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By J. ARTHUR REAVELL, M.I.Mech.E.

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The Rôle of Science in Industry

In this age of intensive commercial competition in which we live, industrialists, financiers and scientists generally are faced not only with the problem of doing a particular piece of work well, but of doing this particular piece of work better and cheaper than can be done by their competitors. Moreover, the present trend toward the formation of large combines by the fusion of firms of kindred interests has added to the complexity of the problems which have to be solved, by extending those which formerly were of local importance into problems having a much wider basis embodying national, or even international, considerations.

Let us first, however, obtain a clear conception of what I mean by the term "Science." Herbert Spencer says "Science is organised knowledge," but I prefer to define it as "ordered knowledge." The late Sir Henry Jones compared any science with the solar system, the facts deduced by reasoning and verified by experiment being analogous to the suns and planets in the solar system. Every one of the facts, too, has a definite place in the system and has a definite relationship to, and dependence upon, the other facts which make up the science, as well as upon other sciences. As in the solar system, if a body belonging to a system becomes displaced the whole system will take up a new configuration, so in science, if one of the fundamental facts is proved wrong, or a new fact established, the whole of the remaining facts have to be re-assembled to form again a complete system.

A scientifically trained mind is, therefore, able to examine a problem in an orderly manner, to pass by ordered reasoning from one aspect of the subject to another, and so to forecast definite results from a particular course of action.

One of the oldest industries in existence is the woollen industry, with records dating back to B.C. 2090. As far as our own country is concerned, evidence is obtainable of the foundation of the Guild of Wool Staplers at Winchester in A.D. 54.

The work done on the chemical constituents of wool is an example of the tremendous assistance science is giving to a number of industries, through research work, on the ultimate constitution of raw materials. It is only in this manner that national progress can be made in manufacturing processes.

Science has discovered that the coat of the sheep is constructed to fulfil a double function and, therefore, consists of two parts: an inner to maintain warmth, and an outer to act as a protection to the former. By a process of definite selection, it has been possible to develop sheep in which the outer coat has almost disappeared, the remnants being found in the form of thick, coarse fibres, termed kemp, which are scattered through the fleece.

Environment, which includes climate, food and rest, also affects the nature of the fleece, so that the biological study of the animal and its environment has been of benefit to the woollen industry, for such work comprises investigations on types and structure of fibre, rate of growth and shedding, as well as pigmentation, and the variations in the total amount of fleece.

Chemistry has had a great bearing on the woollen industry, for upon its guidance depend such problems as the composition of the sheep-dips, and the materials used for marking the sheep and their effects on the wool.

There always has existed a great difficulty in the estimation of damage in a sample of wool, or of cloth. Methodical work on this problem has provided a solution. It is based on a reaction—similar to the formation of an azo-dyestuff—between a reagent applied to the wool and one of the primary constituents of the wool itself.

This reagent can only penetrate to the inner cortex of a fibre when the epithelium, or outer scale of the fibre, is damaged. The injured portions then take on a dark brown stain, whereas the perfectly sound fibres remain white. So successful has this method become that it has been utilised as a means of quantitative estimation of damage to wool fibre. The treated wool is dissolved in a sodium hydroxide solution yielding a coloured liquor, the intensity of which can be matched against a standard solution. The colour intensity is recorded as being proportional to the damage, or degree of unsoundness of the sample of wool tested.

The work of the chemist in regard to the sulphur group in wool has had some interesting results. In a purely chemical study of the nature, linkage and reactions of the sulphur group in wool, a line of work developed showing that use could be made of certain changes, whereby the wool fibre was rendered more soft and plastic. The result of considerable work in this direction has made it possible to obtain a "soft-handle" in the finished fabric when using coarser wool. In the same way, the "soft-handle" obtained in the present finer qualities of wools can be greatly enhanced. This means that by the work of the chemist wool can be given a higher grade finish than is ordinarily possible.

Cystine is the outstanding chemical constituent of wool, and it can be said that the sulphur content of wool, as expressed by the quantity of cystine present, is of primary importance from every point of view in the manufacture. High sulphur content means high resistances to damage during chemical processing, such as chlorination, or rendering the wool unshrinkable.

It is essential that wool should have a high cystine content, as it means great elasticity and good manufacturing power. This knowledge was applied by Professor Brailsford Robinson when practical tests were made by him on large flocks of sheep, by giving them a diet of fodder rich in cystine. This diet improved their wool production, both from the point of view of quality and quantity, and avoided certain troubles which otherwise seemed inherent in the fibre.

The study of wool from the bio-chemical point of view is entirely new. Rimington, working in the Torridon laboratories, was able to isolate from wool a carbo-hydrate of the chemical nature of a sugar, similar to the "humin" which can be isolated from blood. In removing vegetable matter from the wool, prior to further processing, a system of carbonisation is employed in which the fibres are subjected to sulphuric acid and other treatment. This work by Rimington clearly shows that the discoloration of certain wools, which caused so much trouble in the trade, was due to the effect of acid upon this carbohydrate. Having identified the trouble, the necessary precaution can then be taken to eliminate it in practice.

The work of the bio-chemist has also shown the possibilities of great progress. The waste wool, flock, britch wool and other low grade wool, which at present are sold at a low price, have been treated by a solvent so that, by adopting a process similar to that of artificial silk manufacture, a regenerated fibre has been obtained. This can be worked up so that a yarn is produced, either mixed with cellulose, or composed wholly of this wool product.

As far as present discoveries have shown this regenerated fibre has many of the characteristics of wool. If mixtures of wool and artificial silk are used, very wonderful opportunities will be given to the dyer and finisher for colour effects and variety of fabrics.

Science, too, can examine the changes in the natural properties of the wool after shearing, and during transport and storage, and how these natural properties may be maintained during the processes which the wool has to undergo prior to spinning.

It is often found that defects which develop at quite late stages of the process, or even in the finished goods, have their origin in the early stages

In the case of knitted wool fabrics and certain worsted cloths, difficulties have arisen due to stains appearing on the finished product. A careful investigation of this whole trouble has shown that it was due to the use of certain mineral oils. When the cloth or fabric was exposed to the action of light and air these stains developed. Having found that the stains arose from the mineral oil, investigation led to the development of a rapid method whereby all such oils could be tested and graded, so that instead of waiting as long as six months before these stains developed in the material, the oil itself could be tested and it could definitely be determined that, by using the proper oil, these defects would be avoided This method consists of exposing such oil under standard conditions for a period of thirty hours to the radiation from an arc lamp. It was found that samples of oil exposed in quartz tubes to the light, or an electric arc, gradually deposited a precipitate which could be separated and weighed.

This technical work, no doubt, has applications far beyond this particular use, as, for instance, the examination of transformer oils, where the deposit is a source of trouble.

Difficulty has been experienced in the past in the production of a single warp yarn from coarse wool, so as to produce a cheap cloth. The difficulty was one of being able to obtain a suitable size. Work was carried out on a large number of adhesive substances in which due regard was paid to the properties of wool and the necessary requirements of mechanical processes. The investigations were so successful that, having produced the proper size which will protect the single yarn warps, they can now be woven into a satisfactory cloth.

The physicist too has his part to play in the woollen industry, for by his work is found the inherent physical properties such as elasticity, rigidity, plasticity, as well as thermal, electrical, and absorbent properties.

Work which has been done on the thermal conductivity of woollen goods has shown that the looseness of the texture greatly affected the conductivity. It has also been found that the conductivity for heat has a definite relationship to the percentage of moisture absorbed. Staff estimates that the thermal conductivity increases approximately as the square of the relative humidity of the atmosphere in which the wool is placed. The woollen manufacturer is indebted also to the physicist for the knowledge that a woven material of open texture, having a hairy surface which entraps air, has greatly enhanced heat retaining properties.

Leather is another of our age-old industries, an industry which has long been held in the grip of tradition, but the work of science is rapidly penetrating its mysteries. It is recognised on all hands that the successful conduct of a business to-day consists in cutting down waste, and a leading authority tells us that at least half of the problems which occur in tanneries, leading to a poor quality of output and financial loss, are due to the unsatisfactory condition in which the tanner receives his raw materials.

Investigations are now being carried out on the physico-chemical changes which occur in the curing of hides for storage, between the time of flaying from the freshly killed animal and the time when the tanner is ready to treat these goods. The common method of curing is dehydration by sodium chloride, but it has been shown that unless the salt is applied to the goods in a clean condition the penetration of the salt into the substance of the skin is very slow and putrefactive changes, leading to the loss of the substance of the hide, will occur during the salting process. Moreover, a particular group of organisms, known as the halophilic organisms, are capable of existence and growth, even under conditions in which the hide is fully salted.

Following up an observation that French commercial salt, which is denatured with naphthalene for the purpose of making it inedible (on account of the salt tax), is not generally affected with halophilic organisms, a series of experiments was carried out which showed that this substance very materially checks the growth of the halophilic organisms and, therefore, assists in maintaining the condition of the hide during the time in which it is lying in cure. Many other substances give the same results, but naphthalene is readily obtainable pure at a cost which makes it a commercial proposition.

In these days, when economic pressure is leading to a tendency to shorten the period of tanning and, therefore, to the use of tans which penetrate rapidly into the hide, the experimental error in working, for the practical tanner, has become increasingly less. In the old days, the acid—which must be present in tan liquors—was obtained by allowing the liquors to ferment under the action of yeasts which grow freely on the surface and which, by decomposition of the tannins, produce organic acids in the liquor. This method was wasteful, both in tannins and time.

Scientific investigation led to the direct addition of acids to the tan liquors by the tanner. Of these, lactic acid is generally added to the tanning liquors, and sulphuric acid is frequently used to neutralise the lime, which is carried over by the skins from the lime yard as a result of the process used for removing the hair. It will be readily understood that the use of such acids, particularly of a strong mineral acid like sulphuric acid, requires very careful adjustment. The determination of the " acidity " of tan liquors by the old method of adding a lime solution to a tan liquor until the point is reached where the tans precipitate, is of very little use in dealing with an acid like sulphuric acid. The conception of measuring the effective acidity by means of the pH determination was then introduced and has had an increasing use in the tanneries of this country. It has been shown that to obtain a leather of good colour the earliest tanning liquors must have a pH value lying only within a very narrow zone. Roughly speaking, this must be between the values of pH 3 and 5. This range is, it can readily be seen, a very narrow one and in dealing with liquors like tan liquors, which have a varying extent of the buffering action, it is impossible for any works to run on a standard recipe; actual measurement of the pH value must be made continually to work inside this safety zone.

It was also shown that the acidity of the tan liquor has a very important influence on the final substance of the leather.

The use of the microscope as a routine method in tannery laboratories is of quite recent development, and as regards the commercially very important problem of substance and quality, the tanner has in this a very valuable instrument of laboratory control.

It can readily be understood that a colloidal system which owes its most important properties to histological structure must be amenable to the use of this tool. Quality, such as firmness or flexibility in a leather, is obtained by the degree to which the skin fibres are opened up into their separate fibrils. In a firm leather the fibres must be kept closely together throughout the process and drawn up by the astringent tanning liquors into a more or less vertical weave. In a soft, supple leather the fibrils must be, as it were, sprayed out from their original bundles, and should be kept running more or less parallel to the surface of the leather. It has now been shown that by following through the tanning process by means of the microscope it is possible to check the condition of the fibres at any stage of the process.

Do not let us imagine that the one idea of science is that of increasing output or reducing costs. The human side also comes in.

The problem of preventing anthrax among tannery workers has been the object of two years' important work. The trouble in disinfecting hides is that the anthrax spores are highly resistant to all ordinary methods of disinfection, and any drastic method leads to a very serious injury of the hides. By research a method has been found by which infected hides in a tannery can be disinfected with certainty without interfering to any great extent with the ordinary tanning process. When the work is completed, it is expected that it will have such favourable results on the tanning of dried hides that it will be used as a routine method, regardless of whether or not the goods are infected. Even when this point has been attained research will not cease, as it is felt on all sides that the control of anthrax should occur at the port of entry rather than at the individual tanneries.

Let us consider briefly how science is working in other industries. Taking agriculture, which comprises such subdivisions as bacteriology, botany, chemistry, entomology, and so on, we find here work of the following nature being carried out: (*a*) increasing the yield per acre; (*b*) altering within limits the percentage of various materials or characteristics in the crop; (*c*) investigation of the attack of disease organisms and pests and the finding of insecticides and fungicides to preserve plants; (*d*) discovery and cultivation of new raw materials.

Under the first of these headings comes the study of soil and its improvement, and the manuring for a higher crop production. This fertilising to produce a larger crop is not such a simple or straightforward problem as it may appear at first sight, since the fertiliser which might increase the crop might also introduce, or increase in the crop, a constituent undesirable to the industrialist.

An excellent example of this is shown in barley, a raw material of the brewing industry. In malting barley the amount of the " extract " varies inversely as the nitrogen content of the barley, while the diastatic power of the malt is directly as the nitrogen content. The brewer, therefore, requires a barley of low nitrogen content and his problem is to increase the yield per acre of the barley without raising its nitrogen content.

Experiments have shown that by using 1 cwt. of ammonium sulphate per acre a larger crop per acre can be obtained of barley suitable for brewing. One advantage of this fertiliser is that the greatest increase in yield is obtained in years when the crop is small and the least in years when the crop is abundant, so that it tends to even up the yield per acre.

Ammonium chloride is another fertiliser which gives a grain of low nitrogen content and increases the yield per acre. The brewing industry is also largely indebted to the sciences of biology, chemistry and biochemistry and it has, at various times, availed itself of the valuable work of Liebig, Pasteur, Buchner and others on the biochemical side.

The sugar industry, both cane and beet, are further examples of my theme. About thirty years ago the Java Sugar Growers' Association decided to form a research department, and to obtain funds for this purpose made an annual charge on its members of 5s. per acre under sugar cultivation. This brings in an income of £100,000 per annum. Among the benefits which have resulted from the establishment of this station is the new cane sugar plant termed 2878 P.O.J., which has a larger sugar content and gives a greater yield per acre than any of the existing varieties grown on the island. Moreover, this plant does not require to be reared in the highlands and then transplanted to the sugar field. From figures supplied to me I understand the increased yield per acre of this new cane amounts to about 30%.

The world's consumption of both cane and beet sugars has shown a steady increase from 2,000,000 tons in 1850 to 31,350,000 tons in 1929, which means that the consumption per individual has gone up from 4.18 lb. to 28.81 lb. during this period.

Many economies in working have been effected as a result of scientific researches, one example being the enormous reduction in steam consumption, which has fallen from 896 lb. of steam per ton of roots during the period from 1830 to 1850, to 100 lb. of steam per ton of roots in 1930.

In the beet sugar industry by a careful study of the beet itself it has been possible to raise the sugar content from 11% to about 18%. As chlorophyl plays an important part in the production of this sugar, it is with no surprise that one observes that the ratio of tops to roots has largely increased. Investigation has also shown that nitrogenous fertilisers deepen the colour and increase the size of the leaves, whilst reducing the weight of the root and the sugar content per 100 parts of leaf, and that full growth of the sugar beet cannot be obtained unless sodium, and perhaps magnesium and chlorine, are supplied to the plant.

Knowledge of organisms directly affecting plants, soil algæ, as well as disease organisms and pests, help to prevent loss of yield and to protect the crop. The loss which occurs from insect attack, and the study of insecticides necessary to prevent this loss, provides a great scope for science.

Two methods of attacking insect pests are available; one, to destroy the eggs before development, and the other to destroy the insect itself. The eggs offer the greater resistance to poison and, therefore, a stronger poison must be employed, but as this can be applied in winter, no harm is done to the foliage and fruit by the application of strong washes.

Washes which are applied in summer may kill either by contact, or by being taken internally, through the insect eating the leaves upon which the poison has been sprayed.

Research in insecticides has shown that promising poisons may be obtained from Dewis grown in Malay, Tephrosia obtained from tropical Africa, Haira, a native plant of British Guiana, and Pyrethrum which can be grown in temperate climates; and this investigation has reached the stage where it is possible to advise the grower whether he is increasing, diminishing or maintaining the toxic properties of the particular plant which he is cultivating.

Agricultural science by the development of an artificial farmyard manure is assisting the cultivator and, through him, the industries which use his produce as raw materials. This development has been brought about by a greater knowledge of how cellulosic material can be decomposed. This renders the farmer free from the necessity of maintaining a certain number of live stock and the necessary arable land for feeding purposes.

These few isolated examples show how science is working in agriculture and its importance to the agricultural industry.

In the building trades science is being used to account for various phenomena. The search for light materials for the construction of internal partition walls, etc., led to the use of breeze blocks formed by cementing together particles of furnace clinker with Portland cement. In several cases, after erection, serious cracks developed in these blocks and, although these were repaired, further cracking occurred to such an extent that the structure had to be demolished. Investigation showed that the failure was due to unburned, or partially burned coal in the clinker. All breeze blocks do not disintegrate in this way, although unburned coal may be present in the clinkers from which they are made. It was ultimately shown that it was not the coal but the kind of coal which was responsible for the trouble, and that this defect in the blocks would be present if clinkers were employed made from coals which were liable to spontaneous combustion.

The dislocation of traffic during the relaying of streets in our large cities has emphasised the need for a quick-setting cement, or the acceleration of the time of the setting of existing cements. New cements have been developed and existing cements accelerated, either by the inclusion of accelerators or by the employment of finer particles. The latter method is of special interest to the chemical engineer, since it opens up the very interesting question of grading large quantities of particles having very small dimensions.

The whole problem of the weathering of stone has been the subject of scientific investigation and the use of silicon esters, whereby a deposit of pure silica is made on disintegrated stone, with consequent hardening of it, is the outcome of this work.

In the manufacture of putty—a common material used by the building trades—science has been able to be of service. Putty is made by mixing whiting, essentially calcium carbonate, with boiled linseed oil and one might be inclined to think that in such a simple process science could be of little assistance. If, however, we try to mix pure calcium carbonate with acid-free linseed oil the resultant mass will be more like sand and water than commercial putty. Recent investigations have shown that to produce the gel structure required to give putty its plastic properties, alumina or iron oxide, to the extent of one part in ten thousand, or thereabouts, must be added.

Varnish is a material with enormous applications, and one of the difficulties is the question of " bloom." The " bloom " of varnish (a " veiling " of the surface revealed as a " loss of gloss ") is sometimes a deformity of the surface induced by certain conditions, and at other times it is a crystalline deposit of ammonium sulphate obtained from the atmosphere. The surface brittleness of brass has been long associated with the action of atmospheric ammonia, but as a result of the work on " bloom " of varnish it is now suggested that the initial mechanism of the breakdown of the brass is the formation of a deposit of ammonium sulphate, which can only form if the surface of the metal is sufficiently attractive to water. If so, the trouble would probably be minimised by rendering the surface of the metal more repellent to water.

An industry that has become increasingly important is that of laundering, in which science is playing a very large part. Many instances have arisen in which fabrics have failed without apparent cause since faults in the laundry had been carefully eliminated. Scientific study of such cases has shown that there was an inherent weakness in the fabric due to the bleaching process being too severe, resulting in the chains of celloboise molecules being broken into short lengths, which does not greatly affect the mechanical strength of the fibre in the early stages, but which renders the fibre more susceptible to chemical attack. The cuprammonium viscosity test has been of great service in this direction. Another interesting example for which a scientific explanation is forthcoming is the presence, from no apparent cause, of minute holes in woven goods, for example, in table linen. The British Launderers Research Association inform me that if these holes are carefully examined, tiny specks of metal will be found. These have a catalytic effect in the degradation of cellulose, this deterioration being more rapid when the material has to be subjected to alternate washings with soap and soda alone.

Investigation into the discolouration of woollen goods after repeated washings has shown that this may be due to two causes. The first results in a yellow tinge being given to the goods by the reoxidation of the colouring matter in the wool which was rendered colourless by bleaching. The second is due to the fact that wool, being an extremely absorbent material, takes up and retains traces of metals present in the washing water which gradually accumulate and impart to the garment a yellow or greyish tint. These metal particles may also accelerate the oxidation of the reduced colouring matter present.

Iron, steel and other metals and their alloys play an important part in the life of to-day, and in their winning and production we are more and more seeking the aid of science. On the advice of the geologist greatly depends whether or not money shall be expended on boring operations to determine if the ore is present and in what quantity it is likely to be found.

Within recent years, realisation of the enormous wastage which takes place annually by the rusting of iron and steels, estimated by Sir Robert Hadfield at £500,000,000 per annum, has led to the investigation of iron and steel alloys which would be more resistant to corrosion and to the production of chromium-iron and chromium-nickel steels. The behaviour of metals at high temperatures has also been investigated, and has shown that the ultimate tensile strength and creep stress, of iron and steel, fall off very rapidly after a temperature of about 200 to 300° C. has been reached. As the tendency of the present day is to use, in many reactions, high temperatures combined with high pressures, the metallurgist has again been called on and has succeeded in producing steels which have much greater strengths at high temperatures. On this branch of metallurgy depends, too, the ultimate development of high pressure boilers and steam power plants generally. In many other fields the metallurgist has been able to help industry by producing metals or alloys with greatly enhanced properties in a particular direction.

The physicist and electrical engineer knew that improvements in the transmission of signals through cables could be effected if the cables were continuously loaded with a material having a high magnetic permeability when placed in a low magnetic field. Until recently the best material which could be used for this purpose had an initial permeability of about 500 c.g.s. units, but research in this direction has resulted in a nickel-iron alloy, consisting of 78% nickel, and 22% iron, which has an initial permeability of 10,000 c.g.s. units. To give it this high permeability, however, it must undergo a definite heat treatment in which it is cooled at a definite rate from a high temperature. As the above permeability is greater than is required, other elements can be added to the alloy so as to improve other properties without impairing too much the initial permeability.

The development and improvement of permanent magnets by the discovery of cobalt steels by Professor Honda showed further advance. These steels contain 36% of cobalt and are oil-hardened at 1000° C., when they have a coercive force of 250 c.g.s. units and a remanence of 10,000, which is a considerable advance on the previous test made from a steel containing 0·6% carbon, 6% tungsten and a small amount of chromium, which gave a coercive force of 70 c.g.s. units and a similar remanence.

Sometimes the demand is for a non-magnetic steel and here again science has been able to meet the requirements by the production of steels of the nickel manganese type containing 25% nickel and 13% manganese, or of the chromium-nickel steels.

Everyone connected with the construction of plant has some knowledge of the great advances which have been made in the manufacture of tool steels. Great as these advances may be, the end does not yet appear to be in sight, for recently a new tool steel has been introduced which, it is claimed, can cut cast iron at a speed of 600 ft. per minute. A moment's thought will show the importance of such a steel to our engineering shops.

The oil industry is one in which science in all its branches is playing an increasingly important part. Upon the geologist depends the selection of the site where the well is to be drilled, whilst the drilling, capping and pumping of the well is dependent on the engineer. Once the oil has been brought to the surface, the separation into its various fractions becomes the work of the chemist and chemical engineer.

The following is an illustration of the type of problem met in this field of refining which has been successfully solved. The Anglo-Persian Oil Co. were faced with the problem of the removal from the distillate oil of certain thio-derivatives which gave to the oil an objectionable smell.

These thio-derivatives were shown to belong to the lower aliphatic mercaptans and the thio-esters, and oxidation at once suggests itself as a means of their removal. As in all commercial problems, the question of cost had to be considered, and it was eventually found that sodium hypochlorite provided the cheapest method by which this oxidation could be obtained. The limitation of the supply of oil, and the growth of the demand for oil products from day to day, have led to continued research with a view to the synthetic production of petrol.

Ipatieff carried out the purely theoretical investigation of the problem, and his work was developed first by Bergius in the hydrogenation of coal, and later, on a still larger scale, by the Interessen Gemeinschaft, who have made a plant which produced 70,000 tons of synthetic petrol during the past year.

The paper this afternoon by Mr. H. Tongue on "The High Pressure Equipment of the Chemical Research Laboratory, Teddington," gives an idea of the problems which are under investigation at these laboratories, and the type of plant which is being employed on these researches, the importance to industry of which cannot have failed to impress our members. For the work done on hydrogenation and de-hydrogenation of many organic compounds under catalytic conditions, industry is indebted to Sabatier and his co-workers, who thoroughly investigated the chemical aspects of the changes involved.

As a result of these investigations, industries have come into existence, and works have been erected, for the production of hard fats by the hydrogenation of unsaturated fats and fatty acids, the manufacture of synthetic butyl alcohol, decalin, tetralin, cyclohexanol and hydrogenated benzols, with their derivatives, many of which are useful in industry.

Many industrial distillation problems depend for their solution on the fact first enunciated by Young that certain liquid mixtures boil at temperatures below the boiling points of any of their constituents. In such cases, the liquid boils at a constant temperature, and gives off a vapour of constant composition as long as all the constitutents are present in the vapour. This azeotropic distillation can be used for drying organic liquids for the production of absolute alcohol, which by this method can be made almost at the same cost as alcohol of 95% strength, the production of esters by the distillation of an appropriate acid and alcohol in the presence of a catalyst, and the dehydration of acetic and formic acids.

The production of quinine is an instance where science will have to come to the help of industry. Professor Muller of Cologne estimates that 800,000,000 people suffer from malaria and Sir Ronald Ross estimates that this disease is fatal in 2,000,000 cases every year, whilst Dr. Andrew Balfour placed the monetary loss to the British Empire from this disease at between £50,000,000 and £60,000,000 per annum. Cinchona, from which the quinine is obtained, is grown in India and Java and the South American forests. Java is responsible for 90% of the world's supply of cinchona bark, while India, with 4% does not produce sufficient for its own consumption. Dr. Cowan has pointed out that "to grow cinchona on the same land for a considerable number of years, is a difficult and hazardous undertaking, for the first crop, in a manner not altogether understood, renders the soil at least temporarily incapable of producing a satisfactory second crop." With an unrestricted area of forest land this is not a serious matter, but as the shortage of virgin forest land increases with the years, the problem becomes acute, and it is here that scientific research will be necessary to effect its solution, either by finding suitable means of treating the land, or by the development of the tree in such a way that an increased output per acre is obtained. On the other hand, science may effect a solution by synthesis of quinine from more easily obtained raw materials.

With the development of the ultra-violet ray, another scientific instrument has been put at the disposal of industry, which has taken human vision a stage past the ordinary possibilities of sight and has given the scientist a new eye, of great value in the laboratory.

The ultra-violet ray is used in the manufacture of patent leather, the object being to toughen the varnish medium so that it forms a hard bright surface that will remain pliable.

The modern quartz lamp apparatus transmits rays of wave-lengths from 3,000 to 4,000 Angstrom Units, all visible rays being stopped. These rays, after absorption by a substance are often emitted having a longer wave-length which is within the visible range. A large number of organic and inorganic substances, by this means, exhibit characteristic fluorescent colours, which property is made the basis of a simple and rapid method for testing and identifying materials.

In the rubber industry ultra-violet rays may be used for checking the purity of zinc oxide, lithophone, oils, accelerators, etc., and for the detection of errors in mixings due to mistakes in the incorporation of the ingredients. Changes can also be detected rapidly and systematically followed, such as those produced by natural or artificial oxidation and ageing.

In certain cases this method of analysis is useful where ordinary methods fail, as for example, in the detection of the addition of treated olive oil, soya bean oil and other adulterants, to the natural olive oil.

Industry must make proper use of research. Research is a much abused expression, and the industrialist has often expected more from it than could possibly be obtained in any circumstances.

There is a feature of interest that must be borne in mind in this connection, namely, that there is a time-lag, a very definite time-lag, between developments in the laboratory and execution in the factory. If a particular case is followed through, this is generally the line of events. Circumstances arise which demand that some product be made and the research department is put to work on it. This work may take a longer or shorter time, depending on whether it is necessary to dig deep down into the fundamentals of the problem, or whether these fundamentals are already known. When the work is completed, it is then presented to the board of directors, and it is at this stage that delay and difficulties so often arise. First of all, the scientific staff have to be able so to put their case that the whole board may appreciate it, and realise the necessity, or otherwise, of carrying it out. There is an inherent difficulty in this, namely, that the unscientific man has either to trust his scientific staff entirely, and go blindly on their advice or, alternatively, he must take sufficient time to convince himself, as far as he is able, that what is claimed can be done, and at the cost mentioned.

This is always more difficult when a Board is composed entirely of industrialists and has not sufficient weight of technical directors. It is at this stage that the time-lag develops and permission to proceed with a scheme, or its rejection, will vary depending on the mentality and training of the directors.

I have been told recently by the scientific head of one of our big concerns that he estimates that it takes an average of two years from the time a complete scheme with its reports has been handed to his directors, before instructions are given by them to begin operations. This time-lag is very important. Unless in these modern days, when decisions must be arrived at promptly, there is enough technical ability on a Board to come to quick decisions, opportunities for obtaining a market may easily be delayed so long, that the cream of the business has gone elsewhere.

In the selection of the title for my address I have used the expression SCIENCE IN INDUSTRY. I feel very strongly that in the past we have had science as an appendage to industry. Science was used in the past in the way that doctors were used, that is, called in when it was too late to do anything. I am pleading for science to be a fundamental part of industry.

Now, all this seems to show that it is essential in modern industry that there should be scientific representatives on boards of companies in whom their non-scientific colleagues have sufficient confidence, to enable decisions to be taken in a reasonable time.

Do not let us blame the industrialist. In the past the industrialist director has suffered much from the scientific side, simply because the scientific man has not been sufficiently interested in the financial or the commercial aspect of business. After all, in these progressive days every phase of a business must be represented on the board in order to get a proper balance between the commercial, the financial and the scientific sides, each with confidence in the other, so that quick decisions can be made.

Have we not, all of us, seen the attitude of mind adopted by many scientific people towards commerce and finance. It is so often one of superiority, if not almost of contempt, and it is this whole spirit that must be altered. It may have arisen through the teaching of some of our professors in the past who felt that it was rather *infra dig.* for a scientist to be concerned with commerce or finance, as it not only lowered his " tone " but had a demoralising effect on his scientific judgment.

Whatever may have been the cause, we have all to realise that to-day science is a part of industry and must become increasingly more so ; and if we in this country are to hold our own in the world's markets it will be only when industry takes science completely into partnership.

THANKS TO THE PRESIDENT.

SIR ALEXANDER GIBB (Past President), proposed a hearty vote of thanks to the President for his Address, which proved conclusively that industry could not exist without science, and that it was almost entirely dependent upon it. Further, he had woven a mystic web of science around such homely matters as boots, clothing, whisky and noxious insects, which had added very much to the interest of the Address. The members had expected to hear something good from Mr. Reavell, and they had certainly not been disappointed.

PROF. W. E. GIBBS, seconding, said that the President's survey of the role of science in industry was very stimulating, and the width and breadth of that survey was amazing.

The vote of thanks was accorded with acclamation.

THE PRESIDENT briefly responded, and the meeting was adjourned.