reproduced from the plate accompanying Mr. R. V. Subramanyam s paper on benzil. In the case of aromatic compounds, the infra-red vibrations with which we are principally concerned are those of relatively low frequency involving rotational or translational movements of the aromatic rings. It is evident that the crystal planes parallel to the aromatic rings would be strongly affected by such movements and would therefore give intense quantum reflections, while the lattice planes parallel to the rings would be unaffected by such movements and would therefore fail to give the quantum reflections. This indication of theory is strikingly confirmed by observation. Indeed in the case of benzil, the intense quantum reflections observed immediately indicate the number, orientation and azimuth of the benzil molecules present in each lattice cell.

CAMOUFLAGE PAINTS

BY

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SINCE the World War of 1914–18 the word camouflage, originally a French word, has been adopted throughout the world to denote a particular type of military deception in which paints and artists play the major role. In the unrestricted sense the word may be applied to any device which is calculated to mislead the enemy. Such general camouflage has been practised by belligerent nations throughout history. The Wooden Horse of Troy, the Moving Forest in Shakespeare's Macbeth and the incalculable Shivaji's escape in a basket of sweetmeat under the very nose of Aurangzeb are some of the popular examples of camouflage in the general sense. Napoleon is known to have made extensive use of camouflage in his campaigns, and it will be readily understood that in war, in which everything is considered to be fair, military deception must occur to generals and soldiers alike as almost a first principle.

As in all great things, man learnt the broad principles of this art of military camouflage from nature. She is the effortless master camoufleur who resorts to camouflage in order to preserve her species. Examples of nature's camouflage extend from the tropical vegetation, through the desert sand, to the bare winter twigs of the temperate zone and the snows of the Polar regions, and these are too many and well known to mention. The principle followed by nature is to produce species which in colour and form are more or less indistinguishable from their surroundings in order to avoid easy detection by enemies. Much of the military camouflage follows exactly the same principle. Gun positions, machine gun emplacements, observation posts, aerodromes, industrial buildings and large installations have to elude detection by the searching eye of the enemy from the air, and the means is camouflage which renders them indistinguishable from the general surroundings. Ships have to mislead submarine commanders as to their exact course, and "dazzle painting"—a form of camouflage in paints—was one of the devices adopted during the last Great War. Even the colours of the field uniforms are a form of camouflage.

Camouflage as an established military and naval practice originated during the Great War of 1914–18. The French gave the lead and the British and the other belligerent nations followed and developed the principle and practice rapidly in all possible spheres. As the aerial eye became ubiquitous and the aerial attack the most potent form of warfare, the necessity for reasonably effective camouflage became one of the fundamental concerns of Governments and fighting forces.

In this article it is proposed to deal with the technical aspects of camouflage paints which are being used in colossal quantities in all belligerent countries. Extensive demands have arisen in this country and paint manufacturers in India are being required to supply large quantities at short notice. These demands are likely to increase as the war situation develops in the Middle and

Far East. Although the special characteristics of camouflage paints were generally known, the paint manufacturers in India were not actually concerned in their manufacture until the war demands arose.

Whereas camouflage painting started as an art, both paints and schemes of painting are now based on definite scientific principles. The effective application of these scientific principles in devising schemes of painting requires the services of biologists, psychologists, artists and service men who have made a special study of the subject of camouflage. Schemes considered satisfactory during 1914–18 have in many instances been shown to be ineffective under the conditions of the present war, and last year *Nature* published strong criticisms of many of the camouflage efforts in England and attributed the unsatisfactory state of affairs to Government's failure to utilise the services of trained biologists and psychologists. Indeed, the camouflage problems under the present conditions of warfare have become highly complicated, and reasonable success can only be expected if the services of biologists and psychologists as well as of artists and service men are harnessed to the work. It is obvious that an intimate knowledge of natural and physical sciences alone can result in forming perfect camouflage effect. By the aid of infra-red photography it is possible to distinguish between opaque mineral colours and organic pigments transparent to these radiations. A reconnoitring aeroplane with a photographer provided with infra-red ray photographic equipment can thus easily detect camouflage in mineral colours against the natural backgrounds of trees, foliage, flowers, etc. It is possible to devise ways and means which will obviate this drawback, but the financial aspect has to be taken into account.

The colours of camouflage paints have been standardised, and as used in the British Empire, these now number seventeen. The colours are all dull and range from different shades of dull brown and red, through dull greys and greens, to black.

One of the most important characteristics of camouflage paints is that they shall dry to a perfectly matt surface. Even a trace of gloss on a painted surface will cause sufficient reflection of light to make objects look prominent from the air. At no angle of observation must there be the slightest suggestion of reflection, and this property must be maintained when the surface becomes wet by rain or dew. The question of fastness of colour is also a very important one, since premature fading may so alter the colour scheme as to render camouflage completely ineffective. This consideration imposes a definite restriction as to the range of pigments that can be used in the camouflage paints. Camouflage is not concerned with the protection of structures from the effects of atmospheric conditions and in that sense durability of the paint is not of importance. On the other hand, from the camouflage point of view a reasonable degree of durability is necessary, and this point has to be borne in mind particularly because the average matt paint shows poor durability when used for outside work. The formulation should, therefore, aim at combining perfect mattness with adequate durability.

In the evolution of camouflage paints many different possibilities, such as flat oil paints, oil-bound distempers, bitumen emulsion paints, wax paints, lanoline emulsion paints, silicate paints and cement paints, were investigated. Of these, three types that have been accepted as standards are flat oil paints, oil-bound distempers and bitumen emulsion paints. In India developments so far have been in the direction of flat oil paints, but the possibilities of bitumen emulsion paints are being investigated.

Camouflage paints are made in both gritty and non-gritty forms. The former is specially suitable for roofs and dries with an uneven surface which counteracts any tendency on the part of rain or dew deposition to reflect light. It is obtained by adding a suitable proportion of a coarse extender to the general formulation for the non-gritty paint. The proportions may be 50 lbs. of the coarse extender to 100 lbs. of non-gritty paint with an allowance for additional medium to ensure correct consistency. The gritty material must be non-reflective, and among those considered to be suitable for the purpose may be mentioned silica, slate powder and pumice powder passing through 40 mesh but retained on 80.

Of the possible white base pigments available for the formulation of camouflage paints, lithopone is acknowledged to be the most suitable, although in ordinary paint

practice lithopone is rarely used for exterior work. The other white pigments, such as zinc oxide, white lead, titanium dioxide, etc., show certain disadvantages, but so far as India is concerned, the supremacy of lithopone is substantially compromised by the fact that this pigment is not manufactured in the country and there has for some time been a definite shortage of the material in the Indian paint industry. Zinc oxide, on the other hand, is manufactured in India, and although owing to the limited capacity of the only one existing factory and difficulties of obtaining the metal, the issue of this pigment is being controlled during the war, it is available against Government orders for paints and consequently available for making camouflage paints. It is to be presumed, therefore, that much of the recent efforts at making camouflage paints in this country has been on the basis of zinc oxide, and unless adequate facilities can be given by Government for continued importation of lithopone, zinc oxide may have to be invariably used by paint firms in India in place of lithopone.

The only red pigments permitted in camouflage paints is red oxide of iron—natural or manufactured—and red ochres. The use of organic dyestuffs is prohibited. The yellow pigments are confined to yellow ochres and chemically prepared hydrated oxides of iron. Lead chromes, zinc chromes and organic yellow colours are prohibited. Different shades of natural and synthetic oxides and hydroxides of iron can be mixed in any proportions to obtain the desired effect. Red oxides and yellow ochres are abundantly available in India.

The most suitable green pigments for camouflage paints are chromium oxide and pigment green B, which is an insoluble dyestuff. These are not ordinarily available in India, and paint manufacturers have presumably to resort to mixtures of Prussian blue and yellow ochre or of ultramarine blue and yellow ochre. These mixtures have limitations from the camouflage point of view but are unavoidable under the present conditions.

Raw and burnt umbers can safely be used for tinting purposes. The permissible black pigments include black oxide of iron, mineral black, carbon black and lamp black. The umbers and various black pigments are stocked by paint manufacturers in India.

Apart from whiting and gypsum which are not favoured for camouflage paints, the majority of the usual extenders are considered suitable. Owing to their flatting properties, barytes and silica are largely used in these paints, and possibly the paint manufacturers in India rely mainly on barytes. China clay, French chalk, asbestine and bentonite may be used in small quantities with advantage, as these reduce the setting tendency of pigments. Owing to the fact that a considerable time may elapse between supply and use and in view of the unusual conditions under which these paints may have to be used, it is very important that manufacturers' formulations should provide adequately against the hard settling of pigment. The tendency to settle may also be checked by using heavy-body litho oil in the medium or by using a small amount of a dispersing agent, such as aluminium stearate or aluminium palmitate.

As an illustration of the composition employed, a few representative formulæ employed in trade are given below:

1. Lighter Colours

Pigment	70%
Non-volatile medium ..	10%
Volatile thinner ..	20%
Composition of pigment:	
Zinc oxide or lithopone ..	30%
Tinters	10%
Extenders and argillaceous matter	60%

2. Deeper Colours

Pigment	70%
Non-volatile medium ..	10%
Volatile thinner ..	20%
Composition of pigment:	
Zinc oxide or lithopone ..	20%
Tinters	20%
Extenders and argillaceous matter	60%

3. Red Oxide Colours

Pigment	75%
Non-volatile medium ..	10%
Volatile thinner ..	15%
Composition of pigment:	
Red oxide with other tinters if necessary	66%
Extenders and argillaceous matter	34%

There are many ways open to manufacturers to secure a perfectly matt surface in paints, and the principles involved are well known to them, since the production of matt paints for interior decoration is a common necessity even under ordinary conditions. The same principles are applied with suitable modifications to the manufacture of camouflage paints, but as already mentioned, a certain standard of durability under outdoor conditions, which is not necessary in ordinary matt paints intended for interior use, has to be ensured. A matt surface in a paint is governed by several factors which include the following:

Character and proportion of non-volatile medium.

Proportion of solvent.

Character and proportion of pigment.

A high pigment content is unavoidable in camouflage paints. Some pigments are more useful in producing a matt surface than others. In the case of flat oil paints which represent the camouflage paints made in this country, the non-volatile medium consists of linseed oil and/or certain types of varnishes, and the thinner is usually white spirit.

It has been mentioned earlier that oil-bound distempers can be used for camouflage purposes, although it is doubtful whether any of the paint firms in India has offered this type of material against demands for camouflage paints. Oil-bound distempers are essentially pigmented oil-in-water emulsion with glue or casein, or a mixture of the two added to the composition. The same restrictions regarding the choice of pigments as have been mentioned above apply to oil-bound distempers intended for camouflage purposes. The oily portion generally consists of a suitable linseed oil varnish containing natural or synthetic resin.

Bitumen emulsion paints for camouflage purposes are an extension of the principle underlying the production of bitumen emulsion as a road dressing material. Bitumen and water together with emulsifying and stabilising agents are the sole ingredients of bitumen emulsion. In bitumen emulsion paints, the proportion of bitumen has of necessity to be comparatively small, since the colour of the added pigments should not be materially affected. As these paints are also required in the standard camouflage shades, the formulation of pigments is generally similar to that adopted in the case of flat oil paints. Bitumen emulsion paints are particularly useful for asphalted surfaces, such as roads and bitumen roofing, as oil paints are not practicable on such surfaces owing to the bleeding effect. These paints are also supplied in gritty and non-gritty types. Attempts are being made to develop this type of camouflage paints in India, but it is unlikely that any large supply has actually been made yet.

From the foregoing description of the composition and characteristics of camouflage flat oil paints, it is clear that tests should be of a thorough character and must include the following points:

1. Complete chemical analysis to show the proportions of pigment, non-volatile medium and thinner and the detailed composition of pigment.
2. Physical tests to ascertain the time of drying, and nature of film on steel, concrete, wood, etc. (finish, hardness, opacity, complete freedom from gloss at all angles, etc.).
3. Fadeometer test to ascertain the fastness of colour.
4. Accelerated weathering test to ascertain the durability of paint.
5. Storage test to ascertain the keeping property of paint.

The expenditure involved in camouflage paints is very large indeed, and the effects of using unsuitable paints can be disastrous. It is, therefore, of the utmost importance to both suppliers and consumers that due care is taken in matters of manufacture and test.