tolerances for the figures which describe a lamp of any particular class.

Some preliminary results were described by Crawford on the basis of a division of the spectrum into six bands. As the tolerance for any one band was of the order of 50 per cent, it is clear that any considerably larger number of bands would be futile from the point of view of colour rendering. These six bands are not regarded as a final choice: further work should enable them to be modified so as to give each one an approximately equal weight in, say, the assessment of mean daylight. But there are certain features which any system of bands should have if it is to be acceptable from the colour-rendering aspect, namely, divisions where blue changes to green and green to red, giving three fundamental bands, and equal subdivision of these three, so that the final number of bands would be three, six or nine. Considerable importance has been attached in the past to avoiding coincidence between mercury lines and divisions between bands; but this can be easily attained by very small wave-length shifts once the bands most suitable for colour-rendering specification have been determined. B. H. CRAWFORD

SPOILAGE OF INDUSTRIAL MATERIALS BY MICRO-ORGANISMS

A VAST amount of spoilage of the perishable materials fabricated or harvested and used or stored by man is brought about by micro-organisms. Incalculable losses are incurred by the rotting of textile fabrics and paper, the making unpalatable of food and feeding-stuff and the decay of wooden structures, quite apart from the less vital but none the less economically important 'mildewing' of these and other organic materials. These matters were discussed at the autumn meeting of the Society for Applied Bacteriology, which was held in London at the Royal Society for Tropical Medicine and Hygiene on October 20, 1953, and which took the form of a symposium on "Microbial Spoilage in Industrial Materials".

In an introduction to the symposium, Dr. T. Richards (Reading) pointed out that the spoilage organisms belong almost entirely to the two groups, bacteria and moulds. Their deleterious effect is due to actual destruction of the material as in rotting, or to the development of unsightly microbial growths, or the production of toxic or offensive metabolic products. Dr. Richards surveyed the principles governing the growth of micro-organisms, since a knowledge of these provides a means of restricting microbial proliferation and consequent spoilage.

Only materials having an available carbon source together with a nitrogenous and mineral salts supply are susceptible to spoilage. Atmospheric ammonia can supply available nitrogen to an otherwise nitrogen-free material. Limiting the supply of nitrogen or mineral salts exercises a marked preservative effect in carbohydrate materials.

Control of moisture offers the most widely applicable means of restricting microbial growth. Atmospheric humidity is the critical factor, and to limit mould growth for storage periods of several years the relative humidity of the storage atmosphere must be less than 65 per cent, although at 72–73 per cent no mould growth may be noted for several months. The same concept of relative humidity is useful in assessing the preservative value of strong solutions of sugar or salt. In solutions the vapour pressure of which can be equilibrated with relative humidities of about 72 per cent, yeast growth and mould growth are inhibited. Many moulds are inhibited at humidities less than 90 per cent, and, apart from micrococci and possibly *Pseudomonas*, bacteria seem to require conditions approaching actual wetness.

Hydrogen ion concentration is a factor of importance in preventing spoilage, especially in combination with anaerobiosis, although these applications are of necessity largely confined to food and fodder. Bacteria are all inhibited at about *p*H 4, save for a few aerobes, and in the absence of air these and all aciduric moulds cannot grow. Yeasts can only proliferate in the limited cases where there is a fermentable carbohydrate.

Low temperatures are of much greater general application in preventing microbial spoilage. 'Chilling' processes, from 0° C. to about 6° C., are successful over short storage periods and with lightly infected material, although preservation over an indefinite period is possible at the −20° C. or so of modern deep-freeze technique. Lack of oxygen, already mentioned, has no preservative effect *per se*, but in acid or low-moisture conditions it becomes a decisive factor in the inhibition of aciduric and xerophilic moulds.

Much could be said concerning the use of specific antimicrobial agents, antiseptics, fungistatics, etc.; but rightly these should be depended upon only when the fundamental necessities of microbial growth cannot be eliminated. In general, where deep refrigeration is impossible, impracticable or uneconomic, one must rely on low *p*H and anaerobiosis, or upon storage in an atmosphere of low relative humidity. Failing these, resort must be made to antiseptic substances, but this is advisedly a last resort: there is no ideal antiseptic, no rules govern their use, their mode of action is obscure, and in many cases tolerance is readily acquired. Some such agents have been successfully used, and examples were given in the symposium by ensuing speakers.

The problems of wood spoilage were dealt with by Mr. J. G. Savory (Princes Risborough), who emphasized the huge bill of damage caused by one species of wood-rotting fungus alone—the true 'dry-rot'. Quite apart from the structural damage due to rotting, much spoilage arises from the fungal discolorations. The so-called 'blue-stain fungi', all Ascomycetes or Fungi Imperfecti, have brown mycelium but stain the wood blue or grey. These organisms do not attack cellulose or lignin, but utilize the starches and sugars in the sapwood.

Basidiomycetes cause the brown and the white rots of timber. Brown rot fungi attack the wood cellulose leaving the lignin, and as the attacked wood dries out the characteristic cubical fracture is seen. The white rot fungi have an oxidase system and attack both lignin and cellulose, leaving the wood after attack with a white fibrous appearance. In the case of brown rots, extracellular enzymes are responsible for much of the decay, and much structural weakening may have occurred at a stage where there is little visual attack.

Originally, bacteria were thought to attack only chemically de-lignified wood, but Virtanen's work from 1928 onwards has shown that thermophilic bacteria will ferment fine sawdust, and in 1951 American workers showed that even coarse sawdust can be fermented by bacteria with a nitrogenous supplement such as peptone or ammonium phosphate. Bacterial attack on solid wood probably occurs only in really damp conditions. Attacked wood shows dull discolorations and is weakened; minute pits and perforations are formed in the walls.

In addition to stain spoilage, microfungi are also responsible for soft rot. This occurs in marine piles and in water-cooling towers, but it is of importance only occasionally in timbers above the ground. Generally there is a soft dark-coloured surface zone of decayed wood which scrapes away easily and shrinks and cracks and takes on a typical brown 'charred' appearance when the wood dries out. In the rotted layer fungal hyphæ can be seen within the secondary cell wall. Species of *Chaetomium*, *Stysanus* and *Trichurus* can cause this type of decay, which is normally of importance in those situations not suitable for wood-destroying Basidiomycetes. Wood submerged in water provides too low an oxygen concentration for Basidiomycetes, while the soft-rot fungi are more tolerant of these conditions. The latter are also more resistant to preservative and sometimes occur in wood proofed against decay.

Laboratory experiments with *Chaetomium globosum* illustrate the need of spoilage organisms for mineral and nitrogenous nutrients. In the absence of mineral salt mixture, experimental decay of wood blocks is slow, but when it is provided extensive rotting occurs at a rate equivalent to that of Basidiomycetes. Chemical evidence suggests that *C. globosum* decomposes cellulose but is unable to attack lignin.

Mr. L. D. Galloway (London) spoke about microbial spoiling of paint surfaces. The problem is not serious in the climates associated with the British Isles, being confined chiefly to damp walls, surfaces liable to condensation, such as laundries and greenhouses, and to splashing with nutrients as in breweries, cheese rooms, etc. Mould-resistant paints are in much greater demand in damp tropical climates.

The problem is essentially one of giving the paint a definite resistance to mildew. A film of several coats of paint (primer, undercoat and finisher) will not provide nutrient enough to support visible growths of mildew: glass or metal surfaces painted in such a way rarely become mouldy. Visible mildew in almost all cases arises from the wood, plaster or paper substratum supporting the paint film, or from surface contamination with nutrients. Since a paint coating plays a passive part, mildew spoilage usually implies that the unpainted support will become mouldy in damp conditions. In accord with theory, it is found that there must be atmospheric moisture greater than a minimum relative humidity and opportunity for infection. Latent infection in the substratum is probably of greater significance than external growth penetrating the paint film, and sterilization of the surface by heat or formalin before painting is advantageous. The nature of the paint film, its hardness, permeability to moisture, content of mould inhibitors (for example, zinc oxide), added preservatives or inhibitors liberated in the film on ageing are important factors in the formulation of the paint itself.

Among the commonest moulds on paint in Britain are the penicillia and the dark-coloured *Cladosporium herbarum* and *Pullularia pullulans*. These latter are less easily brushed off, since the pigment is in the mycelium, and they are also more resistant to ultra-violet light.

Mr. Galloway made a plea for work towards a standard rapid proving test for mould resistance of paints. He surveyed most of the existing tests, including panel, patch and laboratory tests. In the outdoor panel test exposure, paint films should be as far as possible on standard panels of wood, in an atmosphere of high relative humidity, with protection from insect and other contamination. Patch tests are made on a potentially mouldy surface such as a cellar wall, and the paint must be compared with other paints and not with the untreated wall. In any case, the result has only local significance. Of various accelerated laboratory tests with filter paper, agar, wood pulp mats, plaster and wood blocks, the last is probably most suitable. Small blocks of pine sapwood, with their surfaces pre-coated with a thin layer of malt gelatin, are painted as required and hung in an atmosphere of 100 per cent relative humidity for a month. The natural fungi (mainly penicillia) always become dominant and obviate the need for inoculation. Although reproducibility in a test is a highly desirable property of a laboratory test, good correlation with behaviour in practice is far more important, and in this way the wood block test is possibly most successful.

The very large field of textile materials was dealt with by Dr. R. Burgess (Manchester), who pointed out that natural fibres are very readily decomposed under suitable conditions of nutrients, moisture and warmth, although artificial fibres like glass and nylon are very resistant to attack. Damage to natural fibres can occur at all stages of processing and storage, and results in the actual breakdown of the structure (tendering) or in discoloration and smell (mildew), which in turn often leads to unevenness in dyeing. In cotton, the cell wall of the fibre is attacked, but in jute, hemp and animal fibres the cementing material is first dissolved, leading to fraying and an increased surface area for attack. Except in soil burial, final breakdown of cellular elements of wool is rare.

The various factors outlined in Dr. Richards's introduction are well exemplified in microbial attack on textiles. The raw fibres contain a complete range of nutrients and are most readily attacked. Since processing removes a great deal of nutrient, there is increased resistance to spoilage, but the addition of farinaceous and gelatinous dressings considerably reduces resistance, and goods contaminated with nutrients are very susceptible. Trouble is most prevalent in warm weather, and tropical climates with a humidity greater than 75–90 per cent result in very rapid growth of moulds. The structure of the fibre is significant: light soft fabrics deteriorate more rapidly than heavy hard-twisted yarns. Increased susceptibility is caused by mechanical damage, abrasion, weathering and sunlight, as well as by chemical deterioration of the fibres.

Of the natural fibres, cotton is most easily attacked and mildews most readily as unbleached cloth. A long list of moulds is responsible, and as many as half of these can cause tendering by cellulose attack. Fungal breakdown is commonest in damp aerobic conditions, while bacteria will rot anaerobic wet fibres like fishing nets. In flax the fibres, being unlignified, are prone to attack but lack nutrients through earlier microbial processing, so that in fact linen suffers less than cotton. Jute and hemp have inherently greater immunity through their lignin content and suffer attack only at humidities greater than 85 per cent. Most rayons (regenerated cellulose) lack nutrients and show some resistance, while cellulose acetate 'silk' is largely unaffected by micro-organisms.

Animal fibres are less liable to attack than cotton; but even so, large losses may occur in warm weather, and again prevailing humidity is the key factor. Wool withstands greater humidity than cotton, and scoured wool only mildews at about 94 per cent relative humidity (about 19 per cent moisture content by weight). Woollen fabrics kept wet, like bathing costumes and paper-makers' felts, suffer bacterial attack, largely by spore-forming rods. Soaps and alkali aid microbial action by providing available fatty-acid and hydrolysed protein, and of paramount importance is the soluble nitrogenous matter. Horse, calf, pig and human hairs offer great resistance, but camel hair, which is fine and soft, is very susceptible. Silk is more resistant than wool, degummed thoroughly-washed silk being similar to regenerated cellulose rayons.

Methods of control of spoilage depend upon whether the need is short-term mildew-proofing during processing and storage or the more persistent powerful action required in rot-proofing. Control of mildewing can be made easier by the adoption in the industry of lower moisture-regain standards, together with reducing mildew capacity by thorough scouring and avoidance of farinaceous sizing materials; and the inclusion of a silica gel or similar desiccant in shipping consignments can be of value. Mildew-proofing by added fungistatic substances is effective, and salicyl anilide alone or paired with silico-fluoride, *p*-nitro-phenol, mercaptobenzthiazole, or acetanilide has excellent proofing qualities. Rot-proofing is a much greater problem in that a substance specific against a wide range of micro-organisms must be used, and this material must be insoluble and stable enough to withstand sun, weather, wetting and drying over long periods. Dr. Burgess dealt critically with the use of many materials for proofing both cotton and wool.

The testing of mildew-proofing of fibres and fabrics is best accomplished by field-trials, but accelerated laboratory tests are useful in which the material after inoculation with test cultures is held at warm-room temperature at humidities of 87–100 per cent and assessed by visual inspection. Rot-proofing tests require pure culture inoculation or soil burial followed by tests of mechanical strength.

The factor mainly relied on in the prevention of spoilage of paper and paperboard is the use of fungistatic materials. Mr. E. Howard (Kenley), who dealt with this subject, pointed out that paper and, to a much greater extent, paperboard are impure cellulosic materials often containing, in addition, rosin, wax, starch, gelatin and many other organic and inorganic substances in varying amounts. Storage conditions of these wrapping and packing materials frequently involve warmth and high humidities, often from their contents, so that frequent loss of strength by rotting and disfigurement by mildewing are not surprising. The only reliable way of preventing losses is to use an effective fungistatic substance, incorporating it either in the paper pulp or impregnating the paper web with it before drying, of which the first is probably more suitable. Mr. Howard listed the qualities desirable in a fungistatic, among the most important of which are a 'biologically active' persistence and ease of incorporation with the pulp stock, having no harmful effect upon the manufacturing process nor any hazards to personnel during manufacture or in later use. The material must not prevent the disposal of paper-mill effluent, should not impart any undesirable property to the product, and must provide protection at an economic price.

Copper and zinc naphthenates are effective, but give a dark, greasy product with an unpleasant smell and an ability to stain contiguous material. Sodium pentachlorophenate has been widely used, but is steam-volatile and partly lost in the drying section of the making process, besides giving a phenolic odour to the product. 2.2-Methylene *bis* (4-chlorophenol) is an excellent relatively non-toxic preservative, not affecting colour or feel. The very effective organic-mercurial compounds are very poisonous and raise the matter of toxic hazards in the industry. However, one of them, phenyl mercuric dinaphthyl methane disulphonate, was described as being substantive to tissue protein, and its passage into general circulation is prevented; indeed, it is apparently in use as a wound dressing. These three substances, sodium pentachlorophenate, 2.2-methylene *bis* (4-chlorophenol) and phenyl mercuric dinaphthyl methane disulphonate, are being exhaustively tested by the British Paper and Board Industry Research Association in accelerated laboratory tests made with impregnated strips of board in contact with Czapek agar in Petri dishes. Three test organisms, *Chaetomium globosum*, *Aspergillus niger* and a *Penicillium* species, are sprayed on singly or mixed as spore suspensions. After two weeks incubation the amount of mould growth is recorded and, when required, the mechanical strength of the paper strip is compared with uninoculated controls. The results indicate that mould-resistant samples were obtained when the following percentages on the dry weight of the fibre were used: phenyl mercuric dinaphthyl methane disulphonate, 0·25 per cent; 2.2-methylene *bis* (4-chlorophenol), 1·5 per cent; and sodium pentachlorophenate, 1·5 per cent.

The papers described briefly above will be published *in extenso* in the *Proceedings of the Society for Applied Bacteriology*. T. RICHARDS

OBITUARIES

Prof. Edwin J. Cohn

EDWIN J. COHN, Higgins university professor at Harvard University, died in Boston on October 1. He was an outstanding investigator of the physical chemistry of proteins, and the initiator and organizer of the large-scale systematic fractionation of blood plasma proteins, which has made important contributions to medicine and public health. He was born in New York City on December 17, 1892, the son of Abraham and Maimie Einstein Cohn. His decision to undertake a scientific career was made while he was a student in Amherst College. On the advice of Jacques Loeb, he transferred to the University of Chicago, where he received the B.S. degree in 1914, and the Ph.D. in 1917. His doctoral thesis dealt with the physiology of spermatozoa and the physical chemistry of sea water, the latter study being undertaken with Lawrence J. Henderson, of Harvard, who, together with Loeb, was an important guiding influence in Cohn's development. At this point Cohn decided to devote himself to the study of proteins, as substances of prime importance to the