments. It was mixed with this paint to give a concentration of 0.2

per cent in the liquid and it was also incorporated in the microcrystalline wax which we used for luting purposes. Our experiments show that the dry M.T.S., pure or in paint, is scarcely volatile at all, but in the presence of water vapour it is decomposed, probably by hydrolysis, to give a very active fungicidal and fungistatic vapour.

Following hanging-drop tests, binoculars and rangefinders were painted internally with the poisoned lacquer and mixed fungal spores were dusted on thin agar films with which the optics had been coated. The instruments were then assembled in the normal way and placed in a tropic-proofing test cabinet under conditions of high humidities and temperatures. Some of the instruments were also wrapped in damp calico which had been sprinkled with spores, and living mites were introduced into the cabinets. Under these conditions, no fungal growth occurred inside the treated instruments, but there was abundant growth in the control instruments which had not been poisoned. In later experiments, cylindrical tins of 300 cubic cm. capacity were painted internally with black lacquer, some of which had been poisoned with M.T.S. or with its butyl or methyl esters, in concentrations of 0.2 per cent. The space inside was saturated with water vapour, and each tin contained, for the actual test, a microscope slide covered with a film of nutrient agar and dusted with fungal spores. In no instances have spores germinated in tins containing the M.T.S. poisoned paint, although some of these tests were carried out six months after the paint had been applied to tins open to the atmosphere through minute holes. The vapour arising from the M.T.S. paint has been shown to kill the spores as well as to inhibit their growth. Further experiments, carried out by an officer of the Victorian Department of Agriculture, have shown that the vapour arising from the hydrolysis of M.T.S. is lethal to mites, but it does not act as a mite repellent. This corresponds with our own experience ; and we have found that, while mites entering M.T.S. treated instruments are killed, their bodies do not then act as centres for the growth of fungi.

In the experiments with closed tins referred to above, some germination of spores did take place when the paint contained either the butyl or the rnethyl ester of M.T.S., but only when the tins had previously been stored for six months. The methyl ester was the less promising, but Dr. Hutchinson, of the United States, has informed us that the butyl ester which we supplied to him was rather more effective than M.T.S. itself in his Panama Zone experiments. This ester has the advantage of being soluble in lipoid solvents, and further trial may prove it to be a fungicide of better value than the sodium salt (M.T.S.) itself.

Once the value of M.T.S. as a fungicide was established, it became necessary to test its corrosive power. The first results were most discouraging, as it was found that aqueous solutions of M.T.S., both in the acid form and as the sodium, copper and zinc salts, brought about rapid accelerated corrosion of aluminium and some slight corrosion of brass. The corrosion was of a type which suggested that free mercury ions were released in solution and catalysed the reaction. However, it has since been found that when incorporated in a suitable lacquer, the M.T.S. causes no corrosion at all of the metal under the lacquer or of unpainted damp metal surfaces near by, even when the test piece is enclosed in a small volume of warm, damp air. On the contrary, the layer of lacquer protects the metal surfaces against the action of water vapour, which is known to cause extensive corrosion in optical instruments exposed to tropical conditions. So far as experiments have gone, there is no evidence that M.T.S. attacks lens cements (balsam or n-butyl methacrylate), nor does it cause the filming of optics.

This lack of corrosion by M.T.S. in paint may have been due in part to the special properties of the paint we employed. We have recommended the use of a nitro-cellulose lacquer which dries quickly to a reasonably matt surface. It is manufactured by B.A.L.M. under the name of 'Duco Enamel Lacquer'. Recent reports from England indicate that other lacquers are not necessarily suitable. We have also found it not advisable, from the point of view of corrosion, to incorporate the M.T.S. into the zinc oxide-retinax grease used as a lubricant for eyepiece threads. It should be noted here that the M.T.S. makes up 0.2 per cent of the liquid lacquer; when this dries put, the mercurial poison is dispersed in the film at a concentration approaching 0.8 per cent.

Our corrosion tests are supplemented by observations on binoculars which have been tropic-proofed with M.T.S. and exposed for long periods as follows: 1- some instruments were kept for three months in the laboratory in Melbourne; 2- others were exposed for two months in a test chamber to 100 per cent relative humidity and 30 degrees C.; 3- about thirty instruments were exposed to tropical conditions in New Guinea for two and a half months and then returned to Melbourne for examination.

Corrosion in all these instruments was limited to that taking place on exposed aluminium alloy surfaces and its extent was that which would be expected, from

control experiments, to occur whether M.T.S. was present or not. Experiments at the Munitions Supply Laboratories, Maribyrnong, have also shown that black lacquer containing 0.2 per cent M.T.S. does not cause 'season cracking' of brass. Finally, although many thousands of optical instruments have now been tropic-proofed in the way recommended, there has been no report from the Services of corrosion in these instruments.

These tests and observations have convinced us that there is very little danger of corrosion by M.T.S. in paint. They have, at the same time, led us to recommend that all internal metallic surfaces of optical instruments for tropic use should be painted or anodized so as to render corrosion by water vapour negligible.

Since 1943, numerous field experiments in New Guinea have confirmed the value of M.T.S. as a fungicide in optical munitions. A short test in 1944 with thirty-four binoculars in stores at Milne Bay, Lae and Port Moresby was inconclusive in that many of the control instruments did not become infected. However, at Lae, four binoculars containing M.T.S. remained free from infection on all optics, while two untreated instruments were all infected on various optical surfaces.

Later, twenty binoculars and six rangefinders were exposed in Kunai grass near the jungle for six months and then returned to Melbourne for examination. One side of each of the binoculars was tropic-treated, while the other side acted as control. Three rangefinders were treated and three acted as control. After six months, there was no infection in any of the treated sides of the binoculars, except for one slight trace of non-sporing fungus on one prism. Practically all the untreated sides were infected, some badly. All three treated range-finders were free of fungus, while all the untreated instruments were badly infected. This is a striking proof of the efficacy of M.T.S., as the rangefinders are badly sealed instruments and yet even in these the fungicide retained its activity.

A long-term experiment has just been started in New Britain. One hundred instruments (binoculars) have been assembled with exactly the same luting, lacquer and eyepiece grease; but on one side of each instrument the lacquer and luting contain M.T.S., while the other side is free of this substance. Twenty-five pairs are to be returned to Melbourne at six-month intervals for examination. The efficacy of the fungicide will thus be tested over a period if two years.

Three pairs of binoculars treated with M.T.S. in Melbourne have been exposed to tropical conditions in the Panama zone. They are still under test, but they have so far remained free of fungus for a period of five months.

Perhaps the most striking evidence in favour of M.T.S. is its control of fungal infection in aircraft cameras, which are, of course, badly sealed instruments. At the beginning of 1944, the secretary of the Scientific Instrument and Optical Panel was approached by an officer of a camera repair unit of the U.S.A.A.F., who reported very severe damage to aircraft cameras caused by fungi.. The unit adopted the M.T.S. treatment for all its cameras and has reported that none of the 350 cameras so treated became infected during a period when approximately a hundred lenses, including fifty from aircraft cameras, were returned for the removal of fungi from the optics. One aircraft camera, treated with M.T.S., has remained internally free of fungus for a period of twelve months, although, on occasion, fungi have had to be wiped off the external lens faces. Officers of this unit have also found that the growth of fungus in fibre cases for carrying cameras could be prevented by coating the cases internally with black lacquer containing M.T.S.

The Australian Military Forces adopted the M.T.S. treatment in 1944, and all types of optical instruments manufactured or assembled in Australia, including thousands of binoculars, have been treated in this way. The R.A.A.F. and one section of the U.S.A.A.F have also adopted the method, as has the Royal Australian Navy. Recent reports from Britain indicate that the method is undergoing tests by the R.A.F., although it is there recommended that internal metal surfaces should be anodized or covered with a primer before the poison lacquer is applied.

In aqueous solution M.T.S. will prevent the growth of Penicillium at concentrations so low as 1 in 2millions. It is used locally in 1 in 1,000 solution, as a tincture for skin disinfection and as a nasal spray, and it has also proved of value for preserving blood serum. (7) It is regarded as most unlikely to cause any harm to man in the concentrations recommended for tropic proofing, as the lethal dose for man is believed to be about 1,000 milligrams. Its action at a distance is best shown as follows. Black paint containing 0.2 per cent M.T.S. is used to coat glass plates approximately 4 in. square; the painted surface is then apposed to a similar plate coated with thin agar dusted richly with Penicillium spores. The two plates are kept 2 mm. apart by spacing strips round the edges. No spores germinate (in fact they are killed) on the agar when the two plates are incubated under humid conditions. If, however, the paint is applied in two narrow bands forming a cross, spores do germinate to form a thin mycelium, but only in the corners of the plate. The mycelium then slowly spreads towards the middle where the concentration of toxic vapour is at the maximum.

Under these conditions it appears that mutual reaction between the fungus and the vapour keeps the concentration down and allows slowly continued growth of mycelium. The vapour (which presumably contains a mercury compound) takes effect whether the paint lies above or below the agar; but in some experiments it was noticed that the inhibition of growth on plates held vertical was exerted over a greater distance on the lower sides of horizontal painted bands.

Incorporated into paints, M.T.S. may prove to be a useful fungicide apart from its application to optical munitions. For example, Mr. P. G. Law has suggested its use as a preventive of mould spotting in framed prints. Preliminary tests indicate that, if the wooden back of a picture frame is painted with M.T.S. lacquer on the side facing the print, mould growth in humid atmospheres is prevented. Technical officers in museums and galleries may find that further investigation along these lines is worth while.

The authors desire to acknowledge the valuable assistance of the other members of the Scientific Instrument and Optical Panel committee: Mr. P. G. Law, Mr. J. W. Blamey, of the University of Melbourne; Mr. G. C. Wade, of the Victorian Department of Agriculture. Our thanks are also due to Prof. V.M. Trikojus, Mr. G.M. Willis of the Metallurgical Department, University of Melbourne, Mr. M. Pack of B.A.L.M. and several officers of the Munitions Supply Laboratories, who all made contributions towards the solution of the problem. The Tropical Scientific Section of the Scientific Liaison Bureau, Melbourne, rendered assistance in the carrying out of the field tests in -New Guinea.

Footnotes.

1. Scientific Liaison Bureau, Australia. "Report on the condition of Service Material under tropical conditions in New Guinea." Restricted. October 21, 1943.
2. Scientific Instrument and Optical Panel, Ministry of Munitions, Australia. "The Tropic Proofing of Optical Instruments, Part I", July 1944.
3. O.S.R.D. Reports, U.S.A., No. 1833, July 1943. No. 4188, September 1944.
4. Reports of Optical Instruments Panel of Conference on Tropic Proofing, Controller of Chemical Research and Development, Ministry of Supply, Great Britain, papers issued under MG/OPT.
5. Hutchinson, W. G., in O.S.R.D. Report No. 1833, July 1943.
6. Campbell, Major I. G., "Fungi in Optical Instruments under Tropical Conditions, and Possible Control", D.M.E. War Office, Great Britain, December 1944.
7. Simmons, R. T., and Woods, E. F., Austr. J. Sci. 8 (1946) 108.

Chemistry of Sodium Ethylmercurithiosalicylate.

Prof. V.M. Trokojus, University of Melbourne.

Nature 158 (Oct. 5, 1946) 473-474.

Sodium thylmercurithiosalicylate is a white crystalline solid, melting at about 230 degrees C. and easily soluble in water and the lower alcohols, but insoluble in lipoid solvents. Its preparation -was first reported by Kharasch in 1928 (8) (cf. also Waldo (9)).

In the manufacture of the drug in Australia for plasma preservation and tropic-proofing, undertaken initially by J. E. Falk and since, in larger quantities, by R. H. Hackman, ethylmercuribromide was condensed with thiosalicylic acid (15 per cent excess) in aqueous-ethanol with the equivalent of 2-5 mol. sodium hydroxide. About a kilogram of thiosalicylic acid was used per batch. The crude ethylmercurithiosalicylic acid (by precipitation with hydrochloric acid) was purified by recrystallizing <section cut>

Both compounds are insoluble in water but readily soluble in lipoid solvents, an obvious advantage when applying the materials to paints and lacquers; moreover, the methyl ester can be obtained in a pure condition much more conveniently than the sodium salt.

The action mechanism of the sodium salt as a fungistatic and fungicidal agent is uncertain. It has been proved to act at a distance, but it is improbable that a sodium salt of this configuration would possess a significant vapour pressure. Kharasch has pointed out that aqueous solutions of the sodium salt tend to break down to ethylmercurihydroxide (III) and sodium thiosalicylate, the latter, in the presence of oxygen, passing irreversibly to the dithiosalicylate (IV). Thus the access of water vapour, providing conditions for fungal growth, might also favour a similar breakdown of the lacquer-incorporated mercurial, or even further to more volatile substances.

Footnotes.

8. Kharasch, M.S. U.S.P. 1 (1928) 672, 615.
9. Waldo. Journal Amer. Chem. Soc. 53 (1931) 993.

Comments by Dr. J.W.J. Fay, Ministry of Supply.
Nature 158 (Oct. 5, 1946) 474.

I am glad to have seen these two interesting papers, and take the opportunity of offering the following comments on British experience.

Two factors have militated against the use in Britain of M.T.S. on other than an experimental scale.

First, in the design of new instruments, or the modification of old types, the tendency has throughout been towards the improvement of sealing and of packaging. This, coupled with the use, if necessary, of a desiccating agent, is considered the ideal at which to aim, since the need of a fungicide is eliminated.

Secondly, in connexion with the protection of old instruments, including ex-civilian surrendered types of unknown history, the incorporation of volatile fungicides was not without its dangers. Thus, various substances tried gave rise to such troubles as softening of cements, corrosion and filming. Nevertheless, the need for a suitable fungicide was recognized and many were tested.

Among these, M.T.S., of which the vapour pressure is extremely low, was found to depend for its action upon a decomposition in the presence of moisture, giving rise to a volatile mercury compound which is presumably the active agent. The decomposition was found to be accompanied by a corrosion danger, and in the lacquers we have used this danger has not yet been overcome. We are, however, now awaiting samples of Australian lacquer for test.

In general, therefore, even in the case of old-type instruments, our attitude has been to improve sealing and methods of servicing, packing and storing, and the tendency is in any case to regard the incorporation of a desiccant as preferable to the use of fungicides.

With reference to the New Guinea experiments, we have had the opportunity of examining a few of the instruments tested, and our view is that while the results afford evidence of the superiority of the new complete Australian 'tropical treated' method over the old one, it is not entirely clear, in the absence of true controls, how much of the improvement is to be ascribed to the use of M.T.S. For this reason, we shall look forward with great interest to the results of the long-term New Britain experiments in which rigid controls are apparently included.

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Saxena, B.B.L., S.S. Nigam, & S.R. Sengupta. Defence Research Laboratory (Stores), Kanpur.
Fungal Attack of Optical Instruments & Its Prevention.
Paper presented at the Symposium on Instruments, held at TDE (Instruments), Dehra Dun, in November 1959.
Indian Journal of Technology 1 (1963) 283-286.

The nature and pattern of fungus infestation on various components of binoculars in hot, humid conditions (Calcutta, Cochin and Bombay) have been investigated. The organisms isolated and identified include: Aspergillus niger, A. fumigatus, A. candidus, Penicillium sp., Paecilomyces sp., Syncephalastrum sp., Sepedonium sp., Curvularia sp., Fusarium sp., Monilia sp. and Cladosporium sp. Prisms and OG lenses show greater fungal infestation than FL or EL lenses; graticules and lutings show slight to moderate degree of incidence. Protective treatments tried on brass and aluminium materials indicate that satisfactory protection is provided by: 1- incorporating fungicides like Cresatin, Merthiosol, copper naphthenate and pentachlorophenol in lacquers, varnishes, lutings, waxes, greases and paints applied to various components of the instrument; or 2- depositing on the surface, coating compositions containing suitable fungicides by chemical or electrolytic methods.

In tropical climate characterized by high temperature and humidity accompanied by nocturnal condensation, optical instruments are prone to fungal attack during storage. Instruments such as binoculars, rangefinders, telescopes, cameras and similar other equipment lose their functional efficiency when they are attacked by fungi and thus cause considerable financial loss. Although as early as 1932, the fouling of binoculars by fungi was recorded in India (1), it was not until 1939 that it was realized that fungi can grow actively on glasses, prisms of binoculars and on lenses of cameras. (2) In 1943, it was reported from New Guinea that the presence of fungal colonies in optical equipment was the 'rule rather than the exception'. (3) Under favourable conditions, fungal infestation is not confined to a specific component of an optical instrument but spreads to all the parts. Optical glasses, prisms, lutings, seals, greases, waxes, lacquers and varnish coatings are all attacked, pointing to the need for an overall improvement in materials used in the fabrication of optical instruments.

Workers in India were among the first to identify the actual nature of the microorganisms responsible for the unserviceability of optical instruments. In 1940, at Rawalpindi arsenal the use of desiccating valves fitted to binoculars as

a means of reducing the fouling was resorted to. Work was simultaneously carried out in the USA, the UK, Canada and Australia to study the nature of deterioration of optical instruments and also to study the behaviour of a large number of tropic proofing compounds. In 1943, Hutchinson (4) examined a large number of optical instruments and recommended the use of 'Cresatin' (m-cresol acetate). In 1944, Campbell carried out large-scale investigations (5) in order to develop antifungal as well as antifilming measures for use in the Service equipment under jungle conditions of storage and usage. In the same year similar type of work was done in Australia. In India, at the then Inspectorate of Scientific Stores (Instruments and Electronics), Calcutta, work was carried out on the problem of fogging, filming and fungal infestation of optical instruments. In collaboration with that organization, Defence Research Laboratory (Stores), Kanpur (then known as Ordnance Laboratories), investigated the nature and extent of microbial damage in binoculars. In 1945, the Directorate of Armaments (India) carried out extensive exposure trials at Calcutta and later in 1948 at Cochin and Colaba (Bombay). These trials were on different types of optical instruments and consisted in subjecting them to adverse storage conditions.

Failure of Optical Instruments

The failure of optical instruments in the tropical regions may be due to fogging, filming or fungus infestation. In addition, corrosion of metallic parts of binoculars has also been noted. Fogging involves the occurrence of moisture droplets on glass surface due to condensation of moisture from the atmosphere. It is transient and depends solely on the atmospheric humidity of the place. Filming involves the production of a greyish coating on the optical surface and it is progressive and not transient. When condensation / fogging occurs on the optical surfaces, free alkali which is present on the surface of the glass goes into solution. This alkaline solution reacts with the carbon dioxide of the air and forms a solution of alkali carbonate. When the instrument gets dry, the solution evaporates and leaves carbonate crystals on the glass surface. Thus, a permanent film is left on the glass surface. Filming is also caused by the condensation of volatile constituents of eyepiece lubricants and sealing materials. Among the optical instruments, binoculars are most prone to the development of moulds. In other instruments, too, the liability to mould growth is favoured by openness of construction, i.e. whether or not the instrument has focussing eyepieces or bodies, adjustment and apertures or 'breaks' due to rotating mechanism. Even sealing compounds aid in the development of moulds.

The fungal spores germinate on the moist surface of the glass lenses or prisms or more frequently on particles of dust, luting, wax, cork and any organic debris. The mycelium spreads thence over the whole surface of optical glass. The fungi are particularly troublesome when they grow on the graticules. They are also capable of obscuring lenses and prisms. Fungi grow well on the outside of the object glasses and more so when the instruments are stored in mouldy cases. By far the most important source of fungi found within optical instruments or on the exterior is the mouldy case of the instrument.

The present communication presents the results of a preliminary study on the isolation and identification of fungi from a few typical affected pieces of binoculars. The use of certain protective agents has also been investigated.

Experimental Procedure

The binoculars received from the Inspectorate of Scientific Stores, Calcutta, and from the Technical Development Establishment (I & E), Dehra Dun, after exposure trials at Cochin and Colaba, were examined for the nature and pattern of fungal attack on the various components. Cultural studies of the fungal growth on glasses, prisms and graticules were also made.

Visual and microscopic examination: Fungal infection was observed in varying degrees on different parts of the binoculars. The lenses and prisms were most affected, followed by graticules, lutings and greases. Even the paint was attacked by fungi. In some cases the fungus growth had etched the glass. Wherever dead mites, debris or grit were found, fungal growth was luxuriant. The mycelium branched profusely, often forming a dense compact mass bearing spores (Fig. 1). When the food material was not in abundance, the growth on most of the prisms was restricted to a very few delicate branched hyphae bearing occasionally few spores. In extreme cases, where the growth was exclusively at the expense of the food material present in the spore, the mycelium consisted of a few rudimentary hyphae radiating from the spore in the form of a star (Fig. 2). When the growth of a fungus started from the central region of the flat surface as in OG lens, it was usually symmetrical in all directions (Fig. 3); and when the amount of food material was abundant the growth was dense and spread out irrespective of the species (Fig. 4).

In some cases, as a result of fungal action, luting and organic debris partially dissolved in the condensed water vapour and spread out along hyphae producing irregular opaque configuration, thereby interfering with light transmissions (Fig. 5). In prisms, the growth started from the apex and radiated on the two surfaces forming irregular ramifications. In some cases, the hyphae branched profusely and were often enveloped with droplets of water throughout their length, thereby causing fogging of the instrument (Fig. 6).

The patterns of fungal infection of lenses and prisms of binoculars can be considered to belong to the following types: 1- A spidery fungal growth radiating from a central point. The fungal growth is easily removable and does not etch the glass surface. Chlamydospores are often found and conidiophores when produced may bear only a few chains of spores. 2- 'Starfish' type, in which the growth is flat, adhering closely to the glass like a thick whitish drop and on removal leaves the colour on the glass. The growth is composed of fragmented hyphae surrounded by droplets of water. 3- Minute circular spots which always etch the glass. They consist of tiny fungal colonies on small particles.

Isolation of fungi: The following methods were adopted for the isolation of fungi from the infected components of the binoculars: 1- The prisms were placed in Petri dishes containing potato-dextrose agar (PDA) medium. After incubation for a week at 30 degrees, plus or minus 2 degrees C, subculturing was done of the fungi which were found growing. 2- A scraping of lacquer / varnish from the inside of the binocular was obtained and the scraping was planted on PDA medium. 3- Tube culturing was done by placing a drop of sugar solution on the lens over the fungus to be examined, and transferring with a platinum loop, after gentle rubbing, to the surface of a PDA slant. These slants were incubated at 30 degrees, plus or minus 2 degrees C, for a week and the organisms isolated. 4- Infected lenses and prisms of binoculars were washed with sterile distilled water under aseptic conditions and the surface growth was removed with small pieces of sterile filter paper. These pieces were then plated out in Petri dishes with a small quantity of water on Waksman medium. These Petri dishes were incubated at 30 degrees plus or minus 2 degrees C. for a week and the organisms isolated.

Nature, incidence and frequency of fungi: The fungi growing on optical instruments belong to Phycomycetes, Ascomycetes and Fungi Imperfecti (2). Most of the isolates from the binoculars were identified as common fungi. Similar types have also been reported from Australia (2). The common types isolated belong to Aspergillus and Penicillium groups. In some cases, due to prolonged desiccation and unfavourable conditions hyphae and spores (observed under microscope) failed to grow on the medium. The following fungi were isolated from the various components of the binoculars: Aspergillus niger, A. fumigatus, A. candidus, Penicillium sp., Paecilomyces sp., Syncephalastrum sp., Sepedonium sp., Cuvulvaria sp., Fusarium sp., Monilia sp. and Cladosporium sp.

Along with fungi, bacteria and a few yeast cells were observed. Some of the bacteria were chromogenic. Prisms and OG lenses showed greater fungal infection than FL or EL lenses. Graticules and luting showed slight to moderate degree of incidence.

Protective Treatments

Since moisture is the chief cause of fogging, filming and fungus growth, it is imperative to prevent ingress of moisture into the instruments. Several methods of controlling fungus fouling of optical surfaces have been reported, such as sanitation (6), dehumidification (1), use of antidimming substances (unpublished data from Defence Research Laboratory (Stores), Kanpur), and fungicides.

As part of the present study, the suitability and efficiency of several fungicides when incorporated in lacquers, varnishes, luting, waxes, greases and paints against fungal attack were investigated. The application of coatings (by chemical / electrolytic methods) for the protection of metal against corrosion and fungal attack was also investigated.

Lacquers: Nitrocellulose lacquer, cashew nut shell lacquer (CNSL), and BALM Duco lacquer containing Cresatin (0.5 per cent), Merthiosol (0.34 per cent), copper naphthenate (3.0 per cent) and pentachlorophenol (PCP) (1.0 per cent) as fungicides were tested. It was found that: 1- CNSL is less susceptible than nitrocellulose lacquer, 2- lacquers containing Cresatin, Merthiosol and PCP (1.0 per cent) are ineffective, and 3- matt-pigmented CNS lacquer with 2 and 3 per cent PCP is effective. BALM Duco lacquer is also slightly susceptible to mould attack.

Varnishes: Matt-pigmented oil varnish black DTD 34, air-dried or stoved at 120 degrees C. for 4 hours and containing PCP Merthiosol and castor oil distillate, were tested. It was found that: 1- stove-drying does not give satisfactory results, and 2- matt-pigmented oil varnish (air-dried) with PCP (3-0 per cent) is effective. Other treatments were unsatisfactory.

Luting, waxes and greases: Incorporation of PCP (1.0 per cent) in these

materials conferred resistance to mould attack.

Paints: Silicone paint aluminium (air-dried) and silicone paint yellow type (stoved) were found to be susceptible to mildew attack.

Protective coatings: Experiments were carried out to find out suitable methods by which protective coatings can be obtained by chemical or electrolytic action on brass and aluminium. For brass, two methods were adopted successfully. In the first method, the blackening was carried out by immersion of polished brass in a cuprammonium bath containing copper carbonate and ammonium chloride and treated with 0.2 per cent PCP, while the second method involved anodic oxidation of brass in a caustic soda bath and treatment with 0.2 per cent PCP. In the case of aluminium, the blackening was carried out by anodizing the aluminium and then dyeing it with organic black dyes / black inorganic pigment. The panels were treated with 0.2 and 0.4 per cent PCP.

The blackened brass and aluminium pieces were subjected to fungal growth test. The results indicated that the above protective coatings are effective against fungal growth. Matt finish is also adequately protective as compared to that produced by BALM Duco lacquer containing Merthiosol.

Confirmatory trials based on the above findings were made with aluminium tubes. The tubes were anodized, dyed and then treated with PCP in the same bath. The dye concentration was 1.0 per cent and that of PCP 0.2 or 0.5 per cent. These were also found resistant to fungal attack. These results indicate that the application of a protective coating with a fungicide can provide satisfactory protection against fungal attack. In the absence of indigenous production of synthetic resins, coating with the fungicides by chemical or electrolytic methods seems to be the best solution of the problem. Another advantage of coating the surface in this manner would be that by eliminating solvents, the residual solvent effect in producing fogging is overcome.

Acknowledgement

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2.23 Growth of fungus on lenses.

Fungal growth on optical components in the tropics has been a problem for many years, and there is no evidence that any of the thin film coatings are a deterrent to the mycelia attacking the glass. Attempts to clean glass surfaces after they have been contaminated by mould will fail, as the glass itself will have been damaged, and prevention of the mould growth is the only effective cure to the problem. The damage to the glass surface usually takes the form of a general 'greyness' so that the light passing through is diffusely scattered. This leads to a reduction of contrast and 'veiling glare' and if the surface lies on a graticule in the focal plane of an eyepiece system the damage becomes very noticeable.

Even if the air inside instruments is desiccated immediately after initial cleaning and assembly, and then sealed in a suitable package, deterioration often occurs. The main causes of deterioration, in addition to fungus growth, are attacks by water vapour and from the vapours of lubricants and optical cements used in the instrument.

Under tropical conditions once a certain level of internal humidity has been reached the daily range of ambient temperature may cause alternate condensation and evaporation of water on the surface of the glass. The material dissolved out of the surface is precipitated during evaporation and forms an alkaline solution on the following condensation which further hastens the attack.

Where volatile machining fluids have been used during manufacture 'filming' may

occur unless the instrument parts have been very carefully cleaned before assembly, and subsequently desiccated in a vacuum.

The natural grease of the hands may be found in polishing cloths which have not been chemically cleaned and can cause 'films' to form on glass surfaces.

Certain types of brass which are often used in graticule or lens mounts may contain free lead, which is readily soluble in water, and can creep or diffuse from adjacent metal surfaces on to the surface of the glass and cause deterioration under variable temperature conditions.

Most fungal damage arises during storage, and silica-gel bags will reduce the ambient humidity and so make attack less likely. Sealing of the optical parts is usually impossible owing to the need to maintain relative movements of parts for focusing or rotation, as in theodolites or other surveying instruments.

If photographic lenses can be sealed, a clear metal lacquer containing 5% salicylanalide (based on non-volatile content) can be used as a fungicide sealant.

The general approach is to introduce a fungicide which is relatively non-volatile but still adequately lethal. Phenylmercuric acetate and Merthiosal (MTS) are used with some success. All fungicides at present in use:

(a) Are toxic to humans.
(b) Cause condensation on glass surfaces.
(c) Have a deleterious effect on optical cements.
(d) Tend to produce dermatitis.
(e) Corrode metal parts, particularly aluminium alloys.

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Yoder, Paul. Opto-Mechanical Systems Design. N.Y.: Marcel Dekker, 1993. p.60-62. Fungus

When glass components in optical instruments such as telescopes, binoculars, cameras, and microscopes are exposed for long periods to warmth and high humidity, films and localized deposits of mold may develop. Particularly troublesome in tropical climates, these organic contaminants degrade performance by introducing scatter at early stages of development (Rodionova et al., 1972); later they may permanently damage optical surfaces by etching patterns into the material.

Baker (1969) provided a bibliography of 51 articles and papers published between 1941 and 1969 on the general subject of "tropic proofing" optical instruments.

Mold fungi have been found to germinate and grow on glass surfaces even though the surfaces had been thoroughly cleaned to remove fingerprints, dust particles, and lubricants (Theden and Kerner-Gang, 1965). The microscopic spores are ubiquitous and seem to be able to supply sufficient nutrients internally to support limited growth. Some glasses with high resistance to climate and acid seem to resist fungus as well. Others (such as KzFS4) seem to impede mold growth, at least at high humidity levels, although they are otherwise susceptible to climatic and acid conditions. This contradictory behavior indicates that the chemical composition of the glass plays a role in mold susceptibility.

Sprouse and Lawson (1974) reported evidence from tests conducted in the tropics (Panama Canal region) to the effect that natural organic compounds condensed on surfaces of glass and steel could serve as nutrient sources for fungal growth. It was thought that, in the tropics, organic compounds (hydrocarbons) could come from vegetation effluents. Monoterpenes (empirical formula C10 H16) previously thought to play a role in tropical fungal accumulation were not found in any significant quantity in the tropical atmosphere sampled. An aliphatic ester common to certain tropical grasses was found to be present in significant quantity in that atmosphere.

Baker (1967) evaluated some fungicides as mold preventive agents on optics. Later, he described possible adverse effects of two fungicides (Baker, 1968). Baigozhin et al. (1977) reported experiments with some chemically unstable optical glasses that had been protected by fungicidal coatings that did not alter the glasses optical properties. Optics protected with silicone films containing arsenic, mercury, or tin resisted fungus tests for 3 to 4 months, whereas unprotected optics of the same glasses were overgrown with fungus within 1 month of the same test.

Harris and Towch (1989) described a series of environmental tests conducted on several types of infrared windows intended for use in FLIR systems. They included mold growth in this program, expecting to find the materials to be impervious to this damage hazard. After 28 days, the test results indicated that a zinc sulfide sample had lost most of its rain-resistant coating while a monocrystalline germanium window showed coating damage. Transmission losses for these samples exceeded what would be expected if the coatings were completely removed. Similar control samples did not incur any damage or transmission loss so the degradation was attributed to the effects of mold.

Baker, P.W. An Evaluation of Some fungicides for Optical Instruments. Int. Biodeterioration Bull. 3:59, 1967.

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Theden, G. & W. Kerner-Gang. Results of Investigations on the Contamination of Optical Glass by Fungi. (Glastec. Ber. 37:200, 1964). Translation, U.S. Defense Documentation Ctr., Document AD458907, 1965.
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"In Canada, mycologists of the Division of Botany of Agriculture developed 'Tropic proofing for war equipment', especially methods of preventing etching of the optics of binoculars and riflescopes. (D.B.O. Saville ex W.L. Minshall, personal communication, 16 July 1992)"

"In Australia, several organizations paid attention to problems of tropical deterioration affecting optical equipment. (1: Report on Tropic Proofing of Optical Instruments. Optical Munitions Panel Paper No. 22-W, 26 Nov. 1943; Australia: ministry of Munitions, 1943. 2: Tropic Proofing Specifications Committee No. 4, Organic Materials; 2nd meeting of InterService Committee No. 4, 13 Dec. 1943; Australian Scientific Liaison Bureau, Melbourne. 3: Tropic Proofing Progress Report No. 2 for the period 29 Oct. to 31 Dec. 1943; Council for Scientific and Industrial Research, National Standards Laboratory Electrotechnology Section, Australia.)"

"Dr. B.J. Grieve was involved in research relating to fungal contamination of field glasses in New Guinea. (W.A. Lonergan, personal communication, 21 June 1992)"

--page100. Howard, Richard. The Role of Botanists During World War II in the Pacific Theatre. pp83-118. Macleod, Roy, ed. Science and the Pacific War: science and survival in the Pacific 1939-1945. Dordrecht: Kluwer, 2000.
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Notes on fungus from military, commercial, camera, & optical sources.

War Department Technical Manual TM 9-1580; Binoculars M3, M7, M8, M9, M13, M13A1, M15, M15A1, M16, M17 and M17A1 and BC Telescope M65. 1953. (284p) p246. To fungus proof the battery commander's telescope M65, fungicidal capsules were sealed in the instrument. However, the active element not only kills fungus but also speeds corrosion of metal and softens optical cements.

(Note: Antifungal capsules should be removed when they are found during disassembly? This damage has not been reported by modern repairmen.)

MIL-STD-810E Method 508.4 Fungus. Defines testing of optics' ability to withstand fungus.
MIL-STD 810F Method 508.5 Fungus.
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Fungus Testing http://www.ntscorp.com/scripts/test/test320.html?tstcat=104
National Technical Systems fungus testing...To a greater or lesser degree, growing fungus will use wood, paper, leather, hydrocarbons, PVC, polyurethanes, certain plastics, certain paints and other materials as fuel. Live fungus can get under protective covers and mar the appearance or degrade optical capabilities of your product. Metabolic waste products from fungus cause corrosion.
The fungus test is an accelerated environmental test; therefore, the temperature and moisture conditions are specified to support rapid growth of fungi and accelerated deterioration of materials. NTS examines the following conditions.
--Do the materials support fungal growth
--How rapidly will fungus grow on the material
--How will the fungus affect the material, its mission and performance
--Is there a reversal process – can the fungus be removed?
Standard testing takes from 28 to 84 days....we are able to employ both US and European fungus groups.
NTS works to all the standard specifications such as Telcordia; MIL-STD-202, 810; ASTM D 120, D 470, D 518, D 1049, G21, 22, 29; Fed. Test Method Standard No. 191; RTCA/DO-160 as well as D2020-92 (1999) Standard Test Methods for Mildew (Fungus) Resistance of Paper and Paperboard as well as any custom fungus test you may require.
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--Good quality lenses are assembled in 'clean rooms' where the air is micro-filtered. Opening up a lens introduces more fungus spores
--Alcohols are ineffective compared to dilute solutions of ammonia (Windex).....a 50/50 mixture of hydrogen peroxide and household ammonia....(question of whether it removes fungus, or if ammonia-peroxide mixture is in essence a good glass cleaner, rather than a fungicide).....fungus killing formula among painters and gardeners: Mix 1 gallon water with 1 pint Clorox and 2 oz. liquid detergent.....soak the parts in bleach or a commercial fungicide like tilex.....vinegar, household strength or stronger acetic acid, is described as effective in cleaning fungus if it is 'caught early'.
--real fungicides are hard to find and are all very toxic to humans. Ammonia or bleach is only modestly effective, as anyone who has dealt with fungus growth in a shower knows.
--Thymol crystals in a Dish, in an airtight Box, with the Item...Thymol is very dangerous to Humans.....Leave for a few days, or a week.....Works well for Albums, Prints, old negs and Slides..... Thymol Crystals from most scientific chemical supply co.
--soaking the glass (not the metal!) in baths of a hydrogen peroxide-household ammonia mixture, 50/50.
--high-intensity UV, a sunlamp, or even strong sunlight, these methods have mixed success; modern lenses cemented with UV curing cements will absorb UV.
--negative ion generator (also known as ionizer) is the only sure fire way to prevent mold
--alchohol to clean fungus off the glass.....the interior of the scope washed down with a dilute solution of Chlorox (sodium hypochlorate) to kill all the mold spores.
--periodically "gas" the components using formaldehyde gas. For example, remove the optics, place in a zip-lock bag with some formalin (38% formaldehyde)....formaldehyde may affect some components inside the lenses.
--enclose a teaspoon of paraformaldehyde powder in a small paper bag within the microscope case....protects the microscope for a year or two and apparently has no ill effect on lenses and the mechanical parts.
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Storage:
--a heated storage box....put several silica gel packets in the sealed box....Drie-rite (CaSO4) can be corrosive.
--Parafilm wrapped around the lid of any old jar will keep indicator desiccant blue for years.
--Tupperware brand is the best at sealing out humidity of all the commercial sealable food storage containers.
--add N2 gas before sealing.
--do not store in leather or wood cases, which often promote fungus growth; store in open air rather than any kind of case
--isolate lenses with fungus, don't store with uncontaminated glass.

Sources include: http://www.smu.edu/~rmonagha/bronfaults.html
http://www.smu.edu/~rmonagha/mf/fungus.html

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home page: http://home.europa.com/~telscope/binotele.htm