No. 166

The Institution of Post Office Electrical Engineers.

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D. W. GLOVER, M.Sc., A.I.C.

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Chemistry and Communications

Introduction.

Broadly speaking, the scientifically controlled chemical industry, as distinct from the metallurgical industry, had its inception with the establishment of the Le Blanc Alkali Process in 1794. The more or less contemporary development of Schools of Chemistry in various parts of the country provided a limited number of technicians who moulded the growth of the original industry and its ramifications until the beginning of the present century, by which time these had attained sufficient importance to spread with great rapidity.

More recently still it became the practice of some buyers of the more obvious " chemicals " to employ a chemist or skilled tester to ensure that they were getting specified requirements. Gradually since then the practice of examining by chemical or other scientific means a variety of substances not hitherto classed as chemicals has developed, and likewise, as the complexity and variety of materials dealt with has increased, so has the experience and training of the tester extended in order to keep pace with the duties imposed upon him.

To-day the vast majority of commodities, when bought in bulk, are subjected to a comprehensive scrutiny by a man whose knowledge and ability fully entitle him to the name Chemist in its modern sense.

The formation of large scale industrial amalgamations since the war has lent considerable impetus to the employment of research and development chemists to deal not only with the problems of the chemical industry proper, but also with the domestic difficulties of other organisations whose ultimate object may have no apparent relation to chemicals or even to chemistry. So far as the author can ascertain, the Post Office was employing testing chemists before 1900, but it was not until 1914 that research investigations into current metallurgical problems were first made.

Since then the importance of chemistry to the very foundation of communications has been gradually realised until at the present time, to an ever increasing extent, it encroaches on and interlocks with all branches of Departmental activity. It is the purpose of this paper to show how they are, through chemistry, linked with almost every conceivable industrial activity, and thus to sponsor a realisation of hitherto unsuspected ways in which co-operation between chemist and engineer may be of mutual advantage.

The Methods of Chemistry.

Principles of Chemical Analysis.

Before proceeding, however, it will not be out of place to set forth a very brief description of the practical methods of working, particularly in respect of chemical analysis. In so doing it will be assumed that some readers at any rate know nothing as to the truth of the matter, because in the past samples have been sent for examination with an intimation that they should be returned intact.

The determination of the composition of an unknown substance is a perfectly logical process based essentially upon previous knowledge of the behaviour of the various atoms or relatively stable groups of atoms known as radicles. In order, therefore, to elucidate qualitatively the composition of an unknown material it is necessary first to ascertain whether it consists of one or more chemical entities; this knowledge can usually be obtained by physical means such as examination of its crystalline form, melting point and boiling point. The various atoms or radicles are then tested for by a carefully thought out series of reactions which progressively narrow the field of enquiry at each successive step until all possibilities except one are eliminated; the tests generally involve the production of an insoluble body, a colour, or a known gas under appropriate treatment.

Once the qualitative composition of the material is learned its constituents may then be estimated quantitatively by one or more of several general methods, namely:—

1. An element or radicle may be isolated and measured in the form of a known compound which therefore contains it in definite proportion; the separation is usually achieved by the production of an insoluble compound which can be filtered off, or occasionally as a gas which can be measured.
2. Certain substances may be made to undergo a known reaction with a standard solution of another element or compound, the quantity of the latter thus consumed giving the measure required.

   The completion of the reaction is usually ascertained by a colour change either inherent to it or produced by a minute quantity of added material called an indicator. Other physical means of ascertaining the end point of quantitative reactions are in frequent use for special purposes.
3. Some components are converted by known reactions to coloured compounds, solutions of which may then be matched by a measured quantity of a standard solution of the same compound.

Various physical methods which are of great importance will be referred to later, but at this stage an endeavour has been made merely to show that analysis, either qualitative or quantitative, is a reasoned process which consists essentially of converting the unknown into some recognisable material which can if necessary be measured.

Chemical Complexity.

As there are of the order of 500,000 different chemical compounds now known and classified the necessity for the system of investigation to be highly logical is at once apparent.

Fortunately in practice it is seldom necessary to envisage a given body as possibly any one of this 500,000, as a knowledge of its origin and of commercial values, usually narrows down the question of its identity to an enormous extent.

Apart, however, from chemical compounds of which the structure is known with certainty there are a vast number of materials of indefinite or completely unknown composition. The reason for this is not difficult to see when the almost unlimited possibilities of organic complexity are appreciated.

In order to give some idea of this an examination of the structural formula of butane C_4H_{10} is helpful (see Fig 1).

```
   H   H   H   H
H - C - C - C - C   H
   H   H   H   H
```

FIG. 1.

An atom of chlorine may be substituted for any one of the hydrogen atoms thus giving a mono chlor butane; the possibilities are (see Fig. 2):—

```
    H   H   H   H
Cl - C - C - C - C - H
    H   H   H   H

   H   Cl  H   H
H - C - C - C - C   H
   H   H   H   H
```

FIG. 2.

It will be seen that substitution of any hydrogen-atom in the original butane will result in one or other of the two configurations shown and that these are two separate compounds owing to the different position of the chlorine atom relative to the molecule as a whole in each case.

Similarly for dichlor butane the following possibilities exist (see Fig. 3):—

```
        Cl  H   H   H
1.  Cl - C - C - C - C - H
        H   H   H   H

        H   Cl  H   H
2.  Cl - C - C - C - C - H
        H   H   H   H

        H   H   Cl  H
3.  Cl - C - C - C - C   H
        H   H   H   H

        H   H   H   H
4.  Cl - C - C - C - C - Cl
        H   H   H   H

       H   Cl  Cl  H
5.  H - C - C - C - C - H
       H   H   H   H

       H   Cl  H   H
6.  H - C - C - C - C - H
       H   Cl  H   H
```

FIG. 3.

All these dichlor butanes have an identical ultimate composition, namely, $C_4H_8Cl_2$, but different chemical and physical properties; such compounds are called isomers. Butane is a simple compound having a molecular weight of 58, and containing 14 atoms; organic compounds containing hundreds of atoms are definitely known so that there is no need to stress the number of different isomers which are possible in such cases.

With many natural substances the chance of precise chemical definition is rendered even more remote, because, apart from the complexity of the individual compounds, there may be hundreds of distinct entities present, some in large and some in minute proportion. For example, the vitamins which are essential to physical well being occur in many natural foodstuffs, but owing to their extremely minute concentration their existence was entirely unsuspected until comparatively recent years; even now most of them can only be detected with certainty by their physiological action, and the constitution of one or two of them only is known.

More commonplace materials such as mineral oils, bitumen, paraffin wax, paints and photographic emulsions also defy exact description. The object of putting forward these complications and limitations of the science, however, is not for the purpose of causing bewilderment, but in order to emphasise that the fine points of constitution are not always of paramount importance.

Means have, in fact, been devised for dealing with the problems thus presented in a statistical manner; that is to say the reactions of various similar types of the more important atomic groupings in the molecule or mixture are lumped together and examined or estimated as a whole; thus, aided by physical and what are in effect carefully planned performance tests, great progress has been made in the practical understanding and utilisation of such bodies.

Accelerated Performance Testing.

There is coming into use an increasing number of substances of which the quality can only be assessed by practical trial of the important properties; for instance, no analytical technique yet devised will foretell the strength of a synthetic resin or the durability of a paint, rubber or electro-plated coating, and therefore, particularly in respect of materials which deteriorate with time and use, we are at present entering upon a new era of chemical technique, namely, the accelerated life test which will accurately simulate the effects of these factors.

Such tests present far more problems than analysis itself owing to the difficulty of assessing the relative importance of the many influences concerned, and the necessity of paralleling proposed methods by observations under normal conditions of use. The technique of accelerated testing is yet only in its infancy, but a large number of methods now available are of considerable value when interpreted with due regard for their limitations.

CLASSIFICATION OF DEPARTMENTAL WORK.

Turning to a consideration of the association of chemistry with the requirements of the Post Office, the work, as is probably the case in most large industrial organizations, falls naturally under two main headings: —

(1) Routine acceptance examination of stores and preparation of specifications.

(2) Research and development.

The first of these, of course, presents a very large bulk and is carried out by the Test and Inspection Branch. Apart, however, from certain general remarks regarding specifications which will follow later it is not proposed to deal with this at any length for the reason that, although of great interest and importance to other chemists, it is essentially a matter of detail and technique, and therefore of only limited general interest.

The second heading can, however, be very roughly sub-divided into—

(*a*) Problems which arise in the routine practice of Departmental activities.

(*b*) Applications of new materials, and preparation of specifications.

These classes are, of course, by no means water-tight and there is a frequent tendency for cases to move down the headings; experience also indicates that isolated problems are exceedingly rare and that those which at first appear in this light are usually the early manifestation of a more general difficulty.

However, work carried out during the past 15 years has involved such ramifications as examining waters, paints, gases, textiles, insulating materials, synthetic resins, papers and metals, elucidating the cause of corrosion of a variety of apparatus and ascertaining whether a piece of wire swallowed by a cow was Departmental property.

Enquiries have also been received concerning such matters as the effect of lightning on postmen's trousers and the administration of Epsom salts to common clothes moths.

PROBLEMS WHICH APPEAR IN THE ROUTINE PRACTICE OF DEPARTMENTAL ACTIVITIES.

From their general importance some materials have naturally assumed more prominence than others, and in the following pages an attempt is made to give a description of some of the problems which have arisen in connection with these.

Water.

In connection with many problems a frequently occurring question is the composition of water; in the past, large numbers of alleged distilled waters have been examined as the obtaining of reliable supplies for secondary cells appears to present frequent difficulty in some districts, especially where requirements are small. For this reason, and the increased quantities necessitated by discontinuance of the practice of oil floating the batteries, a long series of tests have been carried out to ascertain what quantities of the impurities normally encountered in domestic water supplies can be tolerated by the cells; as a result it is hoped to be able to endorse the use of such sources in many districts.

An occasional variation of this theme is the accidental or malicious addition of some impurity to the topping up water.

The composition of liquids from manholes and ducts is also frequently determined to ascertain, firstly, whether these are harmful to cable sheaths and, secondly, in certain instances to trace their origin. As a rule in such cases the main object is the detection of sewage, as this is a common source of pollution which is highly corrosive to lead.

The examination consists of chemical analysis and a corrosiveness test in comparison with a standard artificial earth water; the analysis furnishes strong presumptive evidence as to the presence or absence of sewage, and will even give an indication as to whether the pollution if present is of recent or past origin. A suspected water is nevertheless subjected to a bacteriological examination in addition.

This is based upon the detection of Bacillus Coli which occurs in the colon of all animals, and is excreted in enormous numbers; the bacillus is not in itself particularly harmful, but its importance lies in the specific inference of excremental pollution which can be drawn from its presence.

In one particular case a copious flow of water into the ducts adjacent to an exchange was observed; this proved to be of a corrosive nature and presented strong chemical evidence of pollution by animal refuse in the past, but no bacteriological confirmation could be obtained, and further, the authorities denied the existence of any faults in the sewers. Investigation of local conditions, however, elicited that the surrounding ground was waterlogged at a depth of about 10 ft. over a considerable area, and that the exchange itself had been built on an old rubbish dump. During the excavations for the foundations of the building the complete skeleton ribbing of a river barge had been unearthed together with vast quantities of oyster shells. Only the assumption that a certain quantity of tissue had originally been present in these was required completely to explain the results of the examination. It is interesting to note in passing that similar peculiarities with a certain water supply in Yorkshire were attributed to the burial, near the site of the well, of a number of the victims of a Civil War battle in the seventeenth century.

Apart from sewage contamination faulty service drains may give rise to the presence of harmful trade effluents in duct lines; here the presence of some characteristic substance will generally point with fair certainty to the business of the offender and a knowledge of local topography is then required to identify him.

Gases and Vapours in Underground Works.

The explosion of the old Pneumatic Parcels Tube in Bloomsbury in December, 1928, left a considerable legacy of gas detection problems; these have been dealt with from the chemical standpoint by adaption and development of two devices, namely:—

1. An automatic sentinel which is installed in the remaining section of the Tube; this operates by the catalytic combustion of inflammable gas upon the surface of a heated filament, the additional energy so produced causes a change in resistance and disturbs the balance of an electrical bridge system, thus operating an alarm.
2. A detector for poisonous quantities of carbon monoxide; these lie in the range below 0.1% and are detected by the reduction of palladium chloride to metallic palladium; the stain thus developed on a test paper is compared with a standard tint. The instrument is, of course, intended for general use by workmen in underground chambers.

It is well known that, owing to the vibration caused by modern traffic, leaks frequently develop in the joints of gas mains, so that when inflammable vapour is detected in underground works in a town this gas is naturally regarded as first suspect. It consists of about 50% hydrogen, 25% methane, 20% carbon monoxide together with a balance of more complex bodies, and its presence is usually regarded as proven if carbon monoxide is found, as this compound does not normally arise from any other underground source.

In addition to coal gas the vapours of inflammable liquids such as petrol and benzene improperly discharged into faulty sewers have been found in manholes.

The occurrence of foul air from sewers, anaerobic gas produced by the fermentation of buried organic matter in a similar manner to marsh gas or methane, and suffocating gases are also possibilities which must be borne in mind.

Oils.

Oils for various purposes have come in for a considerable share of attention at one time and another. When the lubricating value is of first importance a performance test of some kind is essential, but with telephone apparatus this property is often secondary to the requirement that the oil shall stay where it is applied.

An interesting investigation has been conducted on the behaviour of the anti-spray oil layer used until recently on exchange batteries owing to the accumulation of evidence that cells so treated were unsatisfactory in performance and life. The specification to which this was purchased ensured a material suitable for cleaning purposes, but, as was subsequently found, paid no regard to the presence of large quantities of highly reactive bodies which enabled it to become physically attached to sponge lead and hence to inactivate the negative plates when in the charged condition.

Although an oil which is almost free from this shortcoming has since been specified, the general use of the anti-spray layer has now been discontinued; nevertheless the facts discovered have enabled the contaminated negative plates of several large batteries to be reactivated by reversing them temporarily to positives, thereby releasing the attractive forces holding the oil and expelling the latter by means of the oxygen liberated during the gassing period.

Another oil problem of a totally different nature called for the development of a simple means of ascertaining the spontaneous ignition temperature of heavy oils in order to ensure satisfactory supplies of fuel, and to ascertain the fire hazard involved in storage of transformer oil.

A very simple apparatus has been devised for the purpose, consisting of a massive piece of iron furnished with a deep hole into the bottom of which a slow stream of oxygen may be led. The iron is gradually raised in temperature until a drop of oil falling to the bottom of the hole detonates immediately; the temperature at which this occurs shows a well-marked distinction between various oils, and has been found to give a satisfactory measure of the required properties.

Stamps.

Many people are curious as to the use of chemists to the Post Office as apparently the popular conception of Departmental interest in chemistry is limited to stamp gum.

Curiously enough these tokens have only recently been dealt with for the first time in connection with the tendency of stamp rolls to stick up in selling-machines owing to condensation moisture caused by sudden falls of the atmosphere temperature.

By application of a film of pure cellulose acetate about 1×10^{-5} inches thick to the gummed surface it is possible to produce a roll which can practically be guaranteed not to stick up through condensation moistures, although the stamps behave quite normally in use. Fig. **4** shows the appearance of treated and untreated rolls after exposure to a water saturated atmosphere for 8 days. It is probable that the coating acts as a mechanical separator which prevents the damp gum from coming into contact with the adjacent paper surface, but is at the same time sufficiently thin to be disintegrated readily by the lateral friction of the tongue of a stamp fixing machine.

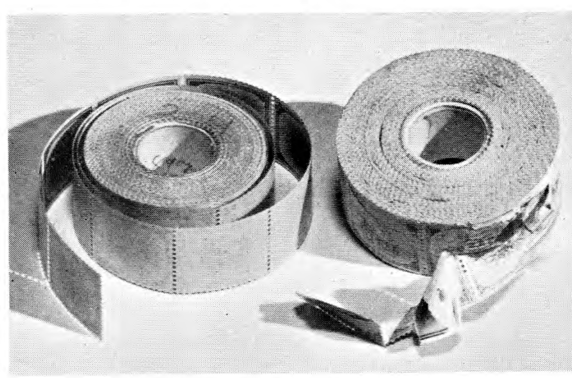

Fig. **4**.—Showing Difference in Behaviour of Treated and Untreated Stamp Rolls after Exposure in a Condensation Chamber.

A fault analysis is at present being carried out on about 100 experimentally treated rolls per week which are going into service. The results of the Spring analysis indicated an appreciable decrease in probable sticking faults and an increase in the percentage of trouble-free deliveries, but during the Summer the difference in behaviour between treated and untreated rolls has not been so marked, apparently owing to generally drier weather conditions.

It is hoped, however, that the advent of Autumn will confirm the results of the spring analysis. Assuming this to be the case, it is not unlikely that the removal of the masking effects of dampness faults will also be of use in enabling certain defects in machine design and operation to be traced and rectified.

The treated stamps can be tested by comparison with untreated controls in a condensation chamber; for process control tests, however, a more rapid method is used where two treated and two untreated surfaces are pressed for a certain time without any lateral movement into contact with a sheet of paper lying upon a damp blotting pad; they are then carefully removed and allowed to set on a dry pad after which the treated stamps can be removed by a touch whilst the untreated ones adhere firmly.

The question of applying the treatment commercially to all rolls is at present under consideration.

Paper.

It is now many years since the first analyses were carried out with a view to standardising the make-up of various telegraph and teleprinter papers; in this connection the identification of the fibres used is the most difficult matter and mainly involves microscopic examination.

Analysis of paper still continues, but at the moment it is related to loudspeaker cones and telegram forms. In regard to the former the behaviour of the cone in the frequency range at which it breaks into complex vibration is greatly influenced by the paper structure, and it is the object of investigation in this field to assist the acoustics engineers in correlating cause and effect.

For telegram forms it is desired to specify a paper which will not electrify and adhere to conveyor belts; as far as can be seen this requirement calls for a material of very high electrical conductivity.

Corrosion.

Cable Sheath Failures. Corrosion in its many forms is probably one of the greatest financial burdens which the Department has to meet, and in connection with external plant the failure of cable sheathing brings a large amount of work both in respect of diagnosis of cause and prevention of attack.

The method of investigation consists of microscopical examination of the fault, together with chemical analysis of the corrosion product and the mud and water with which the cable has been in contact.

From the information thus obtained it is generally possible to form a sound opinion as to whether direct chemical attack or electrolysis by leakage currents from nearby power systems has been responsible for the damage. If the latter conclusion is reached an electrical survey of the district is carried out in important cases.

In areas where corrosion is prevalent protected cables are often used, whilst in addition the application of silicated petroleum jelly to the sheath has also met with considerable success.

Life of Iron Stay Wires. A large quantity of iron stay wire is in use by the Department, and a lengthy research upon the protection of this has recently been completed. The material is galvanised, generally by hot dipping but also occasionally by electro-deposition. The zinc provides a sacrificial coating, that is to say, being anodic to the underlying iron it is attacked preferentially to the latter by corrosive influences and it has been concluded that the principal factor affecting life is the thickness of the coating. The investigation indicated that the zinc disappears about 10 times as fast in an industrial as in a country town, whilst in rural districts the life is even greater.

Nickel Plating. For indoor finishes on articles such as relay parts, nickel is usually preferred; this affords protection only by virtue of its own inherent resistance to corrosion, but it has the advantage that, being a magnetic material, no gaps are introduced into a magnetic circuit by its presence. It is usually plated on to iron over a thin flash of copper and an investigation has been carried out in accelerated corrosion chambers to ascertain the important factors in the control of the process and the minimum thickness required to give adequate life. This is a vast improvement over the position where no supervision is exercised, as most readers who have had articles electro-plated privately will appreciate.

An interesting by-product of the work is a device for determining the thickness of a plated coating on ferrous materials; this operates upon the principle that the force required to remove a small magnetized bar from contact with such a surface is an inverse function of the thickness of coating. The instrument is depicted in Fig. 5, from which it will be seen that this force is measured by a spring balance appropriately calibrated for the particular work in question. As an alternative to dissolving the protective metal from a known area of surface and subsequently estimating it by chemical means the utility of the apparatus for acceptance testing can readily be appreciated.

Corrosion in Relay Windings. Within the last few years a considerable number of corrosion faults in fine wire relay windings has come to light. As far as can be ascertained these are due entirely to the presence of small quantities of electrolytes in the interleaving and wrapping materials. Under even slightly damp conditions these convey leakage currents which cause electrolysis of the delicate wire at the anodic areas. The corrosion products are almost invariably hygroscopic so that the first traces formed tend to set up a vicious circle of action which results in rapid failure.

Whilst chemical analysis is useful for detecting thoroughly bad materials it is incapable of indicating satisfactory ones with certainty. To

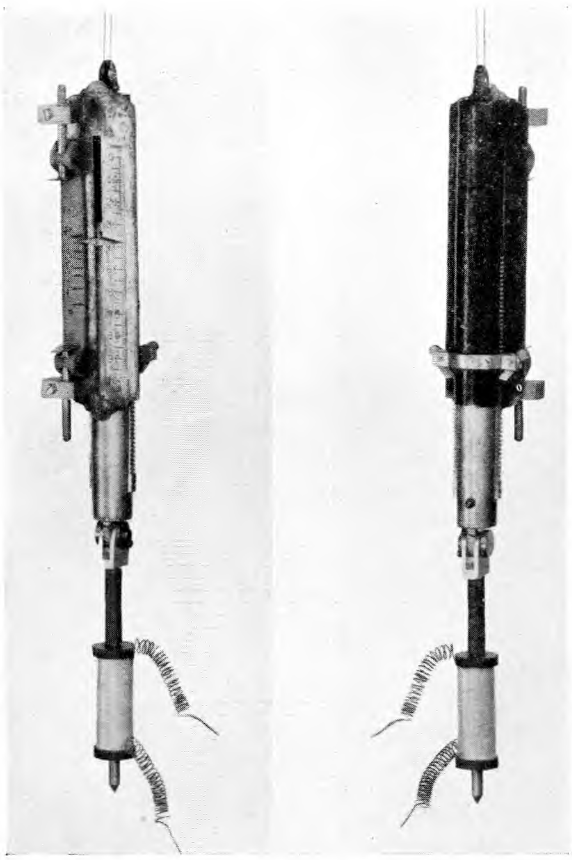

FIG. 5.—THICKNESS TESTER FOR PLATED COATINGS ON FERROUS METALS.

cite a particular instance it would appear from limited statistical information that Empire Cloth and Oiled Silk are superior to bitumenized paper for the purpose, but, on the other hand, extraction of the two materials by cold water under similar conditions yields a fairly acid liquid of relatively high electrical conductivity from the former, and a neutral liquid of low conductivity from the latter, so that as a result of this test it would not be unreasonable to assume that the bitumenized paper would be less prone to cause trouble.

There is, however, some evidence that in practice small quantities of sulphur in the bitumen in time become oxidised to sulphuric acid. Hence, as a result of these and other considerations it is felt that irrespective of analytical data no reliance can be placed upon any material which fails to pass an accelerated performance test designed to accentuate the effect of working conditions. Such a method embodying the combined action of air, moisture, electrolysis and breathing is at present being investigated.

Paints.

As Post Office buildings are maintained by the Office of Works interest in paints is practically limited to those used for letter boxes, telephone kiosks, radio towers, and internal plant, and a comprehensive examination of the suitability of various external red finishes is at present nearing completion. So far the examination indicates that certain of the modern synthetic enamels are superior in the required direction to the paint and varnish which has been used in the past. Owing to their smoother finish they retain their clean appearance longer and there is also a possibility that for re-painting only one coat will prove necessary in many instances. It is an interesting fact that country or seaside atmosphere is far more detrimental to appearance than industrial atmosphere, owing to the bleaching effects of the ultra-violet light on most of the pigments.

Metallurgy.

The Post Office, being an extensive user of metals, encounters many problems in connection with these. Although metallurgy is a specialized subject it is so closely related to chemistry that any account of the applications of the latter would be incomplete without reference to it.

It is perhaps not generally known that metals are crystalline in structure, so that Fig. **6**, which shows a

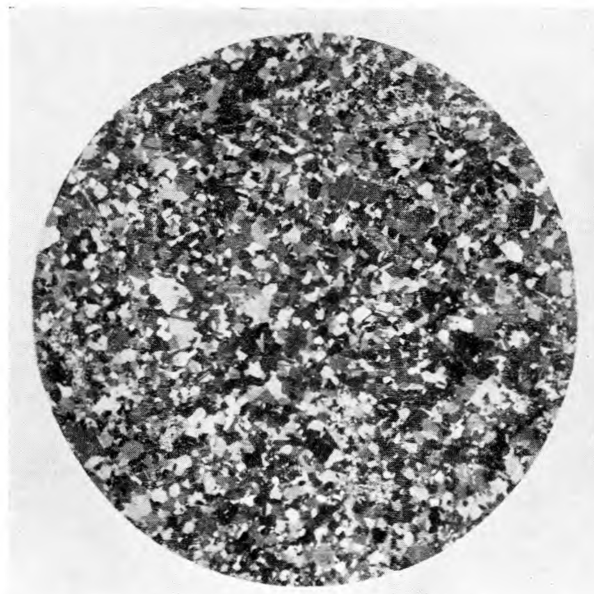

FIG. 6.—SHOWING CRYSTALLINE NATURE OF METAL. LEAD SURFACE MAGNIFIED TO 2 DIAMETERS.

lead surface magnified to two diameters, is instructive.

The technique of investigation consists mainly in the use of the microscope, pyrometric apparatus, mechanical testing equipment and chemical analysis.

Modern Alloys. Owing to the comparatively recent discovery of the profound effect which minute admixtures, often no more than a few one-hundredths per cent. of certain elements, may have upon other metals, and the consequent large number of new alloys which are now appearing, constant vigilance is required to ensure that, whilst the Department is not misled by over-enthusiastic claims, it is at the same time enabled to make use of genuine advances in the science without undue delay. For example: a copper-zinc alloy containing smaller amounts of nickel and aluminium which was marketed some time ago appeared at first sight an ideal material for relay springs, but on investigation it was found that Young's Modulus was too low, and the metal was brittle in bending.

Again, whilst some of the binary and ternary lead alloys containing from $\frac{1}{2}\%$ to 3% of certain metals have undoubted merits for cable sheathing, many differences between the large number available remain to be cleared up and consequently a comprehensive programme of research on this question is in hand. Particular attention is being paid to their behaviour under vibrational stresses much below their tensile strength, that is, to the property generally known as fatigue resistance. Needless to say, the ideal aimed at is immunity both to this influence and to corrosion. In addition the effects of copper, tin, antimony, bismuth, silver and tellurium deliberately or accidentally present in lead in very small quantities are being considered.

Some Surprising Faults. Passing on to more routine problems a description of certain of these is useful to illustrate the amazing phenomena which are sometimes encountered in quite commonplace articles. Of such, perhaps the most startling is the case of a large number of breakages of selector frames at Leeds Exchange. These had been manufactured in 1914 from a die-casting alloy consisting of about 85% zinc with smaller quantities of aluminium, tin, copper and lead. Determination by analysis of these metals produced a result totalling less than 100%, but further examination indicated that the balance consisted of oxygen and the failure was then recognized as a fault common to a number of the older type of die-casting alloys. An inter-crystalline oxidation had occurred and the oxide thus formed, being more bulky than the metal itself had forced the castings apart. The phenomenon occurs more readily in a warm humid atmosphere and faulty frames so treated are shown in Fig. **7**; it is prevented by slight modifications in the composition of the alloy, and the use of the more highly refined metals now available.

The so-called "season cracking" of brass is another surprising effect which has been encountered. This sometimes occurs in articles which have been fabricated in the cold, such as bell-gongs, and is produced by internal stresses left in the alloy; it is characterized by the development of cracks between the crystal grains. Specimens can be rapidly tested by immersion in a dilute nitric acid solution of mercurous nitrate; this amalgamates and so weakens the material between the crystals that if the stresses exist cracks appear in the course of a few minutes. If suspected, the tendency can be removed by annealing at about 250°C. for half an hour.

A few years ago the Stores Department decided to substitute case-hardened mild steel for the high grade cast steel then used for the type holders of hand cancelling stamps. This step reduced initial costs considerably, but it was soon found that the new holders were wearing very badly, and the material became suspect. Metallurgical examination by means of hardness measurements and the microscope immediately indicated that the thickness of case-hardening was but a fraction of that specified, and the faults ceased when this defect was remedied.

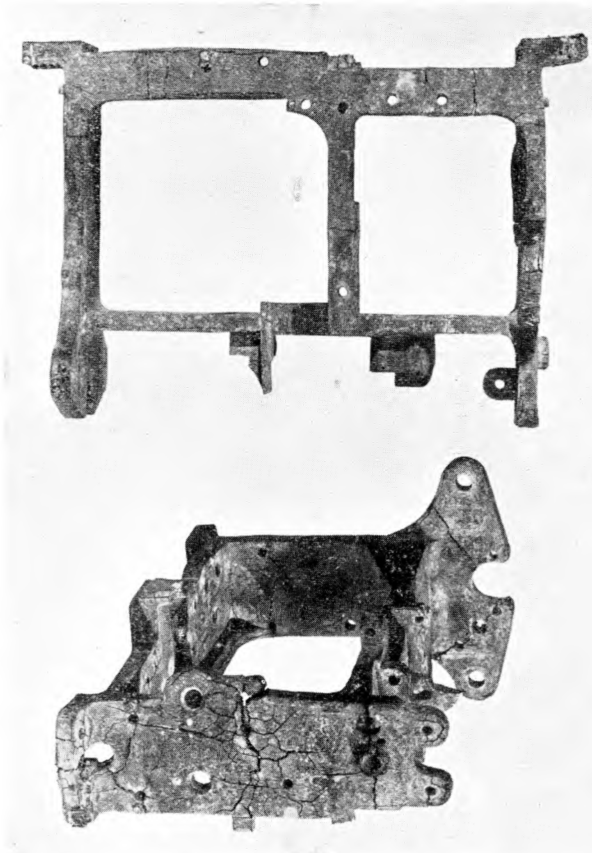

FIG. 7.—SELECTOR FRAMES FROM LEEDS EXCHANGE AFTER EXPOSURE IN A HOT WET ATMOSPHERE FOR SEVERAL DAYS.

Metallurgical Analysis. The chemical analysis required in connection with metallurgy is frequently of an elaborate and time-consuming nature, so that it is opportune to mention here the great utility of the spectrum method in certain cases. This depends upon the fact that the incandescent vapours of practically all elements, and metals in particular, emit visible and ultra-violet radiations which can be analyzed by the spectrograph into spectral lines of one or more specific wave-lengths. These can be photographed in juxtaposition to a calibrating spectrum, usually that of iron, from which their wave-lengths can be interpolated and the elements thus identified. In addition to providing a delicate test for the presence of minute quantities of certain elements which are not easily detected by chemical means, this method can be adapted to quantitative work by comparison of the intensities of suitable lines of the main and alloying elements. Its field of utility is likely to increase enormously in connection with control and acceptance tests.

Although not used for analysis in the ordinary sense of the word the X-ray spectrograph is now being applied to an increasing extent for elucidating more fundamental questions relating to crystal structure.

When X-rays impinge upon matter they are diffracted by the component atoms and a pattern related to the spatial arrangement of these may be recorded photographically.

In addition to metallurgical applications this method is also being utilised for examination of the structure of piezo-electric crystals.

APPLICATIONS OF NEW MATERIALS AND PREPARATION OF SPECIFICATIONS.

At continually decreasing intervals of time industry produces entirely new chemical products or processes, and it is essential that these, in addition to improvements in existing materials, shall be duly examined and assessed in case their adaptation to Departmental purposes should prove desirable. Progress is always from the general to the specific and a single material which is at first reasonably good for a considerable number of purposes is inevitably developed into a number of materials, each one of which is excellent for a particular purpose.

It is the role of chemistry in this connection to act as a liaison between the apparatus designers and the chemical industry; the work involves regular examination of contemporary literature and frequent consultations with manufacturers, in addition to considerable experimental work.

Synthetic Resins.

To go back a little in history, it is probable that the earliest of what, for lack of a better description, may be called the modern synthetic materials brought into use for electrical purposes is Phenol-Formaldehyde resin, more commonly known as Bakelite.

Although the reaction by which this is formed was discovered by Baekeland about 1910, it was not until some 15 years later that the commercial article became freely available. Owing to the remarkable ease with which it can be moulded into complex forms it was then rapidly accepted as a cheap and satisfactory substitute for many apparatus parts which had previously been machined from expensive solid materials such as ebonite and fibre.

Nowadays there is, of course, scarcely any electrical apparatus into the construction of which it does not enter; further, in addition to the original material of Baekeland, a number of other synthetic moulding materials are being produced by what is now called the Plastics Industry. These bodies can be divided into two classes; first, the thermo-setting resins, that is, those which once hardened by the application of heat cannot be softened again: these include phenol-formaldehyde and urea-formaldehyde; and second, the thermo-plastic resins which can be softened at any time by heating to an appropriate temperature; the more important of these are cellulose acetate, polystyrene and methyl methacrylate.

The fundamental properties of these compounds may be modified to a marked extent by the addition of various plasticising agents so that a range of materials with considerable gradation of specific properties is available. A number have already been approved for certain Departmental purposes, whilst others are still under consideration.

One particularly interesting use to which such bodies may be put is the production of a non-metallic cable sheath, with its obvious advantage of freedom from corrosion troubles. This possibility is being closely watched, but whether it materialises or not, it is inevitable that a considerable variety of plastics will become commonplace in the electrical industry during the next few years.

Insulating Textiles.

Cellulose Acetate Silk. Another class of materials which has been the subject of considerable attention by chemists during the past decade or so is insulating textiles. In the early days of the electrical industry natural cotton, silk and wool were the only ones available. The first synthetic fibre to be brought into general use was cellulose acetate artificial silk; this has been found to be an effective substitute for natural silk in many instances. At first supplies were only accepted from one firm of manufacturers, but later a specification was worked out, thus throwing the market open to anyone caring to tender.

Acetylated Cotton. A more recent modified natural substance which is assuming considerable importance is acetylated cotton; this consists of cotton in which the fibres have been converted to a cellulose acetate so that they possess a superficial similarity to cellulose acetate artificial silk; owing to its more regular structure, however, this material possesses superior electrical properties to the latter. In appearance it is indistinguishable from cotton so that on account of possible confusion an interesting test for discriminating between the two textiles has been applied; this depends upon their different behaviour towards certain dyes so that if both yarns are treated in water containing chlorazol blue FFS and duranol red 2B, the cotton is dyed blue and the acetylated cotton red.

Washed Textiles. Washing of textiles under carefully controlled conditions is also promising to provide a useful new series of insulating yarns; for instance, it is possible to reduce the mineral content of natural cotton from 1.2% to about 0.3% by such treatment with a consequent improvement in its insulating properties.

Bearing in mind the objectionable effect of electrolytic compounds in relay wrapping materials it will readily be perceived that they are equally undesirable in bunched wiring which may be subject to humid conditions. Hence, as they constitute a large proportion of the mineral matter removed, the process would appear to offer a twofold gain, in so far as it results in better insulation resistance and a reduced liability of corrosion from such leakage current as does occur.

Wool and Some of its Chemical Derivatives. Wool is still used in large quantities on wiring in situations where the risk of fire constitutes a hazard, but unfortunately this is at all times subject to attack by the clothes moth larvæ. It is very strange, however, that whilst the Department used large quantities of this material on jumper wire until 1930 without experiencing trouble, since that time attacks have occurred in many exchanges. Even so, it is highly significant that only one manufacturer's wire has so far proved susceptible, despite that no peculiarity has been discovered to account for this, although such must without question exist. The facts suggest that it has taken a good many years for the insects to adapt themselves to this particular make, which has chanced to prove more suitable to their needs than the remainder. This hypothesis leaves the uncomfortable implication that it is merely a question of time before they develop a more catholic taste. To anticipate such a possibility all supplies are now being moth-proofed by treatment with a complex phosphorus-containing organic compound which has been found by experiment to be satisfactory.

In the meantime the possibility of substituting natural wool by other available materials is not being overlooked. Wool is an elaborate nitrogenous body possessing what is known as a proteinaceous structure which can be modified by chemical treatment and recent work indicates that certain of its chemical derivatives, in particular the products obtained by treatment with tannic acid and acetylating agents have improved electrical properties, so that if, as is quite possible, these prove to retain the flame-resisting properties of natural wool, and at the same time repel insect attack, they will undoubtedly have a considerable field of utility.

To sum up, therefore, it is not improbable that before very many years have passed there will be few insulating textiles bought which have not had their original properties modified in some way by chemical processes.

Silica Gel.

This paper would be incomplete without reference to an interesting material which has been of distinct value during recent years, namely, silica gel. This has the same chemical composition as sand, that is, silicon dioxide, but each granule appears to be subdivided by an enormous number of fissures so that its superficial area is enormously greater than is apparent; there are, it is stated, almost acres of surface per cubic inch of average granules. On this a correspondingly large quantity of moisture and many other vapours may readily be absorbed; when saturated the gel is easily reactivated by heating slightly above the boiling point of the liquid concerned for a few hours in a current of air.

Fortunately, this substance was first investigated at about the time that flameless methods of working in manholes were required, so that it fell naturally into place as a means of drying out cable joints.

The work consisted essentially of determining drying rates to be anticipated, the capacity of the gel for moisture, the optimum quantity required per given amount of space and finally the provision of a specification: this last gave rise to some difficulty but was eventually solved by measuring the total heat evolved by complete saturation of the finely powdered gel with liquid water.

In addition, silica gel has been substituted successfully for calcium chloride in the petrol-driven cable desiccator, reactivation being carried out by the exhaust heat of the engine; it is also ideal for maintaining apparatus boxes in a dry condition and for many laboratory purposes.

Specifications.

It will now be apparent that the introduction of a new product into use resolves itself into three stages, namely:—

(1) Realization of its potentialities.

(2) Ascertainment of its precise properties in relation to its proposed use, and selection of the most suitable modification of it.

(3) Preparation of a specification whenever possible.

The Post Office is probably the originator of the practice of purchasing to specification, and many of these have been copied and used throughout the world; the importance of the specification can scarcely be over-rated as it may concentrate on a printed page or less the result of months of work. When scientifically drawn up with due regard to all relevant factors, so that the material may be bought in the open market, as distinct from purchasing proprietary articles it results in an enormous financial saving. Its value is, of course, not limited to new materials and cases have in fact occurred where Patent licencees who have been taking unreasonable advantage of their monopoly have agreed to substantial price reductions at the mere suggestion that research might be undertaken with a view to developing a specification and contesting their rights.

It must, however, be emphasised that a specification which is inadequate or imperfectly understood in all its implications is often worse than none at all because, although an expensive material may be necessary in order to pass one clause, this can be actually inferior for the purpose proposed owing to the omission of some more vital consideration. Similarly a specification which is more rigid than necessary will inevitably increase the cost of the material by restricting the potential supply.

Conclusion.

Admirable as some materials and chemical methods employed may appear, they are at best imperfect, and sometimes little better than makeshifts, but the intensive study to which they are now subjected renders certain revolutionary changes in the nature of many of them within limited time.

The author acknowledges the valuable work carried out by the technical staffs of various contractors and organisations both here and abroad; this has been referred to freely in the paper; he also thanks his colleagues, in particular Dr. Radley, for various assistance.

SUMMARY OF THE DISCUSSION

Mr. F. O. Barralet stated that the application of chemistry to communications is not of such recent date as might be inferred from the paper, although he admitted that the growing stringency of modern requirements has increased its importance greatly.

It was also pointed out that claims for considerable financial saving, as a result of the work described, could be justified.

A large number of specific queries in connection with almost every subject mentioned were also answered by the author; these indicated plainly the discriminating realisation by engineers of the potentialities of chemistry for solving a number of the problems which they encounter.

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