DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT

FOR THE YEAR

1933-34

Presented by the Lord President of the Council to Parliament by Command of His Majesty January, 1935

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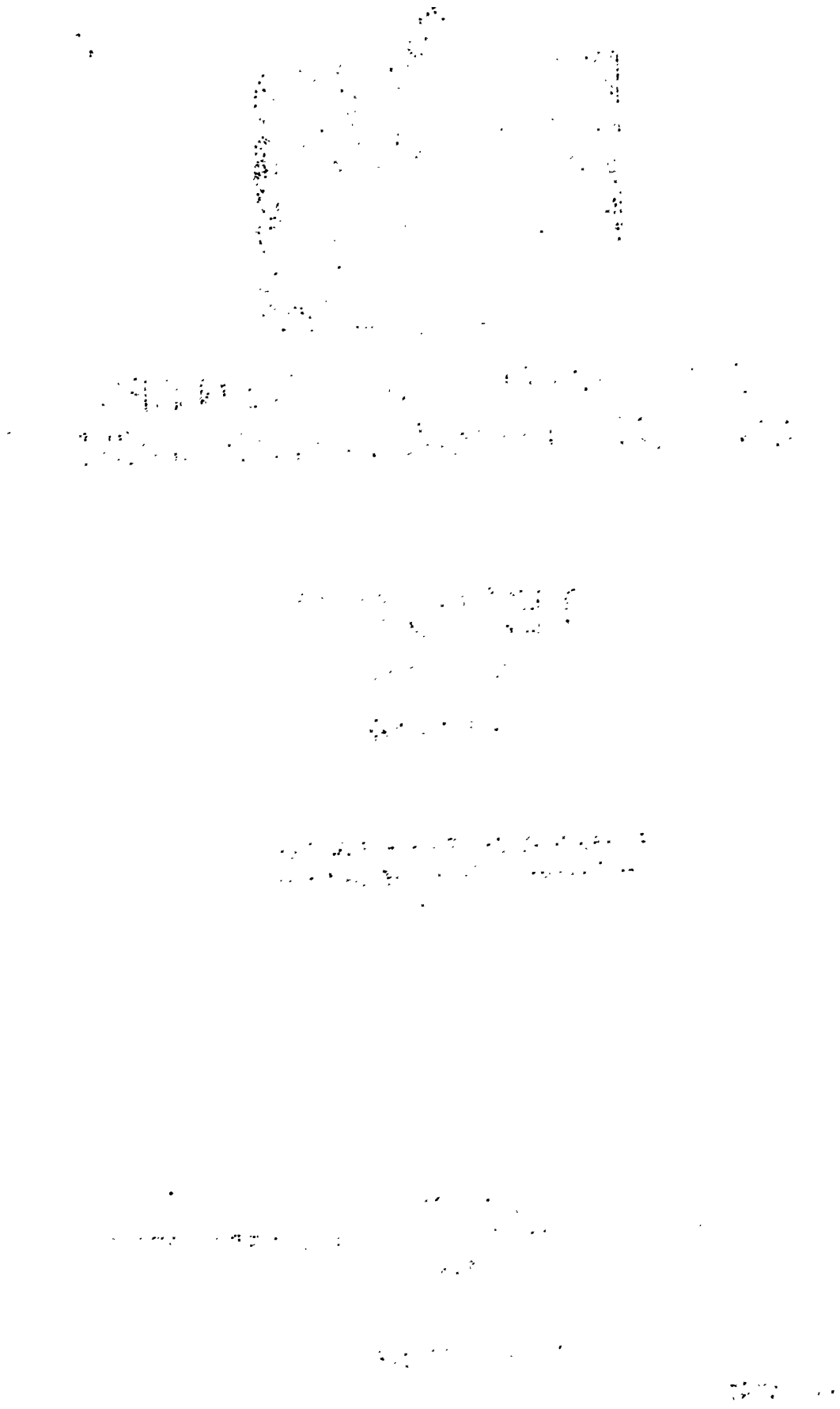

CONTENTS

REPORT OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF THE ADVISORY COUNCIL

SUMMARY OF WORK

RESEARCH ASSOCIATIONS

APPENDICES

REPORT OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH FOR THE YEAR 1933–34

TO THE KING'S MOST EXCELLENT MAJESTY IN COUNCIL

MAY IT PLEASE YOUR MAJESTY,

WE, the Lords of the Committee of Your Majesty's Privy Council for Scientific and Industrial Research, humbly submit to Your Majesty the Nineteenth Report of our proceedings covering the period from 1st October, 1933, to 30th September, 1934. We subjoin the Nineteenth Report of our Advisory Council. To this is appended a general review of the work carried out by the Department, together with a section describing the work of Research Associations.

THE ADVISORY COUNCIL

Three members retired from the Advisory Council during the year, viz., Sir Arthur Balfour, Bart., K.B.E., J.P., Sir William H. Bragg, O.M., K.B.E., D.Sc., F.R.S., and Lord Rayleigh, Sc.D., F.R.S., whose periods of appointment terminated on 31st July, 1934. We desire to record our appreciation of the valuable services they have rendered.

With great pleasure we learnt during the year that Your Majesty had been graciously pleased to confer the honour of Knighthood on Sir Kenneth Lee.

RESEARCH BOARDS AND STANDING COMMITTEES

A number of members of research boards and standing committees of the Department have retired during the year under the rules governing the periods of their membership, and we have appointed new members to fill the vacancies thus created. These changes are shown in the list of Boards and Committees in Appendix I. The assistance which these bodies render to us is invaluable, and in associating ourselves with the expression of appreciation of their work which concludes the report of our Advisory Council, we desire especially to record our indebtedness to all retiring members for the services they have so willingly given.

Research Associations

The most important of our proceedings during the year concerned the provision of further grants to Research Associations to be offered on conditions which would secure a larger measure of support from the industries benefited. Some twelve months ago we received representations from our Advisory Council that conditions were then favourable for beginning a movement to secure increased financial contributions from industry for the Research Associations. In March last we were pleased to be able to make the public announcement which is set out in full in the report of our Advisory Council.

Building Research Board

We have during the year reconstituted the Building Research Board to conform to the general principle which we have adopted in recent years of confining membership of Research Boards to independent members and providing for the representation of Government departments by assessors. The present constitution of the Board is shown in Appendix I.

Dental Investigation

During the period under review we received notification from the Dental Board of the United Kingdom that, owing to the extent of the existing and irreducible calls upon its available funds, the Board found itself unable to continue to finance beyond 31st March, 1935*, the investigations on dental materials which have been in progress for many years at its expense under the supervision of our Dental Investigation Committee. Steps were taken in accordance with the wishes of the Board to ensure that the researches in progress should be brought as soon as possible to a stage at which the work could be wound up with the minimum loss and the results placed on record as a starting point for further research. We learnt of the Board's decision with very real regret and, while we appreciate that, in the circumstances in which the Board found itself no alternative was open to it, we trust that the Board may see its way at a future date to make renewed provision for work which we believe has already yielded valuable results, and that the researches may be considered merely to be temporarily discontinued.

Empire Timbers Committee

Mention is made in the report of our Advisory Council of the dissolution of the Empire Timbers Committee, on the termination of the payment made to the Department by the Empire Marketing Board for the investigation of Empire timbers, and the establish-

* Since this report was made, the Dental Board has agreed to continue till 31st March, 1936, one investigation which had reached a promising stage.

ment of a Standing Conference on Timber Utilisation. We take this opportunity of thanking the Committee warmly for the valuable work it has done.

Fabrics Research Committee

Three years ago we reported the dissolution of the Fabrics Co-ordinating Research Committee and the appointment of the Fabrics Research Committee in its place for an experimental period. During the past year the Committee has submitted a review of its work from which it appeared that the researches undertaken had been completed and that the only task remaining for the Committee was the advisory work in connection with Service specifications. Arrangements have been made departmentally for the continuance of this advisory work and the recommendation of the Committee, endorsed by the Advisory Council, for its dissolution has been accepted.

Mechanical Testing of Timber

During the year we have received the Report of the Committee on the Mechanical Testing of Timber which we appointed in 1929, with Sir Alfred Ewing as Chairman; and the Report has now been published. We desire to express our appreciation of the services rendered by the Committee. We feel assured that the results of its work will be widely welcomed and that the recommendations made in the report will be of great service in assuring that the maximum usefulness and reliability is attained in test work.

Patents

During the period under review fifteen British patent applications have been filed, and ten British patents (with, in one case, two foreign equivalents) and patent applications have been allowed to lapse or have been abandoned. The subject matter of the new applications covers the improved manufacture of glycerol derivatives and of ascorbic acid and its analogues, a method of adjusting the water content of concretes or mixtures of granular materials, improvements in and relating to radio direction-finding apparatus, in cooling or heating systems and apparatus, and in wireless signalling, improvements in indicating instruments, in the preparation of base exchange materials for water softening, and in processes for obtaining motor spirit and lubricating oil from rubber, gutta percha and similar materials, apparatus for measuring the relative brightness of objects, including clouds, smoke and the like, a process for pickling and preserving materials containing oils and fats, improvements in extensometers and strain gauges, improve-

ments relating to the production of low temperatures, the use of cathode ray oscillographs with internal electrodes, and the use of iodised wraps and packings for the preservation of foodstuffs.

Further licences have been granted under the British patents for the anodising and colouring of aluminium, while the foreign equivalents to these patents have been disposed of for a cash consideration, subject to certain conditions. Licences have also been granted for the " wetting out " agent being marketed under the name " Shirlacrol." In addition, licences have been acquired by firms under patents covering a portable charcoal burner, an electrical distant-reading thermometer, an improved method of recording sound, and a method for the storage of fruit. Negotiations are also proceeding for licences under the various wireless and direction-finding patents.

As a result of the efforts made to exploit departmental patents various industrial organisations have consulted the Department concerning the utilisation of the patented results of research. A Chemical Patents Committee has been appointed to advise upon the patenting and exploitation of the results of the Department's chemical researches that may have industrial possibilities. In addition to departmental members the Committee includes representatives of the Association of British Chemical Manufacturers and of the British Chemical Plant Manufacturers Association.

International Congresses and Foreign Visits

Professor G. T. Morgan, Director of Chemical Research, was appointed one of the delegates of Your Majesty's Government at the Ninth International Congress of Pure and Applied Chemistry held at Madrid in April, 1934.

A representative of the Geological Survey attended the Jubilee Celebrations of the Swiss Geological Society in September, 1934.

Mr. J. E. Sears, Superintendent of the Metrology Department of the National Physical Laboratory, attended the Eighth General Conference of Weights and Measures held in Paris during October, 1933, as official delegate of Great Britain. He also, during the same period, attended the meetings of the International Committee of Weights and Measures, of which he is a member.

During June, 1934, Mr. J. E. Sears visited the Physikalisch-Technische Reichsanstalt, Berlin, to take part in an intercomparison of the metre end-standards of the National Physical Laboratory and of the Physikalisch-Technische Reichsanstalt in terms of wavelength, using the apparatus of the latter institution. Arrangements have been made for a similar intercomparison to be carried out at Teddington.

At the request of the Government of the Union of South Africa, Dr. R. G. Tomkins, of the Low Temperature Research Station, visited the Dominion to consult with the authorities there on the citrus industry.

Mr. A. Lumley, the Superintendent of the Torry Research Station, visited Norway at the request of the Sea-Fish Commission to report on the brine-freezing and cold-storage of herrings.

Director of Food Investigation

We desire to associate ourselves with the tribute paid by our Advisory Council to the memory of the late Sir William Hardy, D.Sc., LL.D., F.R.S., who from 1917 till his death was Director of Food Investigation and for eight years was a member of the Council itself. To succeed him as Director of Food Investigation we have appointed Mr. E. Barnard, D.S.O., who had been Assistant Director since January, 1931.

Director of Forest Products Research

We have appointed Mr. W. A. Robertson, late of the Indian Forest Service, to be Director of Forest Products Research, in succession to Sir Ralph S. Pearson, C.I.E., LL.D., to whose retirement we referred last year.

Expenditure

A summary of the expenditure of the Department during the year ended 31st March, 1934, will be found in Appendix V. The total net expenditure was £476,897 as compared with £451,952 in the preceding year.

STANLEY BALDWIN,
Lord President.

F. E. SMITH,
Secretary.

January, 1935.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH,
16 Old Queen Street,
Westminster,
London, S.W.1.

ADVISORY COUNCIL

(1933–34)

Lord RUTHERFORD of Nelson, O.M., D.Sc., LL.D., F.R.S. (*Chairman*).

Sir ARTHUR BALFOUR, Bart., K.B.E., J.P.

Sir WILLIAM H. BRAGG, O.M., K.B.E., D.Sc., F.R.S.

E. J. BUTLER, Esq., C.M.G., C.I.E., D.Sc., M.B., F.R.S.

A. C. G. EGERTON, Esq., F.R.S.

Professor A. FOWLER, D.Sc., Sc.D., F.R.S.

Sir CLEMENT D. M. HINDLEY, K.C.I.E., M.Inst.C.E., M.Inst.T., M.I.E. (Ind.).

Sir KENNETH LEE, LL.D.

Lord RAYLEIGH, Sc.D., F.R.S.

T. FRANKLIN SIBLY, Esq., D.Sc., LL.D.

N. V. SIDGWICK, Esq., O.B.E., Sc.D., F.R.S.

Sir FRANK E. SMITH, K.C.B., C.B.E., D.Sc., LL.D., Sec.R.S. (*Secretary*).

REPORT OF THE ADVISORY COUNCIL 1933–34

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, your Advisory Council, beg leave to present our Nineteenth Annual Report.

SIR WILLIAM HARDY

It is with great regret that we have to record the death, during the period covered by this report, of Sir William Hardy, D.Sc., LL.D., F.R.S., the first Chairman of the Food Investigation Board and Director of Food Investigation from its establishment in 1917 till his death. From 1920 to 1928 he was a member of our own body, on which his independence of judgment and his robust commonsense made him invaluable, while the charm of his vigorous personality endeared him to all his colleagues. But it is to his work as Director of Food Investigation that we desire to pay special tribute. To the scientific insight and imagination which he brought to this task and to the unsparing devotion with which he pursued it this country is deeply indebted. Elsewhere in this report we give some account of the scientific co-operation throughout the Empire which has been developed among workers in the field of research which occupied his later years. Hardy would have asked for no better memorial than the imperial team work which owed so much to his inspiration, enthusiasm, and ideals.

RESEARCH ASSOCIATIONS

Last year our report was chiefly devoted to a general review of the research association movement, its underlying principles, its development and the lessons to be drawn from its progress to date. We emphasised that the scale on which the majority of the associations were operating was, in our view, totally inadequate if these organisations were to serve effectively the great industries which they represent and to enable this country to recover its competitive powers in trade. We expressed the opinion that the conditions of the day were favourable to a strong forward movement

on the part of British industry. These views were shared by certain leading industrialists with whom we examined the position, and as a result representations were made to Your Lordships to ascertain whether the Government would give a further lead in the matter and so encourage British industries to place the associations established for their benefit on a more adequate and therefore on a more permanent footing. Those representations were received by Your Lordships with sympathy and met with a response which found public expression from the President of the Board of Trade, speaking for Your Lordships in the unavoidable absence of the Lord President. The words he used are so important that they may well be repeated here :—

> " With regard to the attitude of the Government towards this movement, I can assure you that we are watching it with great interest, and hope to see it develop to a very much greater extent than at present. You are aware of the views of the Advisory Council of the Department on this subject, and I have no doubt that you share their opinion that the present scale of operations is totally inadequate if the Research Associations are to serve their full purpose. I look forward with confidence to industrialists of this country mending matters in this respect, especially now that the prospects of trade look more promising. If they do, you may rely on the Government, on its side, being prepared to play some part in the forward movement and to help extend the scale of operations.
>
> " The published estimates which have been presented to Parliament include a material addition to the amount of State aid that will be made available, if Parliament approves, for the support of Research Associations in the coming financial year. That additional money is to be provided in the belief that industry is sufficiently convinced of the worth of these Associations to augment substantially the funds placed at the disposal of them, especially with the prospect of the inducement to which I have drawn attention. Before the Government can consider any further increase in support of these Associations, they will naturally enquire what you are doing about it, or have done."

By that announcement Your Lordships indicate that our representations have the full sympathy and support of the Government; but it is made amply clear that British industry needs to show in a practical fashion that it is convinced that the application of science to its manifold processes is not merely desirable but is a necessity under modern conditions of world competition.

Following this announcement, we convened a conference in March last, when we had the advantage of exchanging views with leaders in twenty different industries, all possessing co-operative research associations. We desired to obtain the benefit of the

collective experience of those responsible for the control of research associations and to enlist their support in the movement to increase the associations' scale of operations. There was ample evidence that those present shared our conviction that the future prosperity of British industry depended largely on the extent to which science was enlisted for its further efficiency. It was agreed on all hands that the research association movement had done and would do much towards this end. Moreover, evidence was forthcoming that the practical sympathy of the Government would encourage further financial support from firms, and all present agreed to go back and think out with their colleagues enlarged programmes and means for their development. Since then we have conferred with ten research associations and discussed with them arrangements for the future which will secure from industry greater financial support and so lead to a greater degree of permanence.

In these discussions, we have constantly had in view the inadequacy of the scale of operations of the associations, particularly of the smaller ones, and our proposals have been designed to remedy this. Where circumstances warrant it, we are recommending substantial block grants, which, with the support from industry upon which they will be conditional, will provide at least a satisfactory nucleus of an effective organisation. It is the intention moreover that these block grants should be offered for a period of, say, five years in each case, because of the need of the associations for stability of finance. It is impossible to plan intelligently under uncertain conditions of finance, when the short view tends inevitably to prevail over the long, with the result that researches which are vitally important though not immediately productive tend to be crowded out by ad hoc enquiry. Research associations, in short, cannot carry out effectively the researches which are required in the interests of industrial progress or make plans for important sections of their programmes of work unless they can offer prospects of reasonable financial security to their scientific staffs; and they can only hope to do this if they can be assured of financial support to enable them to develop their activities over a period of years.

At the same time, we do not think that the scale of operations which will thus be made possible is one with which the industries should rest content. There will still be room for considerable expansion before the associations can be held to be in a position to give fully effective service to the industries they represent; and we propose to encourage such expansion by recommending additional grant on income raised in excess of a specified figure, up to a prescribed limit. We are well aware that so long as associations are run upon a purely voluntary basis increases of income may become progressively more difficult to obtain; and we have taken account of this in fixing the scale of additional grant. We feel confident that when these plans have been carried into effect they will result in increased stability and increased opportunities for further expansion.

In the preceding paragraphs we illustrated the necessity for greater financial security in the associations, by mention of the more prolonged researches which are of such importance to the ultimate interests of many industries, but which, as already pointed out, cannot be prosecuted with constant vigour unless reasonable prospects of a career can be offered to the scientific staff. But the appeal to industry to support their associations on a more adequate scale must not be assumed to rest wholly, or even mainly, on the expectation of future benefits.

In the first place it is easy to cite instances of industries which are to-day reaping the benefits of research pursued in earlier periods; their ability to help themselves in the present has, in fact, been made possible by patient study in the laboratory in the past. In the same way a scientific organisation needs to build up the necessary intellectual capital if it is to be in a position to give effective help both in dealing with everyday problems and in suggesting new lines of advance. The research associations, which already have behind them many years of work, are undoubtedly becoming more and more capable of rendering such assistance.

Further, the prosecution of research, while of vital importance to an industrial organisation, is not the only means by which science can help industry, and there are other more immediately practical ways in which the research associations can, and do, assist in attacking industrial problems. In many cases the need can be met by the application of existing knowledge; in other cases a series of tests, or ad hoc investigations, will suffice to solve the immediate problem. Equally with research we must lay emphasis on the immediate practical advantages which industry can derive from adequate support and adequate use of their research associations.

We are convinced that the practical outlook requires to be informed by that faith in scientific research which comes only with first-hand knowledge. Three years ago, in a review of the national organisation for research, we laid stress on the need for scientific method in all branches of industrial activity and for machinery which would ensure the application of scientific knowledge. We drew attention to the great advantage possessed by the research associations in the readiness with which they lent themselves " to the promotion of contact between the scientific worker and the industrialist—a vital point," and we went on to describe them as providing the " General Staff " of the industry in applying scientific ideas to technical problems. It is a scientific habit of mind and vigilant and continuous examination of manufacturing practice in the light of available technical knowledge that alone will ensure for industry the fullest advantage of new advances. " Scientific research has in the past made striking contributions to industrial progress and it will make them in the future. But the nation which will enjoy the benefits of science in the day-to-day progress of its industries is the nation which habitually applies scientific method

and scientific knowledge; and it is that nation which will be able to seize the advantages of the more spectacular achievements of science in the industrial sphere."

Researches Conducted with the Financial Co-operation of Industry

From time to time mention has been made in our annual reports, or in the summary of progress appended thereto in the published annual report of the Department, of new researches begun by the Department with the financial and technical co-operation of industry. We are not referring to those special investigations or tests which individual firms or organisations ask the Department to carry out in its research stations, and notably at the National Physical Laboratory, as a repayment service. The facilities of the research stations of the Department are readily held at the service of industrial undertakings and the volume of the use made of these facilities by industry is indicated by the receipts shown in the Department's Estimates as presented to Parliament*. Nor do we refer to such considerable investigations as that into the effect of the discharge of crude sewage into the River Mersey, described in our report of two years ago, the cost of which is wholly borne by the Mersey Docks and Harbour Board, other interested undertakings and the Merseyside local authorities. We have in mind the encouraging growth in the volume of research which the Department, on our recommendation, has from time to time agreed to undertake as a demonstration to industry of the value of co-operation in the conduct of researches and investigations which are either too expensive or too lengthy to be attempted save by some large industrial association or by a group of firms. A large part of the cost of such researches is provided by contributions made by the co-operating firms, either directly or through some industrial organisation, and the balance of the cost is borne by public funds. We mention these researches because the object of the contribution from public funds made to their cost on our recommendation is very similar to that of the grants made to research associations. The scale is, of course, different, for while the grants to research associations are grants towards the cost of a research organisation and intended to put it on an adequate and permanent basis, the expenditure we have in mind is directed to specific researches. For this reason whenever possible we prefer that the problems to which the researches are directed shall be dealt with by a research association; but there remain many problems needing attention which cannot be handled in this way, because no suitable association yet exists or for other reasons. As an indication of the extent to which such arrangements have been made we summarise below those current in the year under review.

At the National Physical Laboratory the William Froude Labora-

* See also Appendix V, p. 164.

tory is mainly occupied in carrying out, in one or other of its two Tanks, tests of designs for new ships. The value of these tests to the industry which pays for them depends, not only on continual study of technique, but on the maintenance of a steady volume of research work into such questions as the effect of waves on resistance and pitching of ships and their propulsion, the effect of wind resistance, the behaviour of rudders and the improvement of propellers; all matters of vital importance to the shipowner whose profits depend on extracting the last economy in the running of his vessel. Research work of this kind is carried out in the William Froude Laboratory and financed as to one half from a fund maintained by industrial subscriptions, for the collection of which the industry is in large measure indebted to the Institution of Naval Architects.

In another department of the National Physical Laboratory important investigations are made for the practical development of steels for use at high temperatures. Developments in engineering practice constantly wait on improvements in the materials used. To secure the highest efficiency in the turbine it is necessary to work at constantly increasing temperatures, while advances in modern chemical engineering require the use of steels capable of withstanding ever higher temperatures and pressures. The investigations aiming at the assistance of industry in this way which are in progress at the Laboratory are financed as to at least one-half from funds raised by the British Electrical and Allied Industries Research Association and the British Iron and Steel Federation. In the same Department investigations have been begun on the design of pipe flanges for power plant involving the use of steam at high temperatures and pressures, and a large part of the cost is being met from funds provided and collected by the Institution of Mechanical Engineers.

At the Building Research Station a number of investigations have been and are being undertaken in co-operation with various branches of the building industry. The subjects cover a wide range. Steelwork so extensively employed in modern building practice is not used to the best possible advantage because of inadequate knowledge of the data which should determine building requirements and specifications. It is therefore necessary to insure against this lack of knowledge by using margins of safety which it may often be possible to reduce when the knowledge is forthcoming, thus securing improvements in design and economies in construction. The work of the Steel Structures Research Committee, which is directed to this problem, began in 1929 and is supported by substantial contributions from the British Steelwork Association. Natural pozzolanas, of which there are notable deposits in Germany and Italy, have proved of great value in increasing the resistance of concretes and mortars to certain forms of chemical attack. Investigations to discover British sources of materials that could

be used for the same purpose, which have led to results likely to be of commercial importance, have been supported by the Associated Portland Cement Manufacturers, Imperial Chemical Industries, and the Anglo-Persian Oil Company. The Institution of Civil Engineers is collaborating in an investigation of the effect of sea water on concrete, in the course of which 474 reinforced concrete piles and 5,388 cylindrical specimens of concrete have been prepared. The piles and cylinders are being exposed to sea water at Sheerness and on the Gold Coast. Two years ago we mentioned in our report an investigation into the problems of driving concrete piles, which was of scientific interest because of the use of the cathode ray oscillograph and the technical co-operation of the Radio Research Station, which had developed the technique of this instrument for the study of atmospherics. This investigation is supported financially by the Federation of Civil Engineering Contractors, and is yielding important results. For the continuous study of heating and ventilating problems throughout the year, instead of during the winter when the necessary weather conditions obtain, a "controlled weather" house is being erected with the financial co-operation of industry secured through the Institution of Heating and Ventilating Engineers. Other co-operative investigations include a study of greystone limes, with the co-operation of the Greystone Limeburners' Association; an investigation into cast concrete products with that of the Cast Concrete Products Association; researches into a range of problems concerning concrete and reinforced concrete, to the cost of which contributions are made by the Reinforced Concrete Association; researches into welding in steel structures to which Messrs. G. D. Peters and Metropolitan Vickers are contributing; researches into the uses of mastic asphalt in building, assisted financially by the Natural Asphalte Mine Owners' and Manufacturers' Council; and investigations into clays and bricks which are largely financed by the Federation of Clay Industries and the London Brick Company and Forders, Ltd.

In other fields the British Road Tar Association is co-operating in work on Road Tars, the Rubber Growers' Association in a research dealing with mixtures containing rubber, and the Association of British Chemical Manufacturers in work on the development of methods for detecting the presence in the atmosphere of toxic gases such as may occur in industrial processes.

Negotiations for further co-operative investigations are continually in progress; for example, extensions of the investigations on chains which have for some years been in progress at the National Physical Laboratory (the further investigations proposed having the special object of developing the manufacture in this country of electrically welded chain) and also investigations on the failure of boiler plates. In both cases conferences with representatives of the industrial interests concerned have been held and there is good reason to

hope that in the near future definite arrangements for co-operative work may be concluded.

In addition to the cash contributions made by industry in respect of these co-operative investigations we should mention the contributions, in kind, such as are made, for example, by the Railway Companies and the Timber Trades Federation to investigations carried out in co-operation with the Forest Products Research Laboratory, involving service trials of timbers on a large scale, or by industrial undertakings to assist particular researches at the National Physical Laboratory. Further, no reference to these contributions would be complete without appreciative mention of the unconditional cash contributions made to the general work of the Department in special fields by industrial bodies or firms. In the financial year ended 31st March, 1934, contributions were received from the Institution of Mechanical Engineers and the Armourers and Brasiers Company for research work at the National Physical Laboratory on the alloys of iron, while the British Electrical and Allied Industries Research Association contributed to the cost of the industrial applications of X-ray analysis. The Institut International du Froid and Imperial Chemical Industries contributed to the Department's work on food investigation. The work of the Building Research Station was similarly assisted by the Royal Institute of British Architects.

Three instances may be quoted of researches which have been transferred to the supervision of industry since the date of our last report on the ground that their value to industry has now been fully demonstrated. The first two are researches carried out for the Department at the Research Department, Woolwich. One, the steel castings research, was originally undertaken in the interests of the Services themselves, but the rapidly increasing co-operation of industry made it possible to leave to the Iron and Steel Industrial Research Council the organisation of the share taken in the work by manufacturers. The researches on electro-deposition, which in the main were also undertaken in the first instance in Service interests, are now to be transferred to the supervision of the British Non-Ferrous Metals Research Association. The third example is the research already mentioned which has been carried out at the National Physical Laboratory, with the financial co-operation of industry, into steels for use at high temperatures. This research will in future be supervised and financed jointly by the British Electrical and Allied Industries Research Association and the Iron and Steel Industrial Research Council.

Co-operation in Research with the Empire Overseas

Storage and Transport of Food

In one field of the Department's work, research into the storage

and transport of foodstuffs, there has been scientific co-operation with the Dominions overseas from an early date. The Food Investigation Board was established during the war, when the circumstances of the time directed anxious attention to the fact that the people of these islands were dependent upon imports for the greater part of their food. In laying plans for the future, it was natural that particular regard should be had to the development of the supplies from the Empire overseas, and the improvement of the conditions under which they were brought to this country. The technical problems involved in bringing beef, mutton, and fruit from Australia, New Zealand, and South Africa had already been studied by the Food Committee set up by the Royal Society at an early stage of the war, of which Sir William Hardy, afterwards Director of Food Investigation, was Secretary. The field had already been surveyed, and the necessity for more scientific knowledge of the conditions affecting the transport of these foodstuffs was abundantly clear. From the first, Sir William Hardy established close personal contacts with the principal shipping lines bringing foodstuffs to this country from the distant parts of the Empire, and with the Port of London Authority, and thus secured their active co-operation. He was equally successful in securing the sympathy and support of distinguished workers in the scientific field, and in arousing their interest in aspects of the biophysics and biochemistry of post mortem change in meat and fish, which had hitherto made only a limited appeal to investigators. In the case of living material, i.e. fruit and vegetables, more knowledge was available and more rapid advance in its application was possible. The interest of the Dominions was aroused at an early stage. Some of the first problems envisaged concerned particularly the supply of fruit from South Africa, while, before the public was familiarised with the new movement in research by the establishment of the Empire Marketing Board, two expeditions had been sent by the Department to Australia to study, with the ready co-operation of the shipping lines and, in the second case, the financial support of Tasmanian apple-growers, the technical problems of the transport of apples to this country. But in all this development care was taken to keep the interests of the home producer in the forefront. It was, indeed, Sir William Hardy's concern lest these interests should be overshadowed by the scientific appeal of the problems of transport from the Dominions that led him first to explore the effects on apples of the composition of the atmosphere in which they are stored. The work was undertaken, primarily, in the interest of the grower in this country. In what is known as " gas storage " the results have today been put into practice on a large scale for the benefit of the home industry. But it is a striking instance of the truth that science knows no territorial boundaries, that the first commercial application of the new knowledge was made in the transport of Australian apples. The determination of the limits within which

apples will tolerate the accumulation of carbon dioxide produced by their own respiration opened a new field in the control of conditions in ship's refrigerated holds, and at once showed how those conditions which had caused serious losses, through the functional disease known as "Brown Heart," could be avoided. It was for the study of the control of these conditions that the two expeditions to Australia were arranged.

When therefore the Empire Marketing Board was established, the work of the Department had already reached a stage at which a considerable forward movement was possible and, indeed, desirable. By contributing funds for this development the Empire Marketing Board rendered a conspicuous service to the Empire overseas and to the people of these islands. It was the co-operation between the scientific staffs here and in the distant parts of the Empire that made possible the financial co-operation of the Board on the scale actually adopted. It has therefore been particularly gratifying to us that during the year under review Australia, New Zealand, South Africa, Southern Rhodesia, and the Colonial Empire have offered financial contributions to ensure the maintenance of the work in which they are so particularly interested.[1] We value their generous offer the more for the assurance it gives us that this co-operation between the various scientific staffs will receive the fullest official encouragement; its continuance and development is essential if the work the Department is doing is to be of the fullest benefit, not only to the Empire overseas but, in turn, to the people of these islands. The conspicuous contributions which the Department has already made to the solution of the scientific problems involved, are found in the advances in our knowledge of biophysics and biochemistry which can find application in all parts of the Empire. For their complete application complementary work in the Dominions and Colonies is necessary, and we have been gratified to watch the growth of this work during the past years. In a report we made in 1926 for the information of the newly created Empire Marketing Board we wrote, dealing with fruit: ". . . . Exact experiment and small-scale trials have shown that storage properties depend upon the strain, the stock upon which a particular strain is grafted, and upon soil, age of tree, etc. . . . If the storage and transport of the fruits that can be grown here[2] is to be completely mastered, the results obtained here must be tried out and confirmed or modified in those parts of the Empire that grow these fruits under different conditions of climate and soil. It is therefore essential that the Dominions which are interested in growing and exporting fruit of this kind should establish surveys of local needs and laboratories

[1] The amounts of the contributions are: Australia £4,500, New Zealand £3,000, South Africa £1,700, Southern Rhodesia £500, Colonies and Protectorates £100.

[2] *e.g.*, apples as distinguished from, say, citrus fruits and bananas.

in which the results of our work can be checked and adapted to local circumstances and which can act as centres of information and advice to growers and exporters." At the time this was written the development of organisations for research in this field in the various Dominions was in the early stages, and it was pointed out to the Empire Marketing Board that, for this reason and because the organisations overseas would be occupied for some time in coping with the more pressing day-to-day problems of the industries concerned, an energetic development of the work in this country was the more important. But the principle was enunciated that " to carry out a complete imperial scheme, scientific organisations are required in each Dominion of large production " and it was observed that " in South Africa and Canada organisations already exist; in Australia and India a beginning has been made." The advance made in the eight years since this was written is well illustrated in the observation in a subsequent paragraph on the remarkable developments of research in the Laboratories of the Australian Commonwealth Council for Scientific and Industrial Research at Brisbane.

Further, in the case of citrus fruits and bananas, the Department can do only limited work in the United Kingdom because freshly gathered fruit is not available here. This was made clear in the Report of the Imperial Agricultural Research Conference 1927, §228, page 55, which stated " the solution of many problems . . . can, indeed, only be attempted where the clinical material is available on the spot, *e.g.*, subtropical fruit." This applies of course with special force to the more fundamental work on these fruits, and it serves to emphasise the need for scientific co-operation between workers at home and overseas so that ideas and results in parallel enquiries may be freely pooled.

In the offer of further co-operation expressed in contributions from the Empire overseas, amounting in all to nearly £10,000 a year, we find every justification for the considerable sums which, for our own part, we have recommended should be applied by the Department to this important work; and we have every confidence that the encouragement thus given to the co-operation between scientific workers here and overseas, and the increasing facilities placed at their disposal, will lead to steadily growing benefits for the peoples both of the Empire overseas and of this country.

But this co-operation is not confined to the prosecution, on each side of the ocean, of the general programmes of research already indicated. At its Laboratory in Covent Garden, the Department has a full-time officer who has considerable experience in the examination of experimental consignments of fruit and vegetables sent to this country. His services are available for Dominion and Colonial Governments who wish to secure reports upon experimental consignments of fruit and vegetables sent officially to this country in order to test, under commercial conditions, the results of scientific

work carried out overseas. For such examinations, as for other special enquiries undertaken for the Governments of the Empire overseas, an appropriate charge is made to the Government desiring the work to be done.

We have referred in the preceding paragraphs to the co-operation in research on fruit as illustrating the community of interest in this field of work. It is gratifying to be able also to record a definite advance, during the year under review, in the application of gas-storage to shipments of chilled beef from Australia and New Zealand. In ordinary cold storage, the life of chilled beef, which is determined by the growth of micro-organisms, is limited to a period of about five weeks. This period has proved adequate for the supplies shipped to this country from South America, but has been found inadequate for the longer voyage from Australia and New Zealand. This fact, and the desirability of increasing the margin of safety in the case of South American supplies, gave great economic importance to the discovery of some further means of controlling the growth of micro-organisms. Experiment showed that the most important micro-organisms attacking meat are specially susceptible to the action of carbon dioxide, and that at temperatures in the region of freezing-point, a concentration of 10 to 20 per cent. of the gas so delays their growth as to double the life of chilled beef, without deleterious effects in other directions. The first consignment of chilled beef to be carried overseas in gas-storage reached this country from New Zealand in June 1933. It was strikingly successful, and similar shipments, though small, have been made from Australia and New Zealand. In this remarkable development of scientific research the Australian Commonwealth Council for Scientific and Industrial Research, with the splendid facilities it has at Brisbane, is taking a leading part; and it is interesting to record that the officer in immediate charge of the work was sent from Australia to the Low Temperature Research Station at Cambridge and spent several years there before returning to take up his present post.

Empire Timbers

In our report of a year ago we gave a general description of the work carried out by the Forest Products Research Laboratory at Princes Risborough as a repayment service for the Empire Marketing Board to assist that body in promoting markets in this country for Empire timbers. Since that report was made the future of this work has been fully considered by the Executive Council of the Imperial Agricultural Bureaux, to which it was referred by the Governments of the Empire on the recommendation of the Imperial Committee on Economic Consultation and Co-operation which met in London in the early part of 1933. As the result of the Council's deliberations it was decided that the services

rendered by the Laboratory at Princes Risborough might well be placed upon a fee-basis as soon as possible, the fees to be settled directly between the part of the Empire desiring the service and the Department of Scientific and Industrial Research.

Letters were thereupon addressed by the Department to the High Commissioners for the various Dominions and India informing them that Your Lordships were prepared to hold available, on repayment terms, the facilities of the Forest Products Research Laboratory for the investigation of timbers of Empire origin. At the same time they were informed that, so far as the Colonies were concerned, H.M. Government in the United Kingdom had decided that for the present the investigations of their timbers should be continued on the scale already planned and that funds had been placed at the disposal of the Department for that purpose. The letters contained an announcement of the decision, which Your Lordships had therefore reached, to establish a Standing Conference on Timber Utilisation containing representatives of the Colonies, the timber trades of the United Kingdom, the Imperial Institute, the Imperial Forestry Institute, and the Royal Botanic Gardens at Kew, with the object of preserving and developing the good will which was fostered by the now defunct Empire Timbers Committee. The High Commissioners were informed that if any Dominion or India made arrangements with the Laboratory for the use of the facilities as described above an invitation would be sent to the High Commissioner concerned to appoint one or more representatives to attend this Conference.

The first meeting of this Conference was held on July 3rd, 1934, under the Chairmanship of Sir John Stirling Maxwell when it adopted Standing Orders defining its objects, its constitution and its procedure. The Orders confirmed the proposals which Your Lordships had made for the constitution of the Conference.

We consider that the developments outlined above will prove to be a useful contribution to technical co-operation between the Forest Products Research Laboratory and the individual units of the Empire using the facilities offered. The arrangements for replacing those made, with the Department's assistance, by the Empire Marketing Board will be complete when a suitable organisation has been established in this country to perform for the Colonies the intelligence and marketing services we described last year which in the case of a Dominion or India are performed by its Trade Commissioner or Timber Trade Commissioner in London.

We would emphasise that the arrangements we have described supplement, but in no way supersede, the close co-operation and consultation which has always obtained in the conduct of their normal research activities between the Laboratory at Princes Risborough and the Forest Products Research Laboratories or organisations in other parts of the Empire.

RESEARCHES FOR GOVERNMENT

Investigations to promote Safety and Health of Industrial Workers, and like matters

During the past few years there has been a steady development of the demands on the Department by other Government Departments, especially the Home Office, for scientific assistance in connection with problems arising in the course of their administrative duties. Amongst the investigations now in progress which originated in such requests are the work on the detection of toxic gases to which we have already referred, and investigations on the production of cheap and efficient respirators for use as a protection against the inhalation of dust by workers in industries where dust may be a menace to health. The recent movement for the development of the use of compressed gas as a substitute for petrol or heavy oil in road vehicles has led to a request from the Home Office for technical assistance in connection with the formulation of regulations, in the interest of public safety, for gas cylinders to be used as containers for gas on such vehicles. Arrangements have been made for investigations in this connection, including study of the cylinders themselves, the question of necessary safety devices and the possibility of corrosion occurring which may limit the safe working life of such cylinders, to be undertaken at the National Physical Laboratory. Problems in connection with the regulation of gas cylinders generally also arise from time to time and technical assistance in this connection is being afforded to the Home Office.

Box Testing

In July we had before us a communication from the Ministry of Agriculture requesting the assistance of the Department in connection with the preparation of specifications for fibre-board containers, and the testing of such containers, for use in the carriage of agricultural produce. To meet the requirements of the Ministry of Agriculture the installation of a box testing plant is required.

Three years ago we considered proposals for the installation of a box testing plant at the Forest Products Research Laboratory to meet the requirements of industry and transport, and to promote economy in the use of timber. We then recommended the provision of a complete plant capable of testing containers ranging in size from the largest wooden containers used in overseas transport to the smaller wooden and fibre-board containers used in inland transport, together with a new building to accommodate it. The plant then contemplated included a large tumbling drum, a small tumbling drum, crushing testing machine and associated equipment. The scheme recommended in 1931 was postponed in the autumn of that year as part of the economy measures then called for. It was postponed with some reluctance on our part; for the experience of

America, where five such plants are available for industry generally —not taking account of the plants erected by individual firms or corporations—afforded convincing evidence of the value of the tests which can be carried out with a complete plant. The results of these tests have led to undoubted economies in transport; and they provide technical means of determining the data required for preparing specifications of containers, and testing actual containers for compliance with specified requirements. A technique has been developed which simulates the hazards of transport with sufficient exactness to make possible reliable comparisons of new designs of containers with those whose performance has already been established by actual use in practice.

In response to the representations of the Ministry of Agriculture and Fisheries we have now made recommendations that part of the original scheme should be proceeded with immediately, omitting at this stage the large tumbling drum required to test the largest wooden containers. The building would be so planned that an extension could be made at a later stage to accommodate a large tumbling drum and any supplementary equipment.

Fire Resistance of Buildings

For some years the Department has had under consideration the problems of testing building elements for their resistance to fire. In 1929, the Royal Institute of British Architects approached the British Engineering Standards Association (now the British Standards Institution) inviting that body to standardise the terms used in fire regulations. The Association appointed a committee to consider the matter and, if possible, to draft a suitable standard specification. In due course the committee produced a draft standard specification which was circulated to interested parties not actually represented on the committee, and the Association recommended that the specification should be published as a tentative one.

This marked a definite step forward, but it was at once evident that for the application of the specification to fire resistance of structural elements large scale tests would be necessary. For such tests there were no facilities available in the country. In order to classify an element of structure it is necessary to study its behaviour under an exposure to fire and water such as might be experienced in a fire in a building. It is the appreciation of this fact which has led to the construction of fire-testing stations in foreign countries.

At this stage negotiations were entered into between the Building Research Station and the Fire Offices Committee * to explore the possibility of an extension of that Committee's testing station at Manchester to enable it to carry out tests of the type and on the

* A committee appointed and financed by the fire assurance offices.

scale indicated. The results of these negotiations were very encouraging and they led in 1932 to the summoning by the Department of a conference to which a number of bodies interested in the question were invited to send representatives. Invitations were also extended to all those firms or undertakings which had in the past made requests to the Building Research Station for fire resistance tests of building materials and methods of construction. The object of the conference was to ascertain what measure of financial support, in the form of orders for paid tests, might be anticipated from industry, as a necessary preliminary to any capital outlay on the provision of testing facilities. The importance of the issue was emphasised on more than one occasion in 1931 and 1932 by the London County Council in communications addressed to the Department.

Despite the difficulties of the times the Fire Offices Committee after fully exploring the question in consultation with the Building Research Station have found it possible to proceed with the proposals for providing the necessary facilities. We have recently been gratified to learn that the Fire Offices Committee have decided to establish an enlarged fire-testing station in the London area and to allow the Department to make use of it for tests and investigations upon appropriate financial terms. We desire to acknowledge the far-sighted action of the Committee in reaching this decision which will make possible, in the near future, rapid progress in a field in which it is so urgently needed.

Building Research

It is now nearly ten years since the assistance of the Department was sought by the Minister of Health of that day in handling urgent technical problems arising in connection with housing schemes. The services sought necessitated additions to the staff and considerable additions to the facilities of the Building Research Station, then accommodated in temporary wooden buildings at Acton. The request was the immediate cause of the transfer of the Station to larger premises near Watford where expansion could take place as required.

Since that time the Station has developed close contacts with a comprehensive range of industries concerned with the building trades. From time to time the annual reports have recorded the institution, with the financial co-operation of industry, of new researches which aim at the provision of new or improved building materials or at systematizing and extending the scientific knowledge on which building practice rests, and earlier in this report we have mentioned those now in progress. Proposals for alternative methods of construction submitted by industry are examined, on payment, and reports are furnished pointing out merits or demerits and

suggesting such improvements as may be apparent. Tests are made, on repayment, for manufacturers on the properties of their materials or the qualities of their products. Queries are answered on points of difficulty arising in practice; and the answers to these queries are made widely available by periodical publication in the appropriate professional or trade journals. The Station co-operates with the British Standards Institution in promoting standard specifications for building materials to establish the level of commercial quality. Codes of practice have been drawn up for the use of structural steel and reinforced concrete in buildings. In these and other ways the Station is taking an active part in developing a science of building to avoid with new materials and methods of construction the wasteful processes of trial and error by which, in the past, building practice has proceeded from its traditional bases.

The recent announcements by the Minister of Health of his intention to encourage an intensified attack on the problem of rehousing and to set up a technical committee to examine questions of flat construction for working class dwellings engaged the immediate attention of the Building Research Board. They submitted a report indicating the nature of the increasing calls on the services of the Station which would be likely to ensue, and pointing out that the existing premises do not include facilities for some researches which will be necessary to ensure that any development of flat construction for working class dwellings in this country shall be achieved as economically and efficiently as possible.

We have made proposals to your Lordships under two heads. The first of these is concerned with an expansion of the activities of the Station by which the results of research and investigation would become available at an earlier date. The second is concerned with the particular problems of flat construction. These problems are of two kinds: those concerned with fire risk and those concerned with the transmission of sound through the structural elements or through floors and partitions. The examples of flat construction abroad, particularly in Austria and Germany, are frequently referred to in claims made for new or alternative methods of construction. But the continental systems are operated under building rules which prescribe conditions different from those which are common in this country. Amongst these are the requirements affecting fire risk. Whether the practice in dealing with fire risk in this country is too restrictive cannot be decided without experimental work on a large scale. The provision of a large scale fire testing station by the Fire Offices Committee, which we have already mentioned, will make it possible to carry out this experimental work in the early future as the need arises. If it be shown that the present practice is unduly restrictive, new and further problems will arise. The use of thinner walls or different floor construction, and any reduction in the covering of the structural members where steel framed building is used will present problems in avoiding the

transmission of sound from one tenement to another. They may also present heating problems because of losses of heat due to ready transmission through thinner materials. The proposals we have made deal with all these problems.

In conclusion, we desire to acknowledge the assistance we receive in our deliberations from the reports and proceedings of the various Research Boards and Committees, whose members place their knowledge and experience so freely and ungrudgingly at the service of this Department. The volume of this assistance will be realised by a reference to the membership of the various Boards and Committees which is set out in Appendix I.

RUTHERFORD,
Chairman.

F. E. SMITH,
Secretary.

SUMMARY OF WORK

THIS section of the report contains a summary review of the work carried out under the various research organisations of the Department of Scientific and Industrial Research during the year 1933–1934. Several organisations present annual reports on their work which are published by the Department; in these cases the summary below is relatively brief.

NATIONAL PHYSICAL LABORATORY

A COMPREHENSIVE account of the activities of the National Physical Laboratory is given in the Report of the Laboratory for the year 1933[1]. The following summary deals briefly with certain items of special interest and with the main work of the several Departments. As in previous reports, the researches carried out at the Laboratory for the Boards and Committees of the Department are dealt with in the sections of this Report relating to the work of these bodies.

International Standards

Work has been continued, in the several departments concerned, on the fundamental standards of length, mass, electrical resistance and current, candle-power, temperature, and X-ray intensity. In the Metrology Department final measurements of the length of the metre in terms of the wave-length of the red radiation from cadmium have been published[23]. A redetermination of the ratio of the pound and kilogramme has been made in connection with the decennial comparisons of the Imperial and Parliamentary standards of mass. Further observations with the ampere balance have been made, including a complete remeasurement of the dimensions of the coils of the balance. Work has been continued on the absolute measurement of resistance by means of the Lorenz machine and by the Campbell method. In order to investigate the small outstanding difference between the value of the ohm obtained in the earlier work by these two methods, the coils of the Lorenz machine have been remeasured and direct comparisons have been carried out between the inductances of the Lorenz coils and the standard mutual inductance used in the Campbell method. It is anticipated that the results of this work will explain the divergence previously found. In the Photometry Division further work has been done on the proposed standard of candle-power which is based on the use of a black-body maintained at the freezing point of platinum. The investigations in the Physics Department in

connection with the realisation and maintenance of the International Scale of Temperature have been continued. In this Department also, experimental work on the röntgen—the unit of X-ray quantity —has been carried out, and comparisons with the results obtained at the National Bureau of Standards, U.S.A., and the Physikalisch-Technische Reichsanstalt, Germany have indicated that the three laboratories are in agreement within about 0.5 per cent.

Acoustics Building

The erection of the first part of the new acoustics building was completed during the year and the building is now in occupation. The new laboratory contains a reverberation room and a pair of transmission rooms with associated measurement rooms. Complete acoustical and electrical isolation of the experimental rooms has been aimed at. The rooms are asymmetric both in plan and elevation; the enclosing walls, floors and ceilings are massive and double, the inner shells being supported on independent insulated piers.

Aerodynamical Equipment

Reference was made in the last report to the erection of the first two open-jet tunnels to replace the earliest of the seven-foot tunnels of the Laboratory. The erection of the second open-jet tunnel has now been completed. These tunnels afford a much needed improvement in experimental facilities to meet the advances in technique and the increasingly wider range of conditions. A high-speed tunnel has been designed and constructed; it has been installed in the compressed air tunnel building for operation from the exhaust air when the pressure of the main tunnel is released. This tunnel will enable tests to be made on small models at velocities up to about that of sound.

Lithgow Propeller Tunnel

The propeller tunnel erected at the Laboratory through the generosity of Sir James Lithgow, Bt., referred to in the Report of the Committee of Council for 1931–32, is now undergoing calibration and will shortly be employed in the investigation of propeller problems.

Lectures in Provincial Centres

At the Engineering Conference held in 1932, one of the proposals put forward was the delivery of a series of lectures by members of the Laboratory staff at various provincial centres to bring the work of the Laboratory more directly to the notice of industry. The proposal was adopted and the scheme has been continued during the past year with very satisfactory results. Lectures have

been given on various aspects of the Laboratory's work at many of the more important towns throughout the country, and many expressions of the value of these lectures and visits have been received.

Physics Department

In the Heat Division the measurements of the thermal and electrical conductivities of metals and alloys have been extended to higher temperatures, mainly with a view to obtaining data of practical utility in casting. The thermal conductivity of iron has been determined up to nearly 1,100° C., and measurements of the electrical conductivity have been made up to 1,400° C. It has been found that the thermal conductivity has a minimum value at about 900° C.; up to this change point iron has a negative temperature coefficient of thermal conductivity, but it appears that gamma iron possesses a positive temperature coefficient. In the same region the positive temperature coefficient of electrical resistance falls to a lower value, but remains positive. The investigation into the ratio of the specific heats of gases at high temperatures has been continued In the course of this work it became necessary to know the values of the thermal expansion of graphite at temperatures up to 1,500° C., and these values have been determined. The improvement of the performance of open-scale mercury thermometers has received further attention; records of the movement of the meniscus have been obtained by means of cinematograph films, which show that in stems of less than 0·07 mm. bore the behaviour of the meniscus is likely to be unsatisfactory. Several improvements have been made in the equipment for testing precision thermometers. A new low-temperature testing bath has been installed, which enables the Laboratory to give corrections to thermometers at points below 0° C. to a greater degree of accuracy than heretofore. A considerable proportion of the time of this Division has been devoted to researches on behalf of the Engineering Committee of the Food Investigation Board (*see* p. 49), and further investigations have been carried out for the British Electrical and Allied Industries Research Association in connection with the thermal properties of buried cables.

In the Radiology Division the methods of X-ray spectroscopy have been applied to a number of problems connected with the structure of metals. A detailed study has been made of the effect of torsion on the structure of copper wires[28]. The effect of subsequent heat treatment on cold-worked metals has also been examined[29]. Heavy cold work results in the production of both selective crystal orientation and fibre structure, and it has been shown that suitable heat treatment can remove the distortion without affecting the fibre structure. A difficulty which has existed in the interpretation of X-ray diffraction patterns has been overcome by devising a method whereby it is possible to differentiate

between the diffraction effects which are due to the presence of extremely small crystals and those which are due to imperfections and distortion of larger crystals[30]. An account of the work carried out for the Committee on Industrial Applications of X-ray Analysis appears elsewhere in this report. Further attention has been given to the precision measurement of X-ray dosage, and a description of the primary standard equipment installed at the Laboratory for the realisation of the röntgen—the unit of X-ray quantity—has been published[21]. A secondary standard ionisation dosemeter has been designed and constructed with a view to providing a simple, robust and portable instrument having a wide range of applicability. A further advance in the standardisation of X-ray measurements has been made by the completion of the investigation into the calibration in röntgens of the therapeutic " B-dose " as measured by the colour change of barium platinocyanide pastilles when exposed to X-rays. A report on the work is being published. The subject of X-ray protection continues to receive consideration, and in addition to fundamental investigations and the testing of protective materials in the Laboratory, inspections of X-ray equipment and installations have been carried out at hospitals in various parts of the country. The work for the National Radium Commission on the testing, storage and distribution of national radium has been pursued. Nearly 10 grammes of radium have been tested during the year.

The central block of the new acoustics laboratory is now in occupation, and the acoustical characteristics of the reverberation and transmission rooms are being determined. Progress has been made with the work on the absolute measurement of sound intensity, including the absolute calibration of the Laboratory standard condenser microphone. An " artificial ear " has been constructed to enable the acoustical output of telephone receivers to be measured under similar conditions to those obtaining when the receiver is held to the human ear. A report summarising the present position regarding the silencing of aircraft cabins has been published[11]. It is shown that the noisiness of any given aircraft can be inferred from data relating to its airscrew, engine, and cabin walls. In collaboration with the Royal Aircraft Establishment measurements of the noise of engines and airscrews have been made under various conditions, and an investigation into the theory of exhaust silencers has been undertaken[12]. Further work relating to the suppression of noise has included an enquiry on behalf of the Steel Structures Research Committee into the transmission of noise in steel-framed buildings as compared with other types of building, and a research for a railway company on the noise heard in trains.

In the Optics Division the theoretical investigation of optical systems continues to form an important part of the research programme. Among the special problems to which attention has been directed mention may be made of the investigation into the place of

aspherical surfaces in symmetrical instruments, and the examination of the theory of the unsymmetrical instrument. In connection with the work on colour measurement and standardisation, further experience has been obtained with the liquid filters referred to in last year's report, and an improved technique for preparing the solutions from recrystallised salts has been developed. Experiments have been made with a view to the development, for commercial and industrial purposes, of a colorimeter in which the eye of a human observer is replaced by a photo-electric cell; considerable success has been attained by the use of a Weston "photronic" cell in combination with filters constructed in the Laboratory, and the investigation is being pursued[17]. A photo-electric spectrophotometer has been constructed to facilitate the carrying out of the increasing amount of spectrophotometry called for in the Division. To assist the National Illumination Committee in the preparation of a specification for "daylight" lamps a colorimetric survey of over 120 lamps has been completed during the year, and determinations have been made of the spectral distributions of energy for a number of representative lamps.

Electricity Department

The Electrical Standards Division has been much occupied with work relating to the redetermination of the fundamental electrical units, to which reference has already been made. Standard frequency transmissions have been made regularly throughout the year, a new quartz ring oscillator and modified circuits having been employed. It has been possible to maintain the frequency of these emissions within ± 1 part in 10^7 of the 1,785th harmonic of the standard tuning fork. New standards for the measurement of residual inductance have been designed and constructed. These consist of two decade series of resistance coils of calculable reactance covering the range 100 to 10,000 ohms. The effective inductance of each coil has been calculated from its dimensions, so that each may be regarded as an independent primary standard, and experimental intercomparisons of the individual coils have also been made. A simple method has been devised for the measurement of impedance[5] by which the use of alternating current bridge methods is avoided, the only adjustments necessary being made on a potential divider. The equipment is capable of giving results accurate to about 0·5 per cent. For magnetic measurements a ballistic galvanometer has been constructed, the performance of which represents a considerable improvement over the types previously available, both in respect of sensitivity and convenience in use. A detailed study has been made of the conditions governing the design of suitable electrodes for the measurement of the permittivity and power factor of solid dielectrics at radio frequencies[19]. Mercury is considered to be the most satisfactory electrode material for this purpose. The fundamental

research on dielectric losses has been continued on behalf of the British Electrical and Allied Industries Research Association, as well as an investigation into the properties of ferro-magnetic core materials at radio frequencies. The work for the Radio Research Board on methods of measurement of the grid-anode capacitance of screen-grid valves has been completed[20].

In the Electrotechnics Division improvements in the technique of alternating current and power measurements have been further investigated. The reduction of the serious errors due to leakage fluxes, and consequent premature saturation of parts of the core, in current transformers for large currents has been receiving consideration for some time, and a solution of the problem has been found by encasing the core, with its secondary winding, in a massive copper shield[3]. In two transformers rated to carry 12,000 and 20,000 amperes respectively, saturation of the core was entirely eliminated by the presence of the shields, and the ratio errors of the transformers were reduced to about one part in 10,000. A simple and sensitive method has been developed for the precision testing of nickel-iron cored current transformers, the ratio and phase angle errors of which are often very small[4]. Further experience has been obtained with the high voltage equipment referred to in last year's report, and progress has been made with the construction of a high voltage shielded resistor for 70 kV. In the section dealing with direct current measurements, the investigation relating to the erosion and corrosion of manganin tube resistors has been continued. Tests have been made to determine the change in resistance of manganin tubes due to the prolonged passage of water, both when the tubes were protected and unprotected. The unprotected tube showed a change in resistance of 1·27 per cent. when water had passed continuously for 37 days; over the same period tubes protected with a coating of bituminous paint showed a change of only 0·02 per cent. The comparative strength of various types of soldered joints between manganin and brass has been examined and it has been found that the silver-soldered joint is the most satisfactory. In connection with the tests required for the approval of types of meters by the Electricity Commissioners, a photo-electric apparatus has been developed for automatically counting and timing the revolutions of an electricity meter disc[14]. The device is applicable also to other counting and timing operations.

The development of photo-electric methods of photometry has been in active progress in the Photometry Division. All routine measurements of luminous flux are now made on one of the photo-electric photometers in the Laboratory[26]; the extension of the principle to high precision work has been investigated, and a study has been made of the illumination-response characteristics of a number of photo-electric cells[22]. During the year photo-electric methods have been employed for the detection of non-uniformity in the candle-power of a lamp, for absorption measure-

ments on clear toric lenses, for determining the effect of surface blemishes on filter transmission, and for the measurement of the relative intensity of a mercury discharge tube on A.C. and D.C. supply. The difficulties associated with the photometry of gaseous discharge tubes have been studied[8], and it is hoped that as a result of experimental work now in progress it will be possible to evolve a method which will enable consistent results to be obtained. Arising out of the work on spectrophotometry, a method has been developed for the experimental determination of the mean effective wave-length of a colour filter for a given temperature interval[9].

Radio Department

The work of the Radio Department consists almost exclusively of researches carried out for the Radio Research Board. An account of this work is given on pp. 82–87.

Metrology Department

The statutory decennial intercomparisons of the Imperial and Parliamentary standards of length and mass have been completed with satisfactorily concordant results. The opportunity has been taken to effect a redetermination of the relationship of the pound and the kilogramme, with the co-operation of the International Bureau of Weights and Measures. The researches having for their ultimate object the establishment of a wave-length standard of length have reached a further stage by the publication of the results of the determination of the lengths of the yard and the metre in terms of the red radiation of cadmium, both in air and *in vacuo*[23].

The new vacuum chamber for the testing of mercurial barometers has been completed and installed. The development of the vibration clock has proceeded satisfactorily: the clock and the accessory apparatus for temperature and pressure control have exhibited reliability, and tests up to six weeks' duration have been made. The Blythswood ruling engine has been fully occupied during the year with the production of diffraction gratings, the demand for which continues to exceed the supply. The number of measurements carried out on gear cutting hobs has been exceptionally heavy. In this connection it is satisfactory to observe that considerable improvement in the accuracy of hobs has been apparent during the last few years, leading, it is understood, to a marked reduction in the noise caused by turbine gearing on ships. Arising from the alteration in the London taxicab tariff an abnormal number of taximeters and gear boxes were submitted for test over a short period; this necessitated certain temporary changes in organisation to enable the meters to be tested and returned without delay.

Engineering Department

Considerable progress has been made during the year with a number of researches on methods of testing materials. An investigation into the minimum dimensions of test samples for Brinell and diamond pyramid hardness tests has been completed. The work has comprised an experimental examination of the effects of width and thickness of specimen on hardness test results, and data have been obtained enabling the behaviour of various materials to be compared. The investigation is of importance in connection with the industrial application of both Brinell and diamond pyramid hardness tests on small bars and sheet or strip materials. Further work on methods of testing thin sheet metal has indicated that in the case of very thin materials the oil pressure test may be a useful alternative to the tensile test, in regard to measurements both of strength and ductility. In connection with tests on steam-pipe insulating materials[18], it is necessary to know the heat loss from a bare pipe in order to estimate the saving due to the covering. Experimental determinations of the heat loss have previously been made up to 600° F., and these determinations are now being extended to 1,100° F., as the Laboratory is frequently required to test pipe covers up to this temperature. A report on the principles of the air injector has been published[6], and an investigation is in hand on the industrial applications of the injector as a means of maintaining streams of air or water carrying solid matter in suspension. Much attention has been given in recent years to the design and standardisation of lifting gear components, with a view to increased safety in use. Based on work carried out at the Laboratory, a provisional standard design was prepared by the British Standards Institution for hooks of the "Liverpool" type, and sample hooks of this design have now been submitted to searching tests, with extremely satisfactory results.

The research on fatigue phenomena exhibited by large metallic crystals has been continued, tests having been made on a single crystal of aluminium grown by the Bridgman method, and on two single crystals of aluminium under flexural and under combined flexural and torsional stresses. In continuation of the corrosion-fatigue experiments carried out on single-crystal and two-crystal specimens of aluminium[16], tests under similar conditions have been made on crystalline aggregates. The general conclusions drawn from the earlier work have been confirmed. In view of the practical and theoretical importance of a knowledge of the resistance of metals to combined fatigue stresses, a comprehensive research on this subject is in active progress. Two machines have been designed and constructed capable of applying cycles of reversed plane bending stresses, or reversed torsional stresses, or any desired combinations of these two types. A detailed description of one of these machines is given in the Annual Report of the Laboratory for 1933 (p. 151). Further study has been made of the effect of

surface conditions on the resistance of spring steels to repeated impacts. The improvement obtained by machining and polishing appears to be as great as in the case of bending fatigue stresses. The earlier work on spring steel plates and forgings has shown the desirability of investigating the effect of surface conditions on the fatigue resistance of spring steel and other steel wires, and a wire fatigue-testing machine for this purpose has been designed and constructed. The research on the specific heats of gases at high temperatures, which has a practical bearing on the estimation of performance of internal combustion engines, has involved a new series of experiments in which greater refinements have been introduced. The investigation into the strength of thin metal panels as used in aircraft construction has been continued on behalf of the Aeronautical Research Committee. A report has been published on the determination by theoretical and experimental methods of the influence of buckling on the strength of rectangular plane panels of thin sheet metal subjected to compression parallel to one pair of edges[10]. The work is being extended to the case of curved panels. To assist the Home Office in framing suitable regulations for high pressure cylinders for gas traction purposes, tests have been made on the material of which such cylinders are constructed, and internal pressure tests are being made on cylinders drawn from service in order to estimate their safe life. A number of investigations have been carried out for Research Boards and Committees; accounts of this work are given in the appropriate sections of the Report.

*Aerodynamics Department**

As already mentioned, the construction of the two open-jet wind tunnels has now been completed. Tests of the performance of the first tunnel have shown good agreement with the predictions made on the basis of the model experiments. In the Compressed Air Tunnel progress has been made with the establishment of standard aerofoil data at full-scale Reynolds number for well known wing sections, but before results are published it is desired to acquire further information as to the effects of turbulence in the tunnel on maximum lift. A number of tests have been made on aerofoils fitted with flaps for decreasing landing speed and it has been shown that these are likely to be effective in use. A new distant-reading manometer of improved design has been constructed for this tunnel.

The study of fluid flow has been continued, both by means of the ultramicroscope and of hot air shadowgraphs. A statistical analysis of turbulence, using the latter method, has shown that the

* The results of the investigations carried out in the Aerodynamics Department are published in the Aeronautical Research Committee Reports and Memoranda, of which some 65 numbers were published during the past year. Lists of these papers may be obtained from H.M. Stationery Office.

frequency distribution of disturbances of various magnitudes follows the normal law of errors. An arrangement has also been developed for the cinematography of air flow in pipes, providing records of velocity distribution. Tests have been made in the Duplex Tunnel on a model of a six-engined flying boat to determine the effect of the interference of the sea on the lift and pitching moment of a flying boat during the take-off run. These tests involved the development of a new technique: a platform was erected in the tunnel to represent the sea, and measurements were made with the model at various attitudes and hull immersions. Duplex Tunnel tests have also been carried out on a model of the latest design of tailless aeroplane. Much attention has been given to questions of stability and control; the longitudinal instability in a dive shown by some high-speed aeroplanes has been examined both theoretically and by wind tunnel experiments, and progress has been made with the study of stability in stalled flight. A simplified report on the subject of spinning has been published; it includes a condensed collection of data, and the conclusions are presented in a form suitable for use by designers. The research on high-pitch airscrews is now being carried out in the new open-jet tunnel in order to take advantage of the higher wind speed there available. This investigation will provide data for the design of airscrews up to a pitch/diameter ratio of 2.5, and will enable a comparison to be made between experimental results and recent theories. The occurrence of several instances of the flutter of servo-controlled rudders has led to this subject being examined, and a report has been published on the theory of binary servo-rudder flutter. It appears that this type of flutter can be avoided by mass-balancing both the servo-flap and the main rudder, but as this may lead to considerable extra weight further investigations are being made with a view to devising some means of preventing flutter which will involve less additional weight than complete mass-balance. Further work has been done on the buffeting of aeroplane tails, and a second report on the general investigation has been published. Apparatus has been developed for recording piezo-electrically the time history of the lift on an aerofoil following a sudden change of incidence. A knowledge of the effect of such transient forces, which may be caused by gusts, is of much importance in the endeavour to attain increased safety in flight.

Metallurgy Department

The work of the Metallurgy Department is largely concerned with the study of the physical structure of metals and alloys, and progress has been made with several of the long-range investigations which have been undertaken. Work on the constitution of the iron-manganese alloy system has been considerably assisted by the employment of X-ray analysis[15]. The study of

alloy systems involves the use of pure constituents, and the production of iron of high purity has received further attention. Analysis has shown that in the more recent samples of iron produced, the total impurities, excluding oxygen, amount to only 0.012 per cent., the nickel present having been reduced to 0.0006 per cent. The study of the properties of molten metals and alloys has been continued. The work completed has included the determination of the surface tension of a number of lead-tin alloys up to a temperature of 800° C.[7], while an investigation of the viscosity of molten tin has also been concluded[24]. Experimental work has been carried out on the oxidation of both tin and bismuth, and in this work the use of electron beam diffraction apparatus has been tried. The volume changes of metals and alloys during solidification are being investigated at temperatures up to 700° C. by means of a differential gas calorimeter. In many of these determinations, and also in the work on gases in metals, one of the difficulties lies in obtaining suitable refractory materials. The production of refractories impervious to gases and able to withstand high temperatures has been further investigated, considerable progress having been made with the production of articles of pure recrystallised alumina[25]. Work has been continued for the British Non-Ferrous Metals Research Association on the distribution of impurities in copper ingots, while for the same body the influence of added elements to copper has also been under investigation. The analysis and metallographic examination of a number of specimens of copper and bronze from various sites in Mesopotamia have been undertaken for the Sumerian Committee of the Anthropological Section of the British Association[13]. The methods of microchemical analysis which have been developed in the Department have proved useful in many of the investigations undertaken, particularly those relating to copper. For the Joint Committee of the British Electrical and Allied Industries Research Association and the British Iron and Steel Federation work has been continued on carbon and alloy steels for use at high temperatures. The creep properties of a number of plain carbon steels have been determined and the effect of the addition of varying proportions of molybdenum has been investigated. For this Committee the work on corrosion of steels in superheated steam and in flue gases has been continued. Much of the work of the Metallurgy Department is carried out for the Metallurgy Research Board and reference to this will be found in the section devoted to the work of this Board (p. 68). The investigations at the Laboratory on dental amalgams are dealt with in the section relating to Dental investigations (p. 87).

William Froude Laboratory

There has been a considerable increase in the demand for tests on behalf of firms, and less time of the staff has in consequence

been available for research. The equipment of the New Tank has been proceeded with, and this Tank has been employed particularly for propeller tests in open water. Progress has been made with the researches undertaken under the supervision of the Advisory Committee for the William Froude Laboratory, and an opportunity has been taken of summarising the results obtained over a period of years. The results of the methodical series of experiments on ship resistance which have appeared from time to time in the transactions and proceedings of various Societies and Institutions have been collated, and a pamphlet giving the appropriate notes, tables and resistance curves has been published by H.M. Stationery Office[2]. The study of the influence of waves on the resistance, propulsion and pitching of ships has been continued with particular reference to the effect of varying the diameter of the propeller. Some analytical work on the fundamental considerations of seaworthiness has been carried out, and it has been possible to summarise the results of the various phases of the investigation in a paper which indicates the lengths of ship that are advantageous and disadvantageous when the ship is propelled through waves of known length. The screw propeller research has been continued by the further investigation of screws with blades of different aerofoil sections and various amounts of skew back; the part of the research dealing with twin-screws is concerned with the general effect of propeller diameter and revolutions on ship efficiency. In the research on coaster forms attention is being given to performances under conditions of load and ballast, the latter at three different trims. The work shows that considerable improvement in propulsive efficiency is possible. On the theoretical side the calculation of the wave resistance of three-dimensional forms has been advanced to the case of a simplified ship form having parallel sides and parabolic lines at bow and stern. Good agreement is obtained for the measured and calculated wave profiles[27].

[1] NATIONAL PHYSICAL LABORATORY. *Report for the year* 1933. H.M. Stationery Office (1934). Price 13*s.* 0*d.* net.

[2] THE WILLIAM FROUDE LABORATORY. *Abstract of Results Published on a Methodical Series of Resistance Experiments on Ship Models and their use in Design.* H.M. Stationery Office (1934). Price 6*s.* 0*d.* net.

[3] ARNOLD, A. H. M. Leakage Phenomena in Ring Type Current Transformers. *J. Instn elect. Engrs*, 1934, **74**, 413.

[4] ARNOLD, A. H. M. Current Transformer Testing. *J. Instn elect. Engrs*, 1934, **74**, 424.

[5] ASTBURY, N. F. The Measurement of Impedance. *J. Instn elect. Engrs*, 1934, **74**, 445.

[6] BAILEY, A., and WOOD, S. A. The Principles of the Air Injector. *Aeronautical Research Committee, Reports and Memoranda*, No. 1545. H.M. Stationery Office (1933). Price 1*s.* 9*d.* net.

[7] BIRCUMSHAW, L. L. The Surface Tension of Liquid Metals, Part. V.—The Surface Tension of Lead-Tin Alloys. *Phil. Mag.*, 1934, **17**, 181.

(8) BUCKLEY, H. Heterochromatic Photometry, with Particular Reference to the Photometry of Gaseous Discharge Tubes. *Illum. Engr, Lond.*, 1934, **27**, 1186.

(9) BUCKLEY, H. The Experimental Determination of Mean Effective Wave-Lengths and Their Application in Heterochromatic Photometry. *J. sci. Instrum.*, 1933, **10**, 351.

(10) COX, H. L. Buckling of Thin Plates in Compression. *Aeronautical Research Committee, Reports and Memoranda*, No. 1554. H.M. Stationery Office (1933). Price 1*s.* 3*d.* net.

(11) DAVIS, A. H. Silencing Aircraft. *Aeronautical Research Committee, Reports and Memoranda*, No. 1542. H.M. Stationery Office (1933). Price 9*d.* net.

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(14) FELTON, A. An Automatic Counting and Timing Mechanism for Testing Electricity Meters. *J. sci. Instrum.*, 1933, **10**, 369.

(15) GAYLER, M. L. V. Alloys of Iron Research, Part 11.—The Constitution of the Alloys of Iron and Manganese. With Appendix on the X-Ray Analysis of Manganese-Rich Alloys Heat Treated and Quenched from Different Temperatures, by WAINWRIGHT, C. *J. Iron Steel Inst.*, 1933, **128**, 293.

(16) GOUGH, H. J., and SOPWITH, D. G. Corrosion-Fatigue Characteristics of an Aluminium Specimen Consisting of Two Crystals. *J. Inst. Met.*, 1933, **52**, 57.

(17) GUILD, J. The Experimental Side of Colorimetry. *J. sci. Instrum.*, 1934, **11**, 69.

(18) JAKEMAN, C. The Testing of Steam Pipe Insulating Materials. *Engineering*, 1933, **137**, 58.

(19) JONES, T. I. Mercury Electrodes for Measurements of Solid Dielectrics at Radio Frequencies. *J. Instn elect. Engrs*, 1934, **74**, 179.

(20) JONES, T. I. The Measurement of the Grid-Anode Capacitance of Screen-Grid Valves. *J. Instn elect. Engrs*, 1934, **74**, 589.

(21) KAYE, G. W. C., and BINKS, W. The Experimental Realisation of the Röntgen. *Brit. J. Radiol.*, 1933, **6**, 530.

(22) PRESTON, J. S., and MCDERMOTT, L. H. The Illumination-Response Characteristics of Vacuum Photo-Electric Cells of the Elster-Geitel Type. *Proc. phys. Soc. Lond.*, 1934, **46**, 256.

(23) SEARS, J. E., and BARRELL, H. Determination of the Fundamental Standards of Length in Terms of Wave-Lengths of Light. *Philos. Trans.*, 1934 (A), **233**, 143.

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(25) TURNER, D. Special Refractories for Metallurgical Research at High Temperatures. *Trans. ceram. Soc.*, 1934, **33**, 33.

(26) WALSH, J. W. T. Everyday Photometry with Photo-Electric Cells. *Illum. Engr, Lond.*, 1933, **26**, 64.

(27) WIGLEY, W. C. S. A Comparison of Experiment and Calculated Wave-Profiles and Wave-Resistances for a Form having Parabolic Waterlines. *Proc. roy. Soc.*, 1934 (A), **144**, 144.

(28) WOOD, W. A. Selective Lattice Distortion in Wires under Torsion. *Nature, Lond.*, 1933, **131**, 842.

(29) WOOD, W. A. Lattice Distortion and Fibre Structure in Metals. *Nature, Lond.*, 1933, **132**, 352.

(30) WOOD, W. A. Effect of Lattice Distortion and Fine Grain Size on the X-Ray Spectra of Metals. *Phil. Mag.*, 1933, **15**, 553.

Fuel Research

The Report of the Fuel Research Board together with the report of of the Director of Fuel Research for the year ended 31st March, 1934, has recently been published[1]. This contained a more lengthy account of the work in hand, and the results obtained, than can be given here, and includes a full list of other publications containing details of individual investigations. Only a very brief résumé can be given here and reference should be made to the above-mentioned publications for further particulars.

Physical and Chemical Survey of the National Coal Resources

The systematic survey of the coal seams of the country has continued steadily throughout the year; the detailed examination of the coal is carried out in eight laboratories, provided and staffed by the Department, in the various coalfields, and in the laboratories of the Lancashire and Cheshire Coal Research Association, while large scale work is carried out at the Fuel Research Station at East Greenwich.

During the year arrangements have been made for extending the Survey to the Cumberland coalfield, and a committee has been appointed for the purpose. The laboratory work will be carried out in the existing laboratory at Newcastle-on-Tyne, the staff of which is being increased for the purpose. The history, objects, and organisation of the Survey are described in Appendix IV to the Fuel Research Annual Report,[1] which indicates the progress made up to date. A list of the publications dealing in detail with the various seams is included in that report, and a list of those issued during the year is given in Appendix VII.

Purification of Coal

A large, and steadily increasing, proportion of the coal raised in this country is cleaned at the collieries before marketing to remove the extraneous inorganic matter necessarily raised with it. While there are several types of washers and dry cleaners in use that are quite satisfactory in many cases, there is room for improvement in the removal of the dirt and fine coal from the washery water, and in the cleaning of fine coal. If the amount of suspended solids in the washery water is not kept at a low figure they are deposited on the washed coal, spoil its appearance, and may in some cases seriously affect the ease with which the water can be drained from the washed coal, even when the amount of deposited dirt does not appreciably affect the other properties of the coal.

The rate at which the solids separate out from the washery water can be increased either by improvements in the design of the settling tanks, or by the addition of flocculating agents such as gelatin or starch. Investigations are proceeding in both directions. The

slurries from different washeries differ considerably in their properties, and the treatment to be adopted in any case must be related to the characteristics of each slurry; a method that is quite satisfactory in one case may be useless in another.

An allied problem is the cleaning of fine coal (dust), and the vacuum flotation method has been shown to be particularly suitable in some cases. The ease and efficiency with which this process can be applied varies with different coals, and an attempt is being made to correlate the flotation properties of the coal with its composition as determined by analysis.

Coal Breakage

Recent years have witnessed a change in the consumer's demand as regards the size of coal, and the demand for lump coal has fallen off as compared with the demand for smaller graded sizes. This change applies both to domestic and industrial requirements at home, and to export coal, and is partly but not entirely due to the lower price of small coal. Other factors which are influencing the demand are: the greatly increased proportion of small coal that is mechanically cleaned, so that it is no longer necessary to buy large lump coal for the sake of its relative purity; the increased efficiency obtainable by a suitably graded coal, and the avoidance of the necessity of breaking before use; the diminished storage capacity in the modern house or flat; and the steady increase in the use of mechanically fired furnaces. This change in the demand is increasing the necessity for breaking down lump coal at the colliery, and raises the problem of how to break the coal to the sizes required with the minimum production of unwanted sizes and dust.

Allied to this problem is that of preventing so far as possible further breakage during transit from the colliery to the consumer, and especially during the loading and unloading of ships and wagons.

As a preliminary step in the examination of the technical problems involved, an officer of the Fuel Research Station is visiting the various coalfields, at the invitation of the colliery owners, to examine the conditions and determine what, if any, research can usefully be undertaken.

Carbonisation

The narrow continuous vertical brick retorts at the Fuel Research Station have continued in steady use during the year to determine the life of the retorts and to examine a number of coals (suggested by the local Committees of the Coal Survey) for their suitability for the production in this type of retort of a free burning smokeless domestic fuel. A second setting, similar to the one mentioned last year, but built of silica to withstand higher temperatures, was put to work during the year.

The effect of introducing steam to the ordinary type of horizontal gas retort during the carbonisation of the coal has been further studied, and it is satisfactory to note that this procedure has now been successfully adopted by at least three large gas undertakings. The result is an increase of some 10 per cent. in the number of therms of gas produced per ton of coal. The method of increasing the throughput of the retorts by increasing the volume of the heating gases, which has been mentioned in previous reports, is also now in commercial operation.

The vertical intermittent gas ovens are in use for studying the effect of blending different coals, or coal and coke, and for the present they are being used at lower temperatures than the normal with the object of producing free burning domestic fuels.

Hydrogenation

The work on the hydrogenation of tar to produce motor spirit has continued, and the semi-commercial scale plant designed to treat 300 gallons of tar a day is approaching completion. Further progress has been made in the study of the reactions involved in the hydrogenation of coal and the effect of the inorganic substances in the coal.

Pulverised Fuel

The new type of burner for pulverised coal, mentioned last year, is now in commercial use, and has given satisfaction. It is being further developed to increase its flexibility, and in particular to enable it to deal with coals containing little volatile matter. There is no difficulty in dealing with coals containing 20 per cent. volatile matter, and promising results have been obtained with coal containing 15 per cent. There are many excellent " steam " coals of this type available, especially in South Wales and Scotland, which it has not been possible as yet to burn satisfactorily in a pulverised form in boilers with small combustion spaces, such as " Lancashire " and " Scotch Marine " boilers.

General

Various other investigations are in progress, dealing with the methods of examination of coal as regards its constitution, its chemical analysis, and its suitability for various purposes. Increased attention is being paid to the production of lubricating oils from coal, or coal derivatives.

The panel of scientific experts appointed early in 1933 to assist the Director of Fuel Research on the more fundamental aspects of his work has held a number of meetings, and has been instrumental in establishing closer touch with work in the Universities. Investigations on the following subjects are in progress: (*a*) the mechanism of the oxidation of carbon, in Professor Hinshelwood's laboratory at Oxford; (*b*) the action of hydrogen on carbon and the dissociation

of hydrocarbons, in the Department of Colloid Science at Cambridge, under Professor Rideal; (*c*) the system molybdenum-sulphur-hydrogen by a member of the Fuel Research Station Staff working under Professor Rideal; and (*d*) hydrocarbon gel formation, also in Professor Rideal's laboratory.

(1) *Report of the Fuel Research Board for the year ended 31st March, 1934, with Report of the Director of Fuel Research.* H.M. Stationery Office (1934). Price 3*s*. 0*d*. net.

Food Investigation

The Report of the Food Investigation Board for the Year 1933 has been published(1). The Board's own Report gives a brief review of the year's work as a whole, while the progress of the various researches is described, by members of the staff and others responsible for them, in the accompanying Report of the Director of Food Investigation.

Low Temperature Research Station

Fruit and Vegetables.—Interesting observations have been made on the physiology of senescence in fruits. Ripe apples have been found to give off some substance which stimulates an irreversible change, termed, for convenience, the climacteric, which ushers in the senescent phase of life, and which is accompanied by a marked increase in respiratory activity. It has now been shown that ripe bananas, peaches and pears also produce this or a similar substance. On the other hand, ripe oranges and grapes have not been found to have any stimulating effect upon pre-climacteric apples. Wounding and mechanical stimulation have no effect.

If apples are kept confined together in a group, the climacteric occurs nearly simultaneously in each individual at about the time it is self-induced in the most advanced fruit of the group.

The influence of carbon dioxide in the atmosphere is not only to depress post-climacteric respiratory activity, but also to delay markedly the occurrence of the climacteric. Supernormal concentrations of oxygen in the atmosphere accelerate the occurrence of the climacteric, while subnormal concentrations delay it.

In the absence of oxygen the climacteric is not induced by ethylene, as it is in air, nor is there any latent stimulus, for on return to air after such treatment the apples are still pre-climacteric. Oxygen is therefore definitely concerned in the mechanism by which ethylene stimulates the climacteric.

The total volatile products of the metabolism of fruit, other than carbon dioxide, are now being measured, after combustion, as carbon dioxide. The production of these volatile products increases at the climacteric, and a large part of them can be retained by phosphorus pentoxide or concentrated sulphuric acid.

Another important fact clearly established during the year is

that, with the progress of senescence of apples in air, there is a steady rise in the concentration of alcohol and acetaldehyde in the flesh.

The effects of artificially raising the concentration of ethyl alcohol in apples by feeding them with the vapour have been studied. The amounts of alcohol that sound fruit will tolerate without injury are much higher than the quantities found in tissues killed by continuous exposure to atmospheres free from oxygen. This involves a revision of the view generally held up to the present, that death in the absence of oxygen is due to alcoholic poisoning.

It has also been found that, in moderate doses, ethyl alcohol depresses respiratory activity, while in larger doses it increases it; finally, that a relatively small dose of alcohol causes a marked rise in the concentration of acetaldehyde in the tissues, while larger doses do not produce any greater effect.

An advance has been made in the analysis of the respiratory mechanism of the potato. The rate at which carbon dioxide is produced is determined, not by the concentration of the total sugar, but only by that of the sucrose.

Experiments on the conditions which give rise to scald in apples have been continued, and it has now been demonstrated in the small wind-channel that, with constant movement of the air, but varying humidity, the amount of scald developed is inversely related to the water lost by the fruit.

Further advances have been made in the technique of freezing fruits and vegetables, and in particular it has been shown that asparagus blanched in boiling water to destroy enzymes, and frozen quickly in brine at — 22° C. and stored at — 20° C., is far superior in texture to similar material slowly frozen and stored in air at — 20° C. The quickly frozen asparagus should be acceptable commercially as a luxury.

Other subjects investigated have been the changes in the carbohydrate and in the respiration of half-grown apples during storage; the changes in the carbohydrate of apples stored in the frozen condition in the presence and absence of oxygen; the reaction of fruits to wounding; the effect of freezing on the yield of seed-potatoes; the possibilities of using ethylene for retarding sprouting in clamped potatoes; and the effects of a variety of chemical agents upon the growth of fungi.

Meat.—Meyer* has recently reported the isolation of a third fraction of the muscle-proteins, "globulin X," intermediate in properties between myosin and myogen. The significance of this fraction in the chemistry of meat is being investigated. Both myosin and myogen alter in their properties during storage, but, contrary to the view current for more than 30 years, these changes in intact unfrozen muscle are neither rapid nor extensive.

* *Biochem. Z.*, 1933, **266**, 137.

The results of the work on the vapour-pressure isotherm of muscle have been published [2], and used to estimate the bound water of dead muscle, and the amounts of water unfrozen in muscle stored at different freezing temperatures[3]. A method depending on pressure has been developed for examining the state of water in tissues. The results obtained with gelatin gels and albumin sols are similar to those obtained from freezing equilibrium [13]. Pressures up to 3,000 atmospheres have been employed, equivalent to freezing at a temperature of approximately — 130° C.

The bloom of chilled beef stored for long periods is now of considerable importance in view of the shipments from Australia and New Zealand carried in controlled concentrations of carbon dioxide. Further work on the colour of beef-fat has emphasised the importance of maintaining a low concentration (< 20 per cent.) of carbon dioxide if the bloom is to be preserved[4]. The effects on bloom of enriching the atmosphere with oxygen, as well as with carbon dioxide, is under investigation.

A study is being made of the germicidal and inhibitory effects of pure ozone at different temperatures. The results so far obtained indicate many points of interest; for instance, the germicidal concentration varies for different organisms; the inhibitory effect varies greatly with the age of the culture; the concentrations required to inhibit growth are smaller, the lower the temperature; the organisms most susceptible to carbon dioxide are more resistant to ozone. The results are being examined in relation to the practical problem of storing eggs and meats.

A series of experiments has been completed on the storage of chickens in almost pure carbon dioxide at a temperature of 0° C. The longest period over which the chickens can be stored in marketable condition is six to eight weeks. Beyond this time there is marked decomposition of the abdominal wall by enzymes diffusing from the gut.

Work is in progress on the effects of storage, both in air and in air enriched with carbon dioxide, on certain of the chemical and physical changes in eggs.

Pork, Bacon and Hams.—The recent re-organisation of the pig and bacon industires has led to an increase in the demand for information on curing, and a leaflet has been published on the dry-salt and tank curing of Wiltshire bacon[5].

An investigation, in the factory, of the curing of Wiltshire bacon indicated that the final product was influenced considerably by the raw material. Experiments were, therefore, carried out which showed that the rate of growth of the pig played an important part in this connexion, rapidly growing pigs proving more suitable for the production of bacon than slowly growing pigs, which were usually overfat and had less muscular tissue.

Investigations on the rate of penetration of salt during curing

have been carried out in collaboration with the British Food Manufacturers' Research Association. Results showed the value of an initial pumping of the sides with pickle, in the case of both tank-cured and dry salt-cured bacon. Pumping leads to a more rapid penetration, and also to a more even distribution of the salt in the matured bacon.

It has been found possible by storing bacon at + 5·5° C. in an atmosphere of carbon dioxide, in a small gas-store especially designed for the purpose[6], to keep it an extra three weeks after maturation without any development of slime. For longer storage a lower temperature is needed, and a side of mild-cured Wiltshire bacon was stored in carbon dioxide at — 11° C. for eight months, at the end of which period it was indistinguishable from normal bacon, even chemical tests failing to detect any rancidity in the fat.

The fat of bacon is more susceptible to the oxidative changes leading to rancidity than that of pork. Work on lard has shown that the salts used for curing are responsible for accelerating these oxidative changes, and that yellowing can be produced in oxidised fat by traces of alkali or of ammonium salts[8]. A study is being made of the effect of anti-oxidants on this type of oxidative change in fat with a view to delaying the onset of rancidity during the storage of bacon.

A study of the swelling of gelatin gels in salt solutions at 0° C. has shown that a true equilibrium of swelling can acually be obtained. A 15 per cent. gel of gelatin in a 30 per cent. solution of sodium chloride at 0° C. reached an equilibrium after 400 days, and this was maintained for a further 500 days. This material was used to obtain an approximate value for the bound water of gelatin under these conditions. It was observed that the concentration of sodium chloride was appreciably greater in the solution than it was in the gel. Assuming this difference in concentration to be due entirely to the bound water of gelatin, the value for bound water is about 30 g. of water per 100 g. of dry gelatin.

Canning.—Work on similar lines to that of Edwards* on the passage of hydrogen through steel has shown :—

(*a*) That a perfect coating of tin would probably prevent the passage of hydrogen, but that the normal tin coating is sufficiently porous to permit it.

(*b*) A coating of lacquer as used in the canning industry interferes hardly at all with the passage of hydrogen. The lacquer is not loosened, as is often the case with glass enamels, but hydrogen appears to diffuse through it.

The novelty of this work lies in the fact that the diffusion of hydrogen through steel has not previously been considered in relation to corrosion in canning. It probably accounts, however,

* *J. Iron Steel Inst.*, 1924, **110**, 9.

for the fact that hydrogen-swells do not burst. The formation and distribution of hydrogen-blisters in steel also suggests a relation to perforation in canning.

The lag in the formation of hydrogen-swells, due to the use of sugar containing an inhibitor of corrosion, has now been demonstrated for most of the fruits canned in lacquered cans in this country.

A number of beet-sugars have been examined for bacterial content, including thermophilic organisms, which are important in the canning of non-acid products, *e.g.*, peas and other vegetables. The results indicate that most of the sugars have a fairly high content of " flat sour " organisms, and in one case a thermophilic fungus was isolated.

Biological Engineering.—The kinetics of the formation of ice in a stirred viscous fluid have been a subject of investigation in connexion with the determination of the freezing points of egg-yolk, and a paper on the subject has been published [19]. The results promise to have important bearings upon commercial methods for determining freezing points, as, for example, in testing dairy produce.

The rate at which ice is formed in butter stored at low temperatures has been found to be remarkably slow. The thermal capacity of butter has been studied experimentally, and has been found to be a complex function of temperature. It is hoped to relate the results obtained to changes in the state of the water and fats in the butter. The humidity isotherms of a number of food substances and packing materials have been determined. It has been found that packing materials are often the predominant factor in controlling the relative humidity of the atmosphere in contact with the food material stored.

A paper published during the year[18] discusses some of the more important factors governing the relative humidity in cold chambers and ships' holds.

Torry Research Station

Freezing of Fish.—Research is still proceeding on the denaturation of proteins and production of " drip " in white fish as a result of freezing and cold storage. On the commercial side, it is clear that the best results after two or three months' storage are obtained in the case of several species of white fish (haddock, cod, whiting, plaice, lemon sole, halibut) by rapid freezing and storage at a low temperature, *e.g.*,—20° C. A paper entitled " The influence of freezing temperatures on the haddock's muscle " has been published.[14]

Herrings.—For a number of seasons the foreign demand for British salt-cured herrings has been decreasing, and the serious position which has arisen in the industry is common knowledge. Investigations are in progress at the Torry Research Station with

a view to exploring the possibility of increasing home consumption. The " hard " salt-cure, which formerly was a stable food, has long ceased to be an article of diet in Great Britain, and experiments are being made with cures more lightly salted than the usual products of commerce. Several of these light cures have been found delicate in flavour, and appear to be suited to the modern palate. Reducing the salt, however, reduces the period for which the cured fish will keep at ordinary temperatures, and the investigation therefore includes the use of cold storage as an adjunct.

The British herring fisheries are definitely seasonal, and while gluts occur at certain times, supplies are short at others. Shortage occurs particularly during the winter. The possibility of carrying over supplies from periods of glut for kippering and other purposes, by means of brine-freezing and cold storage has been under consideration. As in the case of white fish, *e.g.*, haddocks, storage at a low temperature is essential to prevent the fish from rapidly becoming opaque and commercially useless. Herrings, brine-frozen at —20° C. and stored at that temperature, have been made into good kippers after four months' storage. Tests are now being undertaken on a semi-commercial scale.

A paper on the place of refrigeration in the preservation of the herring as food has been published.[15]

The Metabolism of Carbohydrates in Fish.—In muscle in the frozen state, glycogenolysis is maximal at —3.5° C. A report of the preliminary results has been published[17] and is to be followed shortly by a second report on more detailed work. In the liver, rate of breakdown of glycogen to free sugar decreases with temperature, very small changes taking place at —10° C. over long periods. A definite lag between loss of glycogen and formation of sugar suggests the formation of an intermediate product. Results from a series of analyses have been published, showing that there is no relation between the concentrations of glycogen and vitamin A in halibut's liver.[12]

Study of the amino-acid fractions in fish's muscle is in progress.

Oils and Fats of Fish.—A paper on vitamins from marine sources has been published.[10] The results of the study of the variations in vitamin A potency of halibut's liver oil have also been published.[11]

A further paper [9] has been published in the series on the metabolism of fat in certain marine mammals and fishes (porpoise, dolphin and conger-eel). Work of this nature on the salmon is now being prepared for publication. The question of the cyclisation of certain acids of fishes' fats is being studied. A preliminary paper has been published.[7]

Bacteriology of Fish.—A paper on the effect of exposure to low temperatures on the numbers of bacteria in fish's muscle[22] has

been published. The effect of low temperature as apart from freezing is being studied on pure cultures of organisms in super cooled and frozen media.

A paper on the keeping quality of thawed fish has been prepared for publication. The results of this work indicate that the growth of micro-organisms occurs at the same rate on fresh fish and on thawed fish (previously stored at −12° to −21° C. for one to 12 weeks) during a period of 12–15 days' stowage in melting ice.

The investigation of the effect of carbon dioxide on bacteria isolated from fish and the mode of action of the gas has now been completed but experiments are in progress on a commercial scale to investigate the possibility of gas-storage as a means of assisting in preserving the earlier part of the ice-stowed catch of the short-distance trawler.

A survey of the bacterial flora of fish from the market is being made. The organisms already isolated are all of the types isolated from fresh fish, and are not apparently derived from human contamination.

Ditton Laboratory

Biological Engineering.—The relation between transfer of heat and transfer of water governs the relative humidity of the air delivered from the cooling plant Experiment has indicated that the performance of wet coolers can be expressed in terms of two constants—the thermal and humid efficiencies—and a simple theoretical analysis confirms this treatment. The constants necessarily vary with air-speed, and in a typical case they have been found proportionate to $v^{-0.3}$ a relation which is to be expected if the coefficients of heat-transfer and of water-transfer are proportional to $v^{-0.7}$ as in practice is often found to be approximately the case.

The influence of the production of heat by the stored material on the relative humidity has already been analysed theoretically, and the results shown to conform with practical experience. Leakage of heat from the external environment exerts a similar effect, if this heat is communicated to an air-stream which passes through the cargo, and a jacketed construction for cold-storage chambers in which it is desired to maintain high relative humidities has already been suggested. Recently, in the light of three years' investigations in the experimental hold, and of the increasing accuracy with which it is possible to define the biological requirements of foodstuffs transported overseas, a suggestion has been put forward[20] for a new method of cooling ships' holds, which seems, *prima facie*, suitable for a wide range of cargoes, such as is carried on ships trading from Australia and New Zealand, and which offers certain economies in space and equipment. A two-stage system of air circulation is proposed, the air-stream passing vertically downward through the cargo, and then returning to the cooler by way of a

jacket, lining the sides, in which the heat of leakage is removed. The proposal came at a time when the construction of a number of new refrigerated vessels for the Australasian trade was under consideration. It has aroused considerable interest among shipping companies and refrigerating engineers, and is being adopted, with modifications suggested by the particular requirements of individual cases, in some of the new tonnage now under construction.

The crystallisation of these proposals was made possible by the more accurate information which is now available as to the rate of heat leakage through various walls of an insulated vessel. From a thermal standpoint, these walls are so complicated in structure that large-scale measurement has been necessary, in addition to mathematical analysis. A paper embodying the results of recent investigations has been published.[21]

The preponderating effect of frames and beams in increasing the leakage of heat suggested the practicability of recessing the insulation between these structures in order to provide for the "jacket" referred to in the preceding paragraph. Further experiments are being devoted to an exploration of this possibility.

In some existing ships, when cargoes of fruit are carried in piped spaces which rely mainly or solely on convection to distribute the cold air, the problem of dunnaging the cargo to the best advantage becomes an acute one. A suggestion has been put forward, based on observations in the experimental hold and elsewhere, for a modified method of stowage which gives promise of being at once more effective and more economical for such cases than the existing methods. It has been adopted in several vessels carrying fruit from Australia and New Zealand during the 1934 season, apparently with satisfactory results.

The study of the discharge of air from straight-sided ducts has been completed.

Fruit and Vegetables.—A third series of experiments on the gas-storage of English apples has been carried out during the 1933–34 season. Data are now available for all the more important varieties grown in this country. The characteristic flavour of the Cox's Orange Pippin variety was retained after six months storage at a temperature of 40° F. in an atmosphere of the following composition: oxygen, 2·5 per cent., carbon dioxide, 5 per cent., nitrogen, 92·5 per cent. The capacity of the commercial gas-stores for apples in England is now approximately 7,000 tons.

The important fact that the susceptibility of apples (Bramley's Seedling) to low-temperature breakdown is closely associated with the degree of maturity of the fruit when it is *cooled down* has been confirmed. The fruit is most susceptible to low-temperature breakdown if it is cold-stored when at the peak of respiratory activity.

Researches at the National Physical Laboratory under the Direction of the Engineering Committee

One method of maintaining a low temperature in a store is by distributing cold air by means of a trunk provided with adjustable apertures at various points along its length. Comparatively little is known as to the laws governing the rate of discharge from a series of openings in the side of a trunk, and the experimental work now in progress has yielded some interesting results.

In the case of a closed-end duct with ten adjustable apertures in the side, it has been found that, when the apertures are fully open, so that the area of an aperture is about one-fifth that of the cross-section of the duct, the direction of the discharge from the aperture nearest the air inlet makes an angle of 25 degrees with the axis of the duct, whilst that from the last aperture makes an angle of 80 degrees. For the measurement of the discharge from the various apertures, an indirect method had to be developed, since the air-stream coming from an aperture is not sharply differentiated from the surrounding air. The relative discharge increases for successive apertures downstream, being about 4 per cent. of the total for the first aperture and about 14 per cent. for the tenth aperture.

Another investigation with a bearing on the construction of cold stores, since it may throw light on the factors governing the cracking or flaking of the surface, is the study of the effect of variations in the humidity on the dimensions of surfacing materials used for protecting the insulation. The results obtained indicate a very considerable difference between the behaviour of magnesite plaster and that of the slab cork to which it is commonly applied as a surfacing material. For an increase of 80 per cent. in the relative humidity at −5° C., magnesite plaster expands by less than 0·1 per cent., whilst cork expands by about 0·4 per cent.

Attention has been directed to the materials to be used for containers of solid carbon dioxide, in view of its increasing use for the refrigeration of foodstuffs during transport, and values have been obtained for the thermal conductivity of representative materials down to a mean temperature of −35°C.

Work on the more purely scientific side has included a study of the laws of evaporation from wet surfaces. The rate of evaporation is not proportional to the area of the surface, whether the surface is plane, cylindrical or spherical. For a cylindrical surface the rate of evaporation per unit area in " still " air increases as the diameter of the cylinder decreases, and this result has an important application in the design of wet-and-dry-bulb hygrometers. With a wet-and-dry-bulb hygrometer of the thermo-electric form, using very fine wires, the depression of temperature in " still " air approximates fairly closely to that obtained with the usual mercury-thermometer type of instrument in the stream of air. A wet-and-

dry-bulb hygrometer which does not necessitate forced ventilation has applications in the study of the gradient of humidity above a wet surface in " still " air.

Researches conducted for the Director of Food Investigation by the Imperial College of Science and Technology

Biochemical Work.—An improvement in the half-apple method for comparing the loss of sugar and acid in the apple-fruit with the output of carbon dioxide has been effected by employing diagonally opposite quarters in pairs for comparison, instead of ordinary half-apples. A more equal distribution of the parts of higher (blushed side) and lower (unblushed side) sugar-content was obtained by this means than by the simple half-apple method. The loss of sugar and acid in " Bramley's Seedling " has been shown to be 17 to 30 per cent. higher than can be accounted for by the output of carbon dioxide, thus confirming the results obtained in previous years.

Mycological Work.—The work includes an investigation of the resistance and chemical composition of different varieties of apple borne on selected stocks, and of fruit from manurial trials in progress at East Malling (where effect of stock is also taken into account), and also at Ahorey and Ardress in Northern Ireland. In every instance the experimental methods proved adequate, revealing that differences in resistance or in chemical composition were associated with stock or treatment. The investigation has brought to light complex relationships between host and parasite, and in order to give really satisfactory results should be continued over several years. As an example of the work accomplished during the year, experiments carried out with Lane's Prince Albert apples from sixteen stocks gave different results for each stock, and, in general, results opposite to those obtained with Bramley's Seedling. Curves representing progress of fungal invasion of the fruit were similar to curves expressing the relationship between growth and the acid and sugar supplied to the fungus (*Cytosporina ludibunda*, CE).[16] It was therefore possible in this particular case to find a reasonable explanation of the biological observations on variety and stock in terms of acid and sugar content of fruit when information from the chemical side was not available.

[1] *Report of the Food Investigation Board for the Year* 1933. H.M. Stationery Office (1934). Price 4*s.* 0*d.* net.

[2] BROOKS, J. The Vapour Pressure Isotherm of Muscle. *Proc. roy. Soc.*, 1934 (B), **114**, 258.

[3] BROOKS, J. Bound Water in Muscle. *J. gen. Physiol.*, 1934, **17**, 783.

[4] BROOKS, J.; and LEA, C. H. Changes in the Muscle Pigments. *Report of the Food Investigation Board for the Year* 1933, *p.* 30. H.M. Stationery Office (1934). Price 4*s.* 0*d.* net.

[5] CALLOW, E. H. Bacon Curing. The Dry-Salt and Tank Curing of Wiltshire Sides. *Food Investigation Leaflet, No.* 5. Dept. Sci. Ind. Res., Lond., 1934. *Gratis.*

(6) CALLOW, E. H. The Gas-Storage of Bacon. *Proc. Brit. Ass. Refrig.*, 1933–34, **30**, 61.

(7) EDISBURY, J. R., MORTON, R. A., and LOVERN, J. A. Absorption Spectra in Relation to the Constituents of Fish Oils. *Bio-chem J.*, 1933, **27**, 1451.

(8) LEA, C. H. The Influence of Salts Used in Curing on the Oxidation and Yellowing of Lard. *J. Soc. chem. Ind., Lond.*, 1934, **53**, 182T.

(9) LOVERN, J. A. Fat Metabolism in Fishes. III. Selective Formation of Fat Deposits. *Bio-chem. J.*, 1934, **28**, 394.

(10) LOVERN, J. A. Vitamins from Marine Sources. *J. State Med.*, 1934, **42**, 607.

(11) LOVERN, J. A., EDISBURY, J. R., and MORTON, R. A. Variations in Vitamin A Content of Fish-Liver Oils, with Particular Reference to Seasonal Fluctuations in the Potency of Halibut-Liver Oil. *Bio-chem, J.*, 1933, **27**, 1469.

(12) LOVERN, J. A., and SHARP, J. G. The Diet of the Halibut and Intensity of Feeding, in Relation to the Vitamin A Potency of the Liver Oil. *Bio-chem. J.*, 1933, **27**, 1470.

(13) MORAN, T. The Hydration or Combined Water of Gelatin. *Proc. roy. Soc.*, 1932(A), **135**, 411.

(14) REAY, G. A. The Influence of Freezing Temperatures on Haddock's Muscle. I. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 265T.

(15) REAY, G. A. The Place of Refrigeration in the Preservation of Herring as Food. *J. State Med.*, 1934, **42**, 602,

(16) SETH, L. N. Studies in the Genera Cytosporina Phomopsis and Diaporthe, V. Analysis of Certain Chemical Factors Influencing Fungal Growth in the Apple. *Ann. Bot., Lond.*, 1934, **48**, 69.

(17) SHARP, J. G. Post-Mortem Breakdown of Glycogen and Accumulation of Lactic Acid in Fish Muscle. I. *Proc. roy. Soc.*, 1934 (B), **114**, 506.

(18) SMITH, A. J. M. Some Possible Developments in the Refrigerated Transport of Foodstuffs. *Trans. Lpool engng Soc.*, 1933, **55**, 49.

(19) SMITH, A. J. M. The Relations between Yolk and White in the Hen's Egg. VI. *J. exp. Biol.*, 1934, **11**, 228.

(20) SMITH, A. J. M. New Method of Cooling Ships' Holds, Involving Vertical Air-flow for the Cargo and a Recessed Jacket for Heat Leakage. *Ice cold Stor.*, 1934, **37**, 21.

(21) SMITH, A. J. M., and FARMER, J. D. The Structure of Insulated Holds in Relation to Heat-Leakage. *Trans. Instn nav. Archit.*, 1934, **76**, 52.

(22) STEWART, M. M. The Effect of Exposure to Low Temperatures on the Numbers of Bacteria in Fish's Muscle. *J. Soc. chem. Ind., Lond.*, 1934, **53**, 273T.

GEOLOGICAL SURVEY AND MUSEUM OF PRACTICAL GEOLOGY

THE field work of the Geological Survey during the past twelve months has necessarily been a continuation of the programme of the preceding year, except that certain new districts have been opened, and other districts have been finished and closed. Of the primary survey the mapping of Shetland is now finished and the mapping of Northern Skye has been started. The southern part of Skye was surveyed thirty years ago. The Strontian Sheet (West Highlands) has been finished and the Mallaig Sheet is begun. In England the Wigan Sheet is completely revised and the Preston Sheet may be completed in 1934. The revision of the Wakefield and Barnsley Sheets was completed in 1933 and the Bradford and Leeds

Sheets were begun. Field work was started also in 1933 on the Forest of Dean coalfield, of which there had previously been no six-inch survey. In the Cambridge district the Biggleswade Sheet may be completely revised in 1934 and a start will be made with the Huntingdon Sheet (which was previously partly revised). The revision of the Gosforth Sheet (Cumberland) was completed in 1933. The primary six-inch survey has been further advanced in the Forest of Wyre and the Bridport district.

Six-inch coalfield maps and memoirs on the following coalfields are passing through the press or preparing for publication. In Scotland: Kilsyth, East Fife, Sanquhar and Douglas coalfields. In England: Gosforth, Cockermouth (Cumberland), Rothbury (Northumberland), Wakefield, Barnsley (Yorkshire), Wigan, Preston (Lancashire), Shrewsbury, Dudley.

The International Monetary and Economic Conference met in the new Museum in June 1933 and closed in September. At the end of the year it was announced that the new Museum was no longer required for this purpose and H.M. Office of Works began to remove the fittings installed for the Conference and prepare the Museum for occupation by the Geological Survey. In January part of the office staff was transferred, and some of the laboratories and workshops. This process was continued as fast as the new premises were ready for occupation. The Jermyn Street Museum was closed to the public in January, but the library remained open till July 1934. In August the library was transferred to South Kensington. The remainder of the collections of minerals, rocks and fossils has been packed and is ready for transfer as soon as the necessary fittings are installed. It is expected that the Jermyn Street Museum will be completely evacuated by October 1934. The work of arranging exhibits in the new Museum is making progress, and it is anticipated that the Museum will be opened to the public in June 1935.

The number of enquiries answered during the year has been exceptionally large. Over a thousand of these dealt with the geology of underground water supply. These were received from many districts of England and Scotland but principally from the South-eastern counties. Many of them came from well-sinkers, borers, civil engineers, and the Ministry of Health, or from municipal and county authorities. One water-supply memoir is in the press (Herefordshire) and materials are being collected for several others. The records of borings have been completely overhauled and indexed, as a considerable expansion of activities in this direction may be anticipated.

The Geological Survey is represented on Committees of the Fuel Research Board (all districts), Building Research Board (weathering), Imperial Institute (Advisory Council on Mineral Resources), British Standards Institution (road-making materials), British Association (Water Survey Committee), Water Pollution Research Board (Mersey Estuary Investigation), and has continued to supply

geological information to these and to Government Departments as required. Two geologists also took part in an investigation of soil types in Scotland and in Northumberland under the auspices of the Ministry of Agriculture and Fisheries, Department of Agriculture, Scotland, and the Development Commission. At the request of the Government of Northern Ireland a geologist was sent to report on various geological questions in Antrim.

(1) *Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year* 1932. Part II. H.M. Stationery Office (1933). Price 3*s.* 0*d.* net.

(2) *Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year* 1933. Part I. H.M. Stationery Office (1934). Price 1*s.* 6*d.* net.

Building Research

Details of the work carried out at the Building Research Station during the year are given in the Annual Report of the Building Research Board.(1) The general research is now steadily advancing to the stage at which there is a definite scientific basis for the utilisation of building materials and methods of construction; furthermore, the ever-growing volume of special investigation and enquiry work indicates that the activities of the Station are becoming increasingly known and that the facilities offered are coming into regular demand.

Weathering

Work has been continued on the survey of the national resources of building stone, which is being undertaken in conjunction with the Geological Survey. The study of certain types is progressing side by side with that of methods of testing designed to facilitate the assessment of weathering quality. The physical type of a stone has been found to be of paramount significance; actual correlation of physical characteristics and weathering properties can only be established within a range of materials of similar type, and it is necessary to recognise the type before an attempt can be made to predict the weathering behaviour of a stone. In the main attention has been confined to the limestones (particularly Portland and Clipsham stones), but in the course of the year a certain amount of information has been gathered on sandstones.

A point that has emerged from the work is that the crushing strength of building stone may often afford no criterion of durability.

Tests on the lead peroxide method of estimating sulphur pollution of the atmosphere continue to be carried out in conjunction with the Atmospheric Pollution Research Committee. The method is now in regular use at a number of centres, and is also being employed for certain special purposes in connection with research on the corrosion of non-ferrous metals, the durability of leather in libraries and the recording of pollution emanating from a localised source.

In connection with the physical features influencing weathering, further experiments have been made in the study of the manner in which water is held in the pores of building materials and the mechanism of its movement and distribution. The methods include investigation of the pressure deficiency and water content of stones; examination of the movement of water between stones in contact; and the estimation of the dielectric capacity of moist stone.

In continuation of work previously described on the action of frost on various classes of building materials, particular attention has been paid during the year to laboratory and natural exposure tests on clay bricks and Bath stone.

Professor Paine is continuing his researches at the Imperial College of Science and Technology into the bacteriological aspects of stone decay. A detailed account has been submitted to the Royal Society.[14]

Materials

Further experimental work has been carried out on asphalt mastic for roofing and investigation has been made on the formation of blisters in asphalt mastic roofs.[2]

Considerable attention has been paid during the year to the examination of available data on the resistance of concrete to chemical attack.

In regard to the constitution of cements, investigations have been completed on the phase relationships in that portion of the system CaO–Al_2O_3–SiO_2–Fe_2O_3, of importance in connection with Portland cement manufacture; a paper on the subject has been communicated to the Royal Society. A report has been published[4] giving the method of determining the free calcium hydroxide of fresh cements with results obtained from the examination of a large number of commercial cements.

The study has been continued of the constituent compounds of set cements, on the dehydration of these compounds and on the hydration of high alumina cement. An investigation has been conducted into the effects of storing lime, lime-pozzolana, cement and cement pozzolana mortars in an atmosphere of carbon dioxide. The research on pozzolanas commenced five years ago in co-operation with the industrial interests concerned has now been completed, and a series of reports is being prepared for publication.

The investigations concerned with the suitability of lime for the manufacture of sand-lime bricks have been completed, and a Special Report[5] dealing comprehensively with the manufacture, properties and testing of sand-lime bricks has been issued.

Some tests on hollow pre-cast concrete partition slabs have been carried out in connection with the standard specification which is being formulated by a committee of the British Standards Institution.

The work commenced in 1931 at the Building Research Station in co-operation with the Cast Concrete Products Association has con-

tinued to yield valuable results. Work has been proceeding on the cause and cure of crazing and on pigments suitable for use with cast concrete products. A study has been made of the absorption of concrete pipes with the object of developing a standard test for specification purposes.

Research work on building limes has this year been mainly concerned with the co-operative research on greystone limes. Most of the work on calcium sulphate plasters has related to the preparation of the standard specification for this material. For plasters in general, study has been continued of the effect of different sands on the plaster mix, and on the use of materials to be added to lime to provide early strength, *e.g.*, for work over lathing. In continuation of previous work on roofing slates an examination has been made of the effects of cycles of wetting and drying on a representative series of slates. It has been confirmed that the acid test for slates previously devised by the Station provides a rapid, convenient and accurate means of estimating durability. Results of the various investigations have been embodied in a revised edition of the bulletin on the durability of roofing slates.[15]

From the investigations made of the properties of expanded slate, it is evident that this material possesses all the qualities required in a first class light-weight aggregate. A bulletin describing the material and its properties is being prepared for publication.

Work on clay building materials has been directed to the effect of firing temperature on physical and other properties; the effect of water on bricks; efflorescence; physical structure; crystallisation and other tests, and the durability of bricks underground. A general account of the "cemetery" test has been presented to the Ceramic Society.[8]

Other materials studied include plate glass, with special reference to thermal expansion; paint, with particular attention to its application to building materials, and waterproofers, both surface and integral. A revised edition has been published of the bulletin on the effect of building materials on paint films.[13] Contributions have been published in the Transactions of the Faraday Society on the physico-chemical studies of silica gel.[6, 7]

Structures and Strength of Materials

The investigation has continued throughout the year of the small movements (shrinkage and creep) that occur during the ageing of concrete. Progress continues to be made in the study which is being carried out in co-operation with the Federation of Civil Engineering Contractors of the effect of impact during the driving of reinforced concrete piles; a general note on the subject has been communicated to the press.[3]

A series of studies has been made into the problems associated with the heat development in hydrating concrete; many tests have

been made on different types of cement concrete cured under adiabatic conditions, and much of the information gained has been published.[9, 10] Considerable attention has been paid to the influence of the temperature at which concrete is matured on its subsequent strength, and opportunities have been afforded of sampling concrete during the construction of several buildings in the London area.

The usual periodical investigations have been made of the reinforced concrete piles which are being tested at Watford and Sheerness in co-operation with the Committee of the Institution of Civil Engineers on Deterioration of Structures exposed to Sea-Water. For the measurement of wind pressures which has been undertaken on behalf of the Board by the National Physical Laboratory, the apparatus on the Severn Bridge has been modified in order to make it possible to obtain simultaneous records from four single instruments. Important conclusions have been drawn from a series of observations taken in January, 1934. Tests on the effects of adjacent buildings and wind pressure on roofs are being continued with models of various forms in a 3-foot wind tunnel.

Efficiency of Buildings

Considerable progress has been made towards the design and construction of a " controlled weather house " where investigations can be undertaken in collaboration with the Institution of Heating and Ventilating Engineers.

Simple instruments have been evolved for the measurement of equivalent temperature of a room, and arrangements are being made for the instruments to be put on the market.

In collaboration with the Industrial Health Research Board of the Medical Research Council a comprehensive investigation has been made of infra-red rays in relation to comfort. An account of the work has been published.[11, 12] With the increasing use of thin sheet materials as an inexpensive means of roofing buildings of an industrial type, the problem of devising suitable thermal insulation, which will not unduly add to the weight of such roofs, has become one of considerable importance: tests have been made on the efficiency of such methods of construction. It is found also that moisture content has an important effect on the thermal resistance of various materials; particular investigations have been made on fibre-boards.

Other items of work have been concerned with the exclusion of solar heat, the measurement of the diffuse reflecting power of materials, and absorption of solar radiation. Special attention has been directed to the thermal movements of concrete roofs covered with asphalt.

Intelligence and Minor Investigations

During the year a total of 1,526 enquiries and minor investigations were dealt with, again showing an increase over previous years.

Facilities available for the testing of materials have been extended by the formation of a panel of co-operating testing houses, to whom certain standardised tests can be referred. This extension will enable the Building Research Station to cope with the growing volume of requests for tests and reports, the utility of which the industry is now beginning rapidly to realise.

(1) *Report of the Building Research Board for the Year* 1933. H.M. Stationery Office (1934). Price 2*s.* 6*d.* net.

(2) The Formation of Blisters on Asphalt Mastic Roofs. *J. R. Inst. Brit. Archit.*, 1933, **41**, 139.

(3) Pile-driving Research. *Engineering*, 1934, **137**, 494.

(4) BESSEY, G. E. Free Lime in Portland Cement. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 219T.

(5) BESSEY, G. E. Sand-Lime Bricks. *Building Research Special Report, No.* 21. H.M. Stationery Office (1934). Price 1*s.* 3*d.* net.

(6) BONNELL, D. G. R. Studies in Gels. IV. The Swelling of Silica Gel. *Trans. Faraday Soc.*, 1933, **29**, 1217.

(7) BONNELL, D. G. R. Studies in Gels. V. Effect of Neutral Electrolytes on the Syneresis of Silica Gels. *Trans. Faraday Soc.*, 1933, **29**, 1221.

(8) BUTTERWORTH, B. The Correlation of Laboratory Tests with the Weathering Properties of Bricks. *Ceramic Society, Clay Convention*, Llandudno, 1934. *Preprint*, pp. 27.

(9) DAVEY, N. Influence of Temperature upon the Strength Development of Concrete. *Building Research Technical Paper, No.* 14. H.M. Stationery Office (1933). Price 2*s.* 0*d.* net.

(10) DAVEY, N., and FOX, E. N. Temperature Rise in Hydrating Concrete. *Building Research Technical Paper, No.* 15. H.M. Stationery Office (1933). Price 1*s.* 3*d.* net.

(11) DUFTON, A. F. Radiant Heat. *Proc. Instn Heat. Vent. Engrs, Lond.*, 1932–33, **31**, 230.

(12) DUFTON, A. F., and BEDFORD, T. "Nose-Opening" Rays. *J. Hyg., Camb.*, 1933, **33**, 476.

(13) LLEWELLYN, H. M. The Effect of Building Materials on Paint Films. *Building Research Bulletin, No.* 11. (*Revised Edition.*) H.M. Stationery Office (1934). Price 3*d.* net.

(14) PAINE, S. G., LINGGOOD, F. V., SCHIMMER, F., and THRUPP, T. C. The Relationship of Micro-Organisms to the Decay of Stone. *Philos. Trans.*, 1933 (B), **222**, 97.

(15) WATKINS, C. M. The Durability of Slates for Roofing. *Building Research Bulletin, No.* 12. (*Revised Edition.*) H.M. Stationery Office (1934). Price 4*d.* net.

STEEL STRUCTURES RESEARCH

THE Steel Structures Research Committee has issued a second report covering the two years ended 31st March, 1933.(1)

The Committee draw attention to the fact that the recommendations of the Code of Practice incorporated in their first report have been accepted, practically unchanged, by the London County Council, as the basis of consideration of applications under Section 58 of the London Building Act, 1930, for relief from the provisions of the Third Schedule to the Act. The recommendations have also been embodied in the British Standards Specification No. 449, issued

in April, 1932, by the British Standard Institution. Moreover, the Minister of Health has arranged to make the recommendations available in convenient form to local authorities and the general public, by referring to the standard specification in the Urban and Intermediate Series of Model Bye-Laws. It is understood that the adoption of the new Act has led to reduction amounting to as much as 20 per cent. in the cost of steel work required for the kind of building to which it mainly relates.

In connection with certain of the recommendations in the code, the Committee have thought it advisable to conduct further direct investigations in order to examine possible improvements in the provisions for wind pressure, for the design of bloom bases and for the " effective length " of pillars, and for the strength of filler joist floors. As mentioned elsewhere, see page 56, the Building Research Board has experimental work now in hand at the National Physical Laboratory on the wind pressure on models representing structures in a built-up area, and this work has been arranged to help directly the work of the Committee. In regard to bloom bases, a mathematical investigation has been made of the stresses in flat rectangular slates supporting a central load, and experimental work on the subject is being carried out for the Committee at Bristol University. A note on the " effective length " of pillars is included in a separate paper in the Committee's report, and a working rule will be given when further particulars regarding connections are forthcoming.

The main items of the Committee's investigations may be grouped under four headings: the measurement of strains in existing buildings; the examination of bolted and riveted connections; stress analysis, both mathematical and mechanical, and the study of new methods of design.

Strains in Buildings.—The investigations have been completed during the year on the uncased frame of a hotel building in London, and on the frame after the hollow tile floors had been placed and the construction completed of the stanchion casing and walls. Similar tests have also been made on the framework of an office building, and on a selected portion of the framework of a new block of residential flats. The analysis of the measurements has provided a mass of valuable information.

Riveted and Bolted Connections.—Professor Batho has continued his investigations at Birmingham University on riveted and bolted connections, and has produced a range of data of great importance to the Committee's work. Separate papers dealing with beam and stanchion connections and with bolts and bolted joints are included in the Committee's second report.[1]

Stress Analysis.—Professor Batho has contributed an analysis of the movements and members of a frame for rigid or semi-rigid

connections under vertical loads. This paper should be read in conjunction with the paper, also included with the Committee's second report, by Professor Baker on the stress analysis of steel building frames, giving the method used for the analysis of the strains in the experimental frame erected at the Building Research Station.

The value of mechanical methods of stress analysis has been examined, and a paper on the subject by Professor Baker has been contributed to the Institution of Civil Engineers, who have published it as a selected paper.[2]

A series of experiments has also been carried out on the experimental frame.

Design Method.—The object of the Committee's various investigations is, of course, to develop an improved method of frame design. Considerable attention has already been given to this practical aspect and it will guide much of the work in the future. The vital factor is the treatment of connections between the members. Various proposals in relation to a new design method are receiving serious consideration, and it is believed that it will prove possible to make definite suggestions for considerable improvement in efficiency of design.

Welding of Steel Structures.—The investigations into the use of electric arc (metal arc) welding for structural steel work, which are being conducted on behalf of the Committee at the National Physical Laboratory with the collaboration of welding firms, have not proceeded as rapidly as might be desired though as rapidly as has been found possible. While the possibility of a non-destructive test of a welded joint has not been neglected, and certain investigations are in hand, attention has been concentrated on securing comparative data on the strength and reliability of welded joints made with different electrodes under existing welding technique. It is hoped to secure the co-operation of a large number of firms in the preparation of the samples required for this main series of tests. An examination is also being made at the National Physical Laboratory of the fatigue strength of certain typical joints.

[1] *Second Report of the Steel Structures Research Committee for the Two Years ended 31st March,* 1933. H.M. Stationery Office (1934). Price 7*s.* 6*d.* net.

[2] BAKER, J. F. The Mechanical and Mathematical Stress Analysis of Steel Building Frames. *Sel. Engng Pap. Inst. civ. Engrs, No.* 131 (1932).

ROAD RESEARCH

THE comprehensive scheme of road research visualised by the Road Research Board is described in the first Annual Report of the Board which will be published shortly.[1]

Road Construction

(*a*) *Materials.*—One important item is the study of soil physics, which is of course concerned with the relation between the subsoil and the road. The ultimate object of the research is to provide the engineer with data which will enable him to design his roads with a surer understanding of all the subsoil conditions which will affect their performance. The stability of roads on made foundations is an obvious example of the great importance of a knowledge of the properties of a disturbed soil. Two distinct lines of investigation are being followed. The first is the laboratory study of those physical properties of the subsoil which, through variations in moisture content, etc., may be so modified as to interfere with its mechanical properties as a foundation to the road. This laboratory study will be supplemented by seasonal field surveys of the actual conditions existing in the subsoil in order to determine the effects of climatic conditions and drainage. The second line of investigation is the collection of information on the influence of subsoil conditions on the performance of roads. Comparisons will be made between roads of similar construction carrying the same traffic load but with differences in subsoil. Attention has been concentrated so far on the laboratory method and as a first step a soil punch has been devised for extracting soil cores for test. A standard classification has been adopted for the characterisation of the subsoil samples.

Work on aggregates, fillers and mixtures for use in roads comprises the examination of grading and shape characteristics of aggregates used with hydraulic and bituminous binders; the investigation of the particle size and shape of fillers; and tests on the physical and mechanical properties of mixtures of aggregates and binders. It has been necessary to develop special testing apparatus. Particular points of interest are the examination of seasonal and allied effects on bitumens and bituminous mixtures and the adhesion and wetting properties of bituminous binders to aggregates.

(*b*) *Processes.*—In connection with concrete roads (surfaces and foundations), preliminary work has been carried out on several items relating to field control of concrete and concrete road construction. An investigation has been made into the practicability of the sand inundation method of concrete control. Field tests have been carried out on cylinders and cubes to investigate the cause of variations in the results obtained. Attention has been paid to the variation in cement as supplied in bulk for concrete road construction. Methods are being developed for the analysis of set concrete. Measurements are in progress on the deflection of road slabs under traffic. An important item of work is concerned with the design of concrete road slabs. The problem of road slab design is one of great complexity and at the present time no definite standards of practice have been established. The conditions of support to the slab are largely indeterminate and are variable owing both to local

settlement and to distortion of the slab from shrinkage due to moisture or temperature changes; the loading conditions are also largely indeterminate and the effect of impact is not properly understood. The investigation will include measurement of stresses in an unloaded slab as well as in a loaded slab. Dynamic stresses in loaded slabs will be measured by means of the piezo-electric gauge developed at the Building Research Station for the measurement of strains in reinforced concrete piles during driving.

With regard to bituminous roads, surfaces and foundations, consideration has been given to the processes involved in bituminous road construction, and a general survey has been made of the literature on the subject. Some initial work has been carried out with a view to developing a suitable method for the analysis of tarred stone used for tar macadam. An examination has been made of samples taken from bituminous roads of known characteristics.

Preliminary work on surface dressings is being carried out in a 5½ foot diameter testing machine. Machine spraying and grading apparatus has been designed and built.

The further work will be carried out in the large road testing machine referred to below.

Road Usage

Work on road usage falls into two main divisions: (*a*) forces applied to roads by vehicles; and (*b*) vehicle design in relation to road forces.

Research work on the forces applied to roads by vehicles has been carried out for the Ministry of Transport by the National Physical Laboratory since 1926. A special trailer and recording outfit was designed and constructed for the measurement of impact forces. This series of tests is being continued, but the investigation has so far been confined to roads of concrete construction, plain, or surfaced with an asphalt carpet. Further tests are to be carried out under a variety of subsoil conditions.

The forces applied to roads by a vehicle are doubtless affected by the characteristics of the vehicle, such as tyre equipment, wheel load, size of wheel, type of springing, unsprung weight, inflation pressure (pneumatic tyres).. These factors are being investigated on behalf of the Road Research Board at the National Physical Laboratory. The ideal way of investigating the individual effect of these factors would be by the use of a special vehicle upon which any of these factors could be progressively changed whilst the others remain unaltered. For the present, however, an attempt is being made to get a satisfactory range by the use of three or four separate vehicles which have been agreed as typical. Thanks are due to the Research Section of the Institution of Automobile Engineers, through whose co-operation it has been possible to borrow a selection of commercial vehicles and tyre equipment from several firms.

Development of Special Testing Plant

Very little progress in general research on roads will be possible until some means are available for judging durability other than by waiting for deterioration under normal usage. One method which has been followed is to lay down experimental stretches of roads; another and a speedier method which seems possible is to use road machines. A machine is required which will produce the same effect on model road sections in days as against years of normal wear. But it is important to realise that mere increase in rates of loading, or artificial intensification of weathering agencies, may be misleading; the time factor may profoundly affect such materials as bituminous compounds. Again, some estimate must be made of the effects of foundations and sub-foundations on the rates of wear when factors besides attrition are considered. The first step, once a reasonable type of machine has been designed, is to carry out some tests on samples of road sections whose durabilities are known and so obtain a "scale." Having established the scale to which the machine is recording, it becomes a valuable instrument for estimating rapidly the probable performance of new forms of materials and construction.

The basic considerations are that the road machine should be small enough to allow results to be obtained accurately, quickly, and at a low cost, while large enough to allow materials to be laid and tested in the closest possible accord with road practice. Arrangements have been made at the Road Research Laboratory to use wear machines, with mean track diameters respectively of 5½ ft., 38 ft., and 110 ft. Of these, the first provides the most rapid wear, but departs furthest from road conditions; the second uses a track laid and rolled as on the road, but subjected to wear under specially loaded wheels; the track of the third can also be laid as on the road and worn under an actual road vehicle. The first machine had been in preliminary use at Harmondsworth under the Ministry of Transport and has now been modified and more permanently housed; the second has been transferred from Teddington, where it was originally constructed for the Ministry of Transport, and re-erected at Harmondsworth with some alterations. The third is now being designed.

For the record of the impact imparted to roads special apparatus has been designed and constructed at the National Physical Laboratory. The first measurements are being made on a six-wheeler Leyland chassis of about 6 tons normal capacity, the instruments being fitted to the rear-most axle.

At the request of the Ministry of Transport a special form of motor bicycle and sidecar was developed some years ago at the National Physical Laboratory for comparing the behaviour as regards side-slipping of rubber tyred wheels on different road surfaces and under various types of weather conditions. A special

mechanism has now been designed for combining observations and recording the skidding coefficient directly on a chart. Other methods for measuring skidding or side-slipping on road surfaces are under consideration.

The factor which limits the life of the majority of roads in this country is the development of surface irregularities. There is a definite need, therefore, for estimating this quantity in order that the conditions or degrees of wear of various roads may be compared. Various types of apparatus have been considered. A special 16-wheeled apparatus is being constructed in the first instance which will also be suitable for use on road machines in order that direct correlation may be obtained between the results of the laboratory and road work.

(1) *Report of the Road Research Board for the Year* 1933-34. H.M. Stationery Office (1934). (*In the press.*)

Forest Products Research

The sixth report of the Forest Products Research Board, which covers the work of the Forest Products Research Laboratory in the year 1933, has now been published.(1)

Factors Determining the Technical Qualities of Timber

Advances have been made in investigating the technical qualities of timber so far as these are due to the anatomical structure of the wood. By examining the structure of timbers which have been tested under standard conditions a closer insight has been obtained into the fundamental nature of their various technical properties. This has enabled the properties of certain timbers to be estimated more accurately than was previously possible, and has at the same time increased the knowledge of the way in which the growth of a tree affects the quality of the timber. In certain timbers with a comparatively simple type of structure, it has been shown that within the normal range of conditions the rate of growth is the outstanding factor determining the quality of the timber. This relation appears to hold, for example, with those coniferous timbers which are characterised by a fairly sharp differentiation between the springwood and summerwood zones. In timbers with a more complex structure, however, the influence of the growth rate on the quality of the timber may be outweighed by factors controlling development of the various woody tissues.

Factors in the Layout of an Air Seasoning Yard

The air movements caused by wind in a timber yard have been investigated. The tests indicate that a particular orientation of the alleys through a yard is not of prime importance, and that they

will act as ventilation roads more or less irrespective of wind direction. It has been found that if the piles in a row are separated by about a foot, the space is ample to prevent any retardation of the drying process.

The rate at which softwood can be dried formed part of the test, and for 2-in. material, a period of 60 days was required to attain a moisture content of 25 per cent. and 90 days for seasoning to 20 per cent. These times apply when the timber is stacked in early spring, and the seasoning process is assisted by the subsequent dry summer conditions.

Pin-hole Borer Damage to Empire Timbers

The occurrence of damage by pin-hole borers (beetles of the families Scolytidæ and Platypodidæ) to Empire timbers, particularly those from tropical countries, has become of increasing importance, and it is evident that in certain cases the development of a British home market for many of these timbers will depend on the elimination of, or at least a reduction in, this type of defect. Since relatively little information is at present available upon the prevalence of pin-hole damage, particularly where new tropical woods are concerned, the application of control measures presents a most difficult and complicated problem. Little is at present known of the species of insects responsible for the injury, their distribution, their periods of activity and their preference for sapwood or heartwood. The pin-hole borer problem merits thorough investigation by trained forest entomologists working in the countries concerned in close co-operation with forest officers and those immediately handling the timber.

Although up to the present the Laboratory has been unable to take any direct part in the practice of such investigations, it has been, and still is being, called upon to assist in preliminary work, by planning experiments and by examining and commenting upon proposed schemes of work, which it is encouraging to note are contemplated or are in operation in the Federated Malay States, British North Borneo, Trinidad, and to a lesser extent in the West African Colonies. In this way the Laboratory is becoming more and more a clearing house for information upon timber insects, particularly from those parts of the Empire where at present the services of forest entomologists are not available.

In connection with this work, also, a collection of the insects responsible is being built up and identifications of the species are being undertaken as far as they can be determined. In this way it is hoped to maintain at Princes Risborough for reference a representative collection of the insects concerned.

General Programme of Work

The application of analytical methods to anatomical measurements of various timbers, and the study of the variations which

occur in the cells has facilitated the selection of representative samples for examination of the typical structure of the wood of any species. It has also materially assisted in determining the number of different samples of any timber which must be examined in order to obtain a truly representative description.

Further progress has been made towards the successful measurement of cell-space ratio by means of a photo-electric photometer. Improvements in the apparatus have led to results sufficiently satisfactory to warrant its use in the future as a standard laboratory instrument.

An investigation originally undertaken with a view to the discovery of the nature of the binding forces between wood and water has shown that practically all the water up to the fibre saturation point is held by adsorption, and that the method employed in the investigation has immediate applications of a practical nature in affording a means of measuring directly the fibre saturation point of various woods.

Experiments have demonstrated that the common belief that timber becomes less affected by changes of moisture content as it ages has no foundation in fact, and that there is no material difference between old and new timbers in the amount of shrinkage or expansion which takes place with a given variation in moisture content.

Study of the moisture changes in seasoned timber which take place during sea-transit from British Columbia ports to this country has been undertaken in collaboration with the Forest Products Laboratory of Vancouver.

The changes in dimension in timber that are due solely to temperature as distinct from moisture variations have been under investigation, and apparatus has been devised which it is anticipated will enable the moisture content of a sample of wood to be kept constant during changes in temperature.

A very common defect in commercial soft-wood timber is " stain " produced by the action of certain fungi. The work, which was undertaken to determine what effect, if any, such stain-producing fungi have upon the strength properties of the timbers affected, has been continued.

A report dealing with the effect of creosoting on the strength properties of railway sleepers is in preparation, following the completion of the mechanical tests on certain sleepers which had been seasoned to a moisture content of 20 per cent. prior to impregnation with creosote.

Experiments carried out to determine the effect of varying the cutting angle in working refractory timbers have yielded very satisfactory results. A cutter-block, which allows of adjustment of the cutting angle to the optimum for any particular timber, has been used in these experiments, and it has been found that " picking-up " of the grain can be almost if not entirely eliminated in working sycamore with " fiddle-back " figure, wavy grained yew, and timbers

in which interlocked grain occurs, such as African and Sapele mahoganies, Nigerian walnut, East Indian satinwood, and Okan.[2, 3] Saving in time and labour required for sanding, as well as in material, is thus effected.

Further study of the effect of the micro-structure on the preservative treatment of coniferous woods has led to the conclusion that the numerical distribution of the bordered pits in the tracheids of such woods and the changes which take place when drying materially affect the impregnation of softwoods with preservatives. The results of the investigation have been published.[5]

The work of testing the efficacy of wood preservatives in preventing the destruction of timber by fungi and insects has been continued. Experiments have been carried out with a view to determining whether the protection afforded by various preservatives against wood-destroying insects is merely temporary or reasonably permanent.

Progress has been made in the study of the factors affecting the attack on timber of the *Lyctus* Powder-post beetles, and the investigation of the relation between the pore-diameter in a timber and its liability to infestation has been completed. An account of this work has been published.[4] Further work on the control of *Lyctus* beetles has also been in progress, and the efficacy of ordinary kiln seasoning in a progressive kiln for sterilizing infested oak has been demonstrated. Other possible methods of control are being investigated.

Work on the fungi which attack oak, either while growing or after felling and conversion, has been continued, and several important cases of decay in oak timbers in buildings have been traced to a fungus which has provisionally been identified as *Fomes cryptarum.* The microscopic structure of the fungus and its effect upon the wood have been studied with a view to the publication of a full description later. Further progress has been made in the work which has for its objective the discovery of the cause of the unusual colour in " brown " oak, and the same fungus has been isolated from various samples of the wood. The presence of this fungus has suggested the possibility of deterioration in the strength properties of the timber, and tests to determine whether such deterioration is associated with its presence have been initiated. The results of small scale tests already completed tend to show that " brown " oak does not differ from ordinary oak in its mechanical properties, but confirmatory tests will be necessary before it will be safe to conclude that those properties are unaffected in " brown oak " in general.

The work on the chemistry of decay has been extended to include the chemistry of white rots of wood produced by *Echinodontium tinctorium, Trametes gibbosa, Fomes cryptarum* and *Ustulina vulgaris.* All these have been found to attack the wood-carbohydrates as well as the lignin in the timber.

Work for the Empire Oversea

Major scale investigations of the structure, mechanical, physical and seasoning properties, resistance to decay and amenability to preservative treatment, working qualities and possible uses of munyama (*Khaya anthotheca* C. DC.) from Uganda; Ceylon gurjun (*Dipterocarpus zeylanicus* Thw.) from Ceylon; mora (*Dimorphandra excelsa* Baill.) from Trinidad; santa maria (*Calophyllum brasiliense* var. *Rekoi* Standl.) and banak (*Virola merendonis* Pittier) both from British Honduras; East African camphor (*Ocotea usambarensis* Engl.) from Kenya; and opepe (*Sarcocephalus Diderrichii* De Wild.) from Nigeria have been in progress.

In addition preliminary tests of black cabbage bark (*Lonchocarpus Castilloi* Standl.), santa maria (*Calophyllum brasiliense* var. *Rekoi* Standl.) and yemeri (*Vochysia hondurensis* Sprague) all from British Honduras; mujua (*Alstonia congensis* Engl.) and musisi (*Maesopsis Eminii* Engl.) both from Uganda; coachwood (*Ceratopetalum apetalum* D. Don) from Australia; and mansonia or ofun (*Mansonia altissima* A. Chev.) from Nigeria have been completed. Further preliminary tests on mninga (*Pterocarpus angolensis* DC.) from Tanganyika Territory and podo (*Podocarpus gracilior* Pilg., *P. usambarensis* Pilg. and *P. milanjianus* Rendle), the former from Kenya and the two latter from Tanganyika Territory, have been undertaken.

Special investigations have been in progress in connection with certain of the properties of East African pencil cedar (*Juniperus procera* Hochst.) from Kenya; turpentine (*Syncarpia laurifolia* Tenore) from Australia; mora (*Dimorphandra excelsa* Baill.) from Trinidad; Western hemlock (*Tsuga heterophylla* Sarg.) and Western red cedar (*Thuja plicata* D. Don) both from British Columbia; Queensland walnut (*Endiandra Palmerstonii* C. T. White) and Nigerian celtis (*Celtis Soyauxii* Engl.). Service trials of various Empire timbers have also been initiated.

A full list of the reports on the investigations of Empire timbers and all other publications of the Forest Products Research Laboratory is given as an appendix to the report of the Forest Products Research Board for 1933.[1]

[1] *Report of the Forest Products Research Board for* 1933. H.M. Stationery Office (1934). Price 1*s.* 3*d.* net.

[2] HARRIS, P. Woodworking Research: Effect of Variation of Cutting Angle. *Timb. (Woodw. Mach.)*, 1934, **66**, 222.

[3] HARRIS, P. The Importance of Correct Cutting Angle in Machining. *Emp. For. J.*, 1934, **13**, 63.

[4] PARKIN, E. A. Observations on the Biology of the *Lyctus* Powder-post Beetles, with Special Reference to Oviposition and the Egg. *Ann. appl. Biol.*, 1934, **21**, 3.

[5] PHILLIPS, E. W. J. Movement of the Pit Membrane in Coniferous Woods, with Special Reference to Preservative Treatment. *Forestry*, 1933, **7**, 109.

METALLURGICAL RESEARCH

Behaviour of Materials at High Temperatures

WORK throughout the year has been carried out at the National Physical Laboratory in accordance with the programme recommended by the Supervisory Committee of the Metallurgy Research Board.

Research on the creep and growth of cast irons has been continued in co-operation with the British Cast Iron Research Association, and data have been obtained concerning the mechanical properties and structural changes occurring at temperatures up to 538° C. (1000° F.) of ordinary cast iron, nickel-chromium cast iron, and 6 per cent. silicon cast iron. The creep resistance of the first two irons has been found to be rather low owing to the comparatively high rate of growth which is independent of the applied stress. By giving a preliminary heat-treatment at 600° C. the rate of growth is reduced and the creep resistance found to be considerably improved. The creep properties and structural stability of the 6 per cent. silicon cast iron and of two austenitic cast irons are also being investigated at temperatures up to 850° C., at which temperature it is also proposed to examine their resistance to oxidation.

The creep properties and structure of two chromium-molybdenum steels suitable for super-heater tubes have been examined both in the condition as received and after various heat-treatments. Work on the effect of prolonged heat-treatment at 450° C. on the notched bar brittleness of certain steels has been continued so as to show the influence of testing at various temperatures between 20° C. and 450° C. The investigations on the influence of the initial condition of steels on their creep properties, recovery after creep, and creep under combined stress, are proceeding, whilst an investigation of the nature of creep under stresses produced by pure flexure is being completed.

The study of the nature and mechanism of creep in commercially produced forms of iron and mild steel has continued throughout the year. As a preliminary to the investigation of the relation of age-hardening to creep performance of nickel-silicon-copper alloys, the age-hardening of alloys containing 3 and 5 per cent. nickel plus silicon (in the atomic ratio 2 Ni/1 Si), with and without additions of manganese, has been studied at temperatures between 250° C. and 765° C. after quenching from 900° C. Arising from this work a comprehensive survey of the literature of age-hardening has been completed and some phenomena of age-hardening have been considered in view of their possible bearing in relation to creep performance.

The exploratory research on non-ferrous alloys for high temperature service is being continued in the laboratories of the British Non-Ferrous Metals Research Association. The investi-

gation on the influence of aluminium, silicon, and manganese additions to cupro-nickels of various compositions has now been completed. A preliminary study of the effect of small additions of molybdenum, tungsten, vanadium and tantalum to 80/20 cupro-nickel has also been made, but as the alloys prepared showed no outstanding properties this part of the work has been discontinued. Work is now in progress on four systems of ternary alloys :— aluminium-nickel-chromium, copper-nickel-chromium, copper-nickel-iron, copper-nickel-cobalt. A rapid survey of the first two systems has been completed, and further work is being carried out on those alloys which give promise of useful application.

The research for new ferrous materials is being continued at the National Physical Laboratory under the supervision of the Joint Committee of the British Electrical and Allied Industries Research Association and the British Iron and Steel Federation. As a result of the work on carbon steels it has been concluded that their resistance to creep is not markedly affected by increase in carbon content from 0·15 per cent. to 0·4 per cent. The addition of 0·5 to 1 per cent. molybdenum has been shown to improve steels of these carbon contents, but the previous thermal treatment is of great importance if the high resistance to deformation at elevated temperatures is to be utilised. The occurrence of intercrystalline cracking in molybdenum steels has been noted in tests at temperatures and stresses higher than those which could be used in the case of carbon steels. This is being investigated and a number of complex molybdenum steels are being prepared and tested with the object of finding elements which, when added in small quantities, would eliminate this type of failure at 550° C. without adversely affecting the high creep resistance. Tests for corrosion in flue gases and in superheated steam under pressure are being carried out on the materials developed.

Research on Light Alloys

Considerable progress has been made during the year in researches on magnesium alloys at the National Physical Laboratory. Some work has also been carried out on aluminium alloys and a little consideration given to beryllium.

Specimens of rolled, pressed, extruded and spun magnesium alloy have been produced at the National Physical Laboratory. The mechanical properties of these alloys have been studied as rolled and after further heat treatment.[5] One alloy containing 8 per cent. cadmium, 2 per cent. zinc and 6 per cent. aluminium had an ultimate tensile strength of 26 tons/sq. inch and an elongation of 10·5 per cent. on the rolled rod. Some corrosion tests on selected alloys are to be carried out in collaboration with the Royal Aircraft Establishment. Further, in view of the difficulty experienced in working some of the magnesium alloys, a study of

the more fundamental problem of the relation between the nature of deformation and the lattice orientation is contemplated.

Magnesium-nickel alloys containing up to 50 per cent. nickel have been investigated by thermal and microscopic methods. The solid solubility of nickel and solid magnesium is found to be less than 0·1 per cent. Some exploratory work has shown that the alloys are unlikely to have useful mechanical properties. The results of the work have been published by the Institute of Metals.[2]

Some experiments have been carried out to find whether an adherent coating of cadmium can be produced on a magnesium alloy by rolling together strips of cadmium and magnesium. The first experiments were successful and the coating appears to be a good basis for the electro-deposition of further coatings, but unless extremely thin coatings can be achieved the advantage gained may be outweighed by the disadvantage of an increase in specific gravity.

An investigation has been made to discover if a beam test for cast aluminium alloy bars is more satisfactory than the tensile test in the measurement of ductility in bars of low elongation. Up to the present the bend test applied to sand cast bars has yielded no information concerning ductility which cannot be obtained as readily from the tensile test. Bend tests of machined and unmachined bars have given satisfactory agreement so far as it is practicable to carry out a beam test without machining operations. The results of this investigation have been published by the Institute of Metals[4].

As mentioned in the previous year, the work on the removal of gases from light alloys has progressed satisfactorily. The processes for the removal of gases have now become so efficient that treated metal undergoes considerably more shrinkage in the mould, and consequently provision has to be made for the feeding of the solidifying metal by the employment of more adequate gates and risers.

Some fatigue experiments have been made on beryllium bronze to find out whether its fatigue resisting properties are superior to those of other bronzes and most steels. The claim for this superiority has been only partly substantiated. Beryllium bronze has a higher fatigue range than that of other non-ferrous metals but much less than that of normal spring steel. As with steel the fatigue range is affected by the surface condition.

Steel Castings

Research on steel castings was continued at the Research Department, Woolwich, under the supervision of the Metallurgy Research Board up to 31st March last, when the responsibility for organising industrial co-operation in the investigations was transferred to the Industrial Research Council of the British Iron

and Steel Federation. Further work was carried out during that period upon the design of a test piece for recording "fluidity" and on the strength of cast steel at high temperatures. A study has also been made of the banding effects occurring in many steel ingots and castings.

Alloy Steels

A comprehensive summary of the properties and uses of chromium steels has been prepared for publication.(1) Reports have been written upon the effect of silicon and manganese, separately and together, on 1·8 per cent. chromium steel and upon the constitution and properties of pure tantalum iron alloys and steels. Patent applications have been made to cover the industrial uses of some of the tantalum alloys. The properties of a series of low carbon steels containing 0·5 per cent. chromium and 1·5 to 4·0 per cent. copper are being investigated, with particular reference to temper-hardening. The effect of vanadium on a series of carbon, chromium, nickel, and nickel chromium steels when heat-treated to produce a temper-hardening effect has been investigated.

Gases in Metals

Investigation into the part played by dissolved gases during the solidication of steel has been continued. In the course of further efforts to determine the solubility of hydrogen in pure iron, progress has been made in the production of pure alumina crucibles substantially impervious to gases, and many of the difficulties previously experienced have been removed. Experiments with the molybdenum or tungsten wound furnace referred to in the previous Annual Report have shown that the refractory tubes available are not sufficiently gas tight at the melting point of iron, and a small furnace has been constructed capable of maintaining a high vacuum and constancy of volume at 1550° C., which enables iron to be melted with the use of a minimum amount of heated refractories.

Cracking of Boiler Plates

The prolonged tests in air at 300° C. on mild steel strips subjected to stress locally concentrated at drilled holes and at machined notches have now been in operation for five years, and although considerable local deformation has occurred no cracking has developed. This result indicates that the presence of a chemical agent is essential for the development of cracking.

Prolonged stress tests have been carried out in the specially designed steel cylinder, upon specimens of boiler plate immersed in a strong solution of caustic soda, under a steam pressure of 300 lbs. per square inch, at stresses exceeding, and slightly below, the yield load. Further comparative tests are being made under both permanent and periodical stresses.

Full scale investigations have been begun on the behaviour of steel boiler plate and riveted joints under corrosion-fatigue conditions comparable to those which might occur in a boiler. A machine has been constructed for the application of repeated bending stresses at slow speeds, and the mechanical tests will be supplemented by metallurgical investigations of the tested specimens.

Grain size

The study of the factors controlling the grain size of cast metal has been continued. A report on the macrostructure of aluminium and some alloys has been presented, showing that the presence of dissolved gas in the metal, the use of mechanical dressings, and mechanical agitation of the mould during solidification, all lead to grain refinement, and suggesting that in every case the refinement is actually due to the mechanical agitation of the metal during solidification. Further work has been carried out on the titanium-aluminium diagram. The possibility that a peritectic reaction would cause grain refinement in alloy systems of such composition that the reaction would occur, if at all, in completely molten metal has been examined, and some evidence in support of this view has been obtained. An apparatus has been constructed to determine the electrical conductivity of metals in the liquid state in order to test the persistence of peritectic reactions in liquid metal.

Oxides in Steel

The apparatus for the determination of oxides in steel by the hot extraction method has been completed, and is in operation. The iodine method for the separation and determination of inclusions in steel has been found to be satisfactory, and samples supplied by the Ingots Committee of the Iron and Steel Institute are being examined. Co-operative work on the comparison of different methods has been arranged with the Ingots Committee.

Oxidising Power of Basic Slags

An investigation is being carried out by Professor Hay at the Royal Technical College, Glasgow, into the mechanism of the oxidising power of basic slags, as a continuation and development of the research on inclusions in steel recently completed at the College. The determination of the binary system calcium oxide —iron oxide has been completed and the measurement of the dissociation pressures of the pure and mixed oxides is being undertaken. An optical method of identifying the constituents in basic slags has been developed.

Rust Prevention

The report on materials for rust prevention referred to in last year's Annual Report has now been published.[3]

[1] GREAVES, R. H. Chromium Steels. H.M. Stationery Office (1934). (*In the press.*)

(2) HAUGHTON, J. L., and PAYNE, R. J. M. The Constitution of the Magnesium Rich Alloys of Magnesium and Nickel. *J. Inst. Met.*, 1934, **54**, 275.

(3) JAKEMAN, C. Lanolin Rust Preventers. *Engineering Research Special Report No.* 12. H.M. Stationery Office (1934). 2nd Edition. Price 6*d*. net.

(4) PHILLIPS, C. E., and GROGAN, J. D. Transverse Tests on Sand Cast Aluminium Alloy Bars. *Mon. J. Inst. Met.*, 1934, **1**, 123.

(5) PRYTHERCH, W. E. The Mechanical Properties of Some Magnesium Alloys. *J. Inst. Met.* (*In the press.*)

ELECTRO DEPOSITION

INVESTIGATIONS on electro-deposition problems have been continued throughout the year at the Research Department, Woolwich. The examination of the effect of additions of oxidising agents on the properties of the deposit has been completed, and a report upon the results is in preparation. Data have been collected on the effect of a large number of substances, both organic and inorganic, on the appearance of a deposit, including such materials as might be present in a depositing solution under commercial conditions: methods of removing deleterious impurities from nickel depositing solutions have been studied. Non-porous nickel coatings far thinner than those obtained under ordinary commercial conditions have been successfully produced by careful control of the conditions of cleaning and deposition and by the use of electrolytic iron as basis metal. Some further work has been carried out on electro-deposition of chromium.

The reports on pitting and hardness of electrodeposited nickel referred to in last year's report have now been published.[2, 4]

Further reports have been presented by the Research Department, Woolwich, upon electrodeposition problems in accordance with the arrangements with the British Non-Ferrous Metals Research Association referred to in previous Annual Reports.

(1) CLARKE, S. G. Rapid Tests of the Thickness of Tin Coatings on Steel. *Analyst*, 1934, **59**, 525.

(2) GARDAM, G. E., and MACNAUGHTAN, D. J. The Effect of Annealing on the Microstructure and Mechanical Properties of Electro-Deposited Nickel. *Trans. Faraday Soc.*, 1933, **29**, 755.

(3) HOTHERSALL, A. W. Adhesion of Electro-Deposited Coatings to Steel. *Trans. electrochem. Soc.*, 1933, **64**, 83.

(4) MACNAUGHTAN, D. J., GARDAM, G. E., and HAMMOND, R. A. F. The Influence of the Composition and Acidity of the Electrolyte on the Characteristics of Nickel Deposits. *Trans. Faraday Soc.*, 1933, **29**, 729.

WATER POLLUTION RESEARCH

THE progress made during the past year in the Department's work in relation to water supplies and the prevention of pollution is summarized in the published annual report of the Water Pollution Research Board and of the Director of Water Pollution Research for the year ended 30th June, 1934.[1] At the end of that report a

list is given of papers published during the year, in which the results of some of the investigations are described in detail.

The rainfall in Great Britain in 1933 was one of the lowest on record and the first half of 1934 was also a particularly dry period. This long spell of dry weather not only caused difficulties in the provision of ample quantities of water for domestic, agricultural and other purposes; it also had a detrimental effect on the quality of the water in rivers and streams into which sewage and trade effluents are discharged, as less water than usual was available for dilution of the discharges. The experience of the past year has again emphasized the importance of further efforts to prevent, as far as possible, the pollution of rivers and streams and other sources of water supply in order to avoid expensive methods of treatment of water and possible danger to public health.

Base-Exchange Process of Water Softening

Examples of three different types of commercial base-exchange materials have been employed in experiments at the Department's Chemical Research Laboratory to soften waters containing calcium bicarbonate, calcium sulphate and magnesium sulphate. Under the particular conditions of the experiments, representatives of the two main classes of treated minerals gave base-exchange values respectively equivalent to 0·4 and 0·6 lb. CaO per cubic foot of material; these values were approximately the same for hard waters containing magnesium salts in solution as for waters containing calcium salts. The base-exchange value of a representative synthetic material was equivalent to about 1 lb. CaO per cubic foot with hard water containing calcium salts but was equivalent to only about 0.7 lb. with solutions of magnesium sulphate.

Many samples of British clays have been treated by various methods with the object of preparing base-exchange materials suitable for water softening. In a few cases substances have been prepared with base-exchange values greater than those of some imported commercial materials.

Plumbo-Solvent Waters

Experiments have been continued at the Department's Chemical Research Laboratory on the conditions affecting the contamination of water by lead from service pipes. A summary of existing knowledge of the subject, with special reference to the supply of drinking water, has been published.[3]

Milk Factory Effluents

Further progress has been made in experiments in the laboratories at the Rothamsted Experimental Station on the conditions affecting the purification of effluents from dairies and creameries by a process involving anaerobic fermentation followed by biological oxidation of the resulting liquid. Anaerobic fermentation of the waste liquids

from milk collecting and distributing depots causes separation of most of the fat and some protein. The separated liquid can then be readily oxidised, with an efficiency of about 99 per cent., in percolating filters. Experiments have also been carried out on the treatment of milk effluents by the activated sludge process. The investigation has definitely reached a stage at which it could with advantage be extended to include experiments on a large scale. It is clearly desirable that the industry as a whole should co-operate both technically and financially in such further experiments and an opportunity of co-operating has been offered to representatives of different sections of the milk industry, who are considering the matter. The subject is of great importance as, during the past year, there have been numerous cases in this country of serious pollution of rivers and streams and of difficulties at sewage disposal works arising from the discharge of effluents from dairies and milk products factories.

Biological Oxidation of Fats and Soaps

Experiments have been made at the Rothamsted Experimental Station on the biological oxidation of aqueous solutions of sodium stearate alone and in admixture with domestic sewage. This work was undertaken because fats and soaps are constituents of sewage and of certain trade wastes. The results have shown that the presence of sewage facilitates the oxidation of soap, and that sewage containing 25 parts of sodium stearate per 100,000, a concentration much higher than is usual in domestic sewage, can be readily oxidised in percolating filters.

Sewage Disposal

At the London School of Hygiene, Barcroft respirometers have been employed in experiments, under the immediate direction of Professor W. W. C. Topley, on the effects of various factors on the rates of oxidation of sewage and activated sewage sludge in contact with air. It has been shown that the rate of oxidation of mixtures of sewage and activated sludge is greater than the sum of the rates for the separate constituents. Maximum rates of oxidation of sewage were obtained at pH values between 6·6 and 9·0 and of activated sludge at pH values between 6 and 10 Sewage and sludge previously sterilised by heating, by filtration through a Seitz filter or by treatment with certain disinfectants do not absorb oxygen from air in the respirometers. Inoculation of the sterilised sewage or sludge by the addition of small quantities of untreated sewage or sludge or of suspensions of certain bacteria at once initiates absorption of oxygen. The addition to sewage of potassium cyanide in concentrations ranging from 0·5 to 27 parts per 100,000 considerably reduces the rate of oxidation of the sewage by air during the first five hours. After this period the effect of

the cyanide gradually decreases until the rate of oxidation is approximately the same as for the sewage alone.

In view of the presence of protozoa in percolating filters at sewage works and in sewage undergoing treatment by the activated sludge process, some experiments have been carried out on the effect of the protozoan flagellate *Polytoma uvella* on the oxidation of sewage and sewage sludge by air. *Polytoma uvella* initiated the oxidation of previously sterilised sewage but was not so active in this respect as certain bacteria.

The oxidation of solutions of an ammonium salt, sugars, amino acids, formate, lactate, glycerol, olive oil and phenol in the presence of activated sewage sludge has also been studied. With the exception of phenol, in the concentrations employed these substances were oxidised by air in the presence of activated sludge.

The investigation of the colloidal and other dispersed matter in sewage has been continued for the Department at University College, London, under the immediate direction of Professor F. G. Donnan. During the past year the work has included experiments on the flocculation or coagulation of dispersed matter by passing finely-divided streams of air, oxygen, hydrogen and nitrogen through samples of domestic sewage at 25° C. All four gases have a similar effect in causing in a few hours coagulation of a considerable amount of the dispersed material. Even some of the particles originally so small as to pass an ultrafilter can be coagulated by the action of the bubbles of gas.

River Mersey Investigation

Considerable progress has been made in the investigation of the River Mersey, which was begun in April, 1933, with the object of determining the effect of the discharges of crude sewage into the estuary on the amount and nature of silt and other solid matter deposited. This investigation is being carried out by the Department at the cost of the Mersey-side Local Authorities, the Mersey Docks and Harbour Board, and other interested undertakings.

During the past year existing hydrographic data on the condition of the estuary at various times since 1861 and records of the quantities of material removed by dredging since 1890 have been studied. Hydrographic observations have included surveys of sections of the estuary, measurements of the rates of movement of the water at different positions and depths and at various states of the tide, and measurements of the quantities of fresh water carried into the estuary by the principal rivers and streams. The banks exposed at low tide have been surveyed and classified into two groups according to whether they are covered by sand or by mud. An attempt has also been made to determine the relative stabilities of the different banks from the changes in size and position as shown by the surveys since 1861, and from a biological survey of the banks; areas subject to frequent change as a result of tidal action are not

likely to support certain types of organisms. The chemical section of the work has included the examination of samples of water from all parts of the estuary at different depths and at various states of the tide and the examination of numerous samples of solid matter from exposed banks. Information has also been collected with regard to the quantities and nature of the discharges of sewage and of trade effluents into the estuary.

Summaries of Current Literature

The publication of monthly summaries of current literature[2] relating to water supplies, sewage, trade waste waters, river pollution and kindred subjects has been continued. Abstracts of more than 1,500 papers appeared in Volume VI for 1933.

[1] *Report of the Water Pollution Research Board for the Year ended 30th June, 1934, with Report of the Director of Water Pollution Research.* H.M. Stationery Office, London. Price 9*d.* net.

[2] *Water Pollution Research, Summary of Current Literature.* H.M. Stationery Office. Published monthly, price 2*s.* net. Annual subscription, 24*s.* post free.

[3] INGLESON, H. The Action of Water on Lead with Special Reference to the Supply of Drinking Water. *Water Pollution Research Technical Paper No.* 4. H.M. Stationery Office (1934). Price 2*s.* 0*d.* net.

CHEMICAL RESEARCH

DURING the period under review the Director as President of the Chemical Society delivered his first presidential address entitled "Unification of the Chemical Profession" at the Annual Meeting of this Society held in Birmingham on March 21st and 22nd, 1934.

On October 27th, 1933, the Director gave the public lecture for 1933 to the Institution of Chemical Engineers on the subject of "Engineering in the Service of Chemical Research." This lecture has since been published in the Transactions of this Institution.[8]

Relations of the Laboratory with outside Institutions

The Laboratory has participated in two exhibitions. The section on synthetic resins contributed a comprehensive collection of plastics, resins and relevant intermediate products to the Science Museum Exhibition of Plastics which was open to the public from April, 1933, until January, 1934. An exhibit was arranged by the corrosion section for the Department's stand at the Engineering and Shipping Exhibition at Olympia, September 7th to 23rd, 1933.

On June 7th, 1934, the Director entertained a party of 260 Fellows of the Chemical Society, when three papers were read by members of the scientific staff on Chemical Syntheses under High Pressure.

The other activities of the Laboratory are best indicated under the headings of the respective sections.

Corrosion Research

Atmospheric Corrosion.—The patina found on copper in the open air contains basic carbonate as an accessory either to basic sulphate or to basic chloride and the conditions affecting the entry of this carbonate into the patina have been investigated.

Preliminary work on the atmospheric corrosion of mild steel in presence of sulphur dioxide has led to recognition of a critical humidity below which the attack is insignificant and above which it increases enormously. Humidity also controls the rate of oxidation of magnesium under indoor conditions, the film consisting of carbonate, hydroxide and sulphate. Out-of-doors a permanently protective film is not produced.

Corrosion of Immersed Metals.—The oxide film formed on mild steel specimens by exposure to air or oxygen for various periods and under a variety of pressures has been shown to have little permanent effect either on the corrosion rate or on the number of starting centres.

Inclusions of nitride and oxide in magnesium have little or no effect on the distribution of attack by 0·1 N-sodium chloride solution, but certain metallic impurities, and notably iron, caused acceleration of attack through an effect on over-voltage, especially in sodium chloride solutions of this strength.

Serious losses of elongation may be caused by sea spray on the magnesium alloy—Elektron AZM—even after very slight corrosion. This effect is apparently due to stress concentration caused by corrosion notches.[1, 2]

Chemical Reactions under High Pressure

In the carbon monoxide-hydrogen condensations the study of various catalysts has been continued. Copper oxide, manganese oxide and cobalt sulphide in molecular proportions of 1 : 1 : 1/10 gave an optimum conversion of carbon monoxide into ethyl alcohol (20 per cent.). Improvements have been effected in the separation and identification of higher alcohols.

Synthesis of acetic acid from methyl alcohol and carbon monoxide under pressure and in the presence of phosphoric acid and copper phosphate has been verified. Optimum conditions for the reaction have been determined.

Tar Research

A long investigation into the nature of the colouring matter present in the heavy oils of low temperature tar has culminated in the demonstration that these coloured substances are hydrocarbons of the naphthacene class. The main coloured constituent is 2 : 6-dimethylnaphthacene which has also been prepared synthetically together with several other members of its class.

Several new homologues of phenol have been synthesised and compared with the higher tar acids of low temperature tar.[11]

The mixture of higher tar acids used as a wetting agent under the name of "Shirlacrol" has been obtained in considerable quantities from both low temperature tars and vertical retort tars.[12]

Several technically important intermediates have been produced by aminations under pressure from resorcinol.

The aqueous liquors of the "Coalite" variety of low temperature tar have been shown to contain notable quantities of phenol and catechol. A complete series of nitration products of symmetrical xylidine has now been prepared.

Chemotherapy

The outstanding feature of this research has been the preparation in quantity of succinanilidomethylamide-*p*-arsenic acid, a potent arsenical drug which is being tested clinically both in the Liverpool School of Tropical Medicine and in Nigeria.

Synthetic Resins

In connexion with the Plastics Exhibition (*v. supra*) a lecture was delivered at the Science Museum, South Kensington, on July 19th, 1933, by the Director, entitled "Plastics and their Genesis."[7]

The interactions between formaldehyde and the homologues of phenol have been studied systematically and several new intermediates have been isolated.[6, 10] These reactions are carried out in the presence of catalysts and a quantitative study of these effects has been undertaken.[3]

Polyhydric phenols readily condense with formaldehyde to form resins which have remarkable adsorptive powers for metallic cations, a property of significance in water purification.

Further work on ketone-formaldehyde resins has shown that a resin having useful machining properties is obtainable from methyl ethyl ketone and formaldehyde. In pursuance of these researches a convenient method for preparing hydroxyacetone (acetol) has been discovered.

Water Pollution

Work carried out during the year has resulted in the development of a method of preparing from clays of British origin, base exchange materials for water softening which are superior in exchange capacity to certain of the trade materials at present imported from abroad.

A comprehensive summary of existing knowledge of the action of water on lead has been published.[5]

Microbiology Section

This section was transferred to the laboratory during the period under review. Certain investigations already in hand were completed and continued, such as the degumming of silk by micro-

organisms, the storage of ropes, the storage of woodpulp, the treatment of ropes and cordage, the acetylation of cellulose yarns and fabrics as a means of preventing bacterial decay, and the study of a polysaccharide-splitting myxobacterium of considerable pathological interest.

The principal investigations initiated since the section came to the Laboratory have been (*a*) the study of the biochemistry of the acetic acid bacteria: one particular feature of this work has been the production from glycerol of dihydroxyacetone, a reaction of considerable interest to the Synthetic Resins section. (*b*) A study of those bacteria concerned in the oxidation and reduction of sulphur and sulphur compounds in relation to certain activities of these organisms in nature and industry.

In addition to the above, about a score of matters of microbiological importance were referred to the section by other Government Departments and outside bodies during the year.

Road Tar Research

The main interest has centred round the behaviour of tars on exposure to artificial and natural weathering and in these experiments synthetic tars have given particularly interesting results. The changes which occur in the dark can be approximately duplicated by vacuum distillation, but in daylight polymerisation and accelerated oxidation have been detected. During exposure a substantial skin forms on the surface of tar which has an important bearing on the initial set of tar. Quantitative studies are being made of this skin formation with the object of classifying tars according to their rapidity of set.

Simple relationships have been shown to exist between viscosity and oil content in (*a*) removal of oil from tar by distillation and (*b*) addition of oil to pitch.

Attempts to improve tars by simple chemical or physical treatment are being pursued.

Dental Investigation

Various plastic materials including styrol, vinyl acetate, glyptal and ketone-formaldehyde resins, and benzyl cellulose have been examined with a view to their possible application for dentures. Of these materials styrol resin appears to be most promising as regards tinting, moulding characteristics, low density, surface hardness and a negligible water absorption. The most serious deficiency in this resin is its low strength and attempts are being made to improve this quality.

A report on dental lutes and cements has been compiled and published in the British Dental Journal.[4]

General Research

In collaboration with the Fuel Research Station, work has commenced on the extraction of germanium and other rare metals

from coal ash. Metallic germanium has been isolated from the ash of Northumbrian coal and several of its compounds prepared.

Comparative experiments have been made on the dehydrogenation of pyridine in the presence of five different anhydrous metallic chlorides.[9] Two products, 2 : 2′–dipyridyl and 2 : 2′ : 2″–tripyridyl have proved to be of exceptional interest as affording a delicate test for ferrous iron. Samples of these have been distributed to various enquirers.

A systematic study is in progress of phenanthridine derivatives likely to be of chemotherapeutic interest as antiseptics and antimalarials.[13] Samples of these materials have been sent to the Pathological Department of Glasgow University and to the Molteno Institute at Cambridge.

Chemical Engineering

In addition to the maintenance of autoclaves ranging in capacity from 25 cc. to 10 litres and capable of withstanding pressures of 250 atmospheres at temperatures not exceeding 450°, a super pressure autoclave has now been constructed in the laboratory for a working pressure of 3000 atmospheres at temperatures up to 200°.

(1) BENGOUGH, G. D., and WHITBY, L. Corrosion and Protection of Magnesium and its Light Alloys. *Trans. Instn chem. Engrs, Lond.*, 1933, **11**, 176.

(2) BENGOUGH, G. D., and WHITBY, L. Magnesium Alloy Protection by Selenium and other Coating Processes. Part II. *J. Inst. Met.*, 1933, **52**, 85.

(3) HOLMES, E. L., and MEGSON, N. J. L. Catalysts in Phenol-Formaldehyde Condensations. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 415T.

(4) HOLT, S. Dental Cements. *Brit. dent. J.*, 1934, **57**, 57.

(5) INGLESON, H. The Action of Water on Lead with Special Reference to the Supply of Drinking Water. *Water Pollution Research Technical Paper No.* 4. H.M. Stationery Office (1934). Price 2*s.* 0*d.* net.

(6) MEGSON, N. J. L. Formaldehyde Condensations with Phenol and its Homologues. Part III. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 420T.

(7) MORGAN, G. T. Plastics and Their Genesis. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 675.

(8) MORGAN, G. T. Engineering in the Service of Chemical Research. *Trans. Instn chem. Engrs, Lond.*, 1933, **11**, 142.

(9) MORGAN, G. T., and BURSTALL, F. H. Researches on Residual Affinity and Co-ordination. Part XXXIV. 2 : 2′-Dipyridyl Platinum Salts. *J. chem. Soc.*, 1934, 965.

(10) MORGAN, G. T., and MEGSON, N. J. L. Formaldehyde Condensations with Phenol and its Homologues. Part II. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 418T.

(11) MORGAN, G. T., and PETTET, A. E. J. Homologues of Phenol. *J. chem. Soc.*, 1934, 418.

(12) MORGAN, G. T., PRATT, D. D., and PETTET, A. E. J. Application of Phenolic Constituents of Tars as Wetting Agents. *J. Soc. Dy. Col., Bradford*, 1933, **49**, 125.

(13) WALLS, L. P. Researches in the Phenanthridine Series. Part III. Meso-substituted Derivatives. *J. chem. Soc.*, 1934, 104.

RADIO RESEARCH

A COMPLETE account of the work carried out on behalf of the Radio Research Board in the Radio Department of the National Physical Laboratory and under Professor Appleton's direction at King's College is contained in the Annual Reports of the Board, which are published as separate documents. Only the more important sections of the work are therefore summarised here.

Propagation of Waves

An important part of the work of the Radio Research Board on the propagation of waves consists in exploring the electrical state of the upper atmosphere (the ionosphere) by transmitting pulses of electrical energy vertically upwards and recording the echo patterns of these pulses returned to the ground by the ionised regions. This method was used during the International Polar Year by the British Expedition to Tromso in Norway referred to in the last report. While a complete account of the work of this expedition must await the reduction of the numerous observations recorded, which is proceeding rapidly, a brief summary of certain results has already been published.(1) These show that a greater distinction was experienced in Norway between magnetically quiet and disturbed days than is the case in England. For undisturbed conditions there are usually the two reflecting regions which are observed in England. While the normal daily maximum ionisation content is less in Norway than in England, the seasonal variation is greater. During conditions of increased magnetic activity a complete succession of echoes was found on all wavelengths from 30 to 500 metres. This cannot be due to electron limitation and is therefore to be attributed to an absorption of the waves by the production of ionisation in the lower regions of the atmosphere. The general results confirm the conclusion that while the influence of ultra-violet light from the sun accounts for the normal ionisation of the two main regions of the ionosphere and the daily and seasonal variations in its intensity, it appears that the abnormal variations in the lower region, especially at night and during magnetic storms, are best explained by supposing that charged particles enter an atmosphere from space and are carried towards the Poles by the action of the earth's magnetic field.

The results obtained during the Polar Year have shown the need for further study over a long period of these abnormalities of ionisation in which correlations will be sought between radio data and other geophysical data, as, for example, magnetic, auroral, sunspot and thunderstorm data and possibly data containing meteors.

Means for acquiring the necessary wireless data have been greatly improved during the year by the development of completely automatic methods of recording the equivalent path of waves

entering the ionosphere against frequency over a continuous range of frequencies from 2·5 to 5 Mc/s (120 to 60 metres). In the method now being used the transmitter and receiver are kept automatically in tune with each other and photographic records over the above frequency band are taken for about one minute each half hour, the apparatus automatically switching itself off during the quiescent period.

The employment of this technique is already providing much detailed information regarding the constitution of the ionised regions. For example, it has now been revealed that the intermediate region between the Kennelly-Heaviside and the Appleton regions is much more complicated than was originally apparent. The records also show that round about noon a protuberance or shelf below the Appleton region frequently makes its appearance.

The work referred to in the last report on the theoretical investigation of the propagation of radio waves through the ionised medium has been continued and a further paper giving dispersion curves with collisional friction based on the Appleton-Hartree formula has been published.[8]

Long Distance Transmission

In addition to the detailed exploration of the ionosphere vertically above the observing station work has also been continued on waves transmitted over long distances. Measurements have been published[9] on the angle of incidence in England of waves emanating from stations near New York on wavelengths in the region of 20 metres. This work has an important application to radio engineering in connection with the design of directional aerial arrays. The results indicate that during the first four months of 1933 one main ray was in general received in England accompanied by rays of smaller amplitude. The average angle of incidence of this main ray was 72° and was reasonably constant. Towards the end of April, however, it was found that the angle of incidence decreased from the above value at noon G.M.T. towards a value of 85–90° as sunset approached. This change was accompanied by a decrease in average field intensity. These changes are to be attributed to an increase in ionisation with a resultant decrease in effective height of the Appleton region, at which reflection takes place on these wavelengths, while the fall in signal strength is probably due to the increase in absorption of the waves in their return passage through the lower Kennelly-Heaviside region. It will be seen therefore that the work is giving results capable of correlation with ionospheric measurements at vertical incidence and in conjunction with them is likely to lead to a more complete knowledge of the mechanism of wave propagation in the upper atmosphere.

Electrical Properties of the Earth's Surface

Further work has been done on laboratory methods for determining the electrical properties of samples of the earth's surface. A paper has been published[6] in which curves have been plotted for certain selected sites showing the effect of the electrical properties of the soil on the penetration of wireless waves below the surface. At a frequency of 100 Kc/s (3,000 metres) it is shown that a small part of the current may penetrate to a depth of 20 metres, while at a frequency of 10,000 Kc/s the current is practically confined to the top three or four metres. The effect of such penetration on the field strength of a wireless wave at the surface is being further investigated. A paper has also been published[5] describing the extension of these laboratory methods to corresponding measurements on samples of seawater. The validity of the laboratory methods has been established by comparing the results with those previously found from field measurements.

Propagation of Ultra Short Waves

The above work has been extended to ultra short waves and a paper has been published[7] describing a laboratory method of measuring the electrical properties of soil at frequencies corresponding to a wavelength of 1.5 metres. The length of stationary waves set up in air on a pair of Lecher wires is measured and compared with the corresponding wavelength when the wires are immersed in a sample of the soil under examination. From the results the values of the conductivity and dielectric constants of the soil for various moisture content can be deduced. The results are in good agreement with those obtained by a field method on the same site to an accuracy adequate for most radio communication purposes. A paper has also been published[4] giving the results of experiments made to determine the reflection coefficients in electrical constants of the earth's surface for waves between 1.5 and 0.46 metres. The results show that the reflection coefficient of copper gauze is practically unity for both wavelengths, and there appears to be little difference between reflecting properties of ordinary soil and soil covered by grass. It is suggested that the reason for this is that the bulk of the reflection takes place at a very small distance below the surface.

The investigation of special valves suitable for the production of oscillations of very high frequencies has been continued, and a study has been begun of methods for the reception of waves below 3 metres.

Atmospherics

The instrumental methods employed for studying atmospherics have undergone considerable improvement during the year. A report will shortly be published describing work in which these

methods have been used, in which the wave forms of lightning flashes were recorded from the neighbourhood of a flash up to a distance of 3,000 kilometres from a flash. The position of the lightning discharges was located by the cathode-ray direction finders at Slough and Leuchars in Fifeshire. The results show that the atmospheric radiated from a lightning discharge consists essentially of two portions, one of relatively long duration of the order of 2 or 3 milliseconds, and the other a high frequency portion consisting of oscillations of 10 Kc/s or higher. The observations further show that at short distances the high frequency portion is very close to or actually superimposed upon the slower component, but at greater distances the two portions become separated, the high frequency portion arriving a measurable time ahead of the slow component. This represents an interesting phenomenon in the propagation of waves which may have important consequences in determining the role of the ionosphere in the travel of wireless waves at different frequencies.

Direction Finding

During the year the Radio Research Board has examined in detail the present position of radio direction finding and, in particular, the state of the experimental investigations in progress on their behalf. The object of the review was to make recommendations for the future orientation and prosecution of the work As a result the practical objective of this branch of the Board's work has been taken to be the seeking of an answer to the question : " Is an accuracy of plus or minus 1° in a single radio direction finding observation without exception attainable over either land or sea? " As far as this criterion is concerned no direction finder is at present entirely satisfactory, but short-wave direction finding is in an exceptionally unsatisfactory state having regard to its potential importance. The study of direction finding of short waves has accordingly been given a very high priority in the programme of work. At the same time there are many propagational phenomena on long and medium waves affecting the accuracy of direction finding whose importance cannot yet be quantitatively assessed. Moreover, the technique of investigation is much more complex in much of the short wave work. For this reason is it necessary to approach many short wave problems by way of further investigation on the long and medium wave bands. The programme of work adopted by the Board accordingly includes a production of the most accurate Adcock spaced aerial direction finder it is possible to devise. A complete account of the present position of this type of direction finder has been prepared for publication, while other types of spaced aerial direction finder are under investigation.

Even assuming perfect apparatus, the objective aimed at calls for knowledge that the wave train under observation has not deviated

by more than 1° of the vertical plane containing the sender and receiver or that the amount of greater deviation can be predetermined and allowance made for them. Whether such lateral deviations are absent is at present uncertain. The propagational problem involved is therefore also receiving attention. Simultaneously with the above work a spaced aerial visual direction finder using the Cathode-ray oscillograph is being devised for use on short waves of 40 to 100 metres.

Constant Frequency Oscillators

Considerable progress has been made in the study of the variation in frequency of oscillators. A survey of the existing knowledge on this subject has been published[2] during the year. Accurate determinations are being made of the temperature coefficient of both inductance coils and condensers. It has been found that "former" wound coils possess a temperature coefficient of the unstrained metallic conductor. In this connection it has been shown that the internal residual stresses within the conductor play an important part in its behaviour. The effect of the variation of interelectrode capacities of valves on the variation of frequency is also being studied in some detail.

Progress has also been made with the method of controlling the variation of frequency of a transmitter by means of an electrical monitor or governor. Experiments show that such an arrangement will directly control the frequency of a power transmitter to a few parts in a million.

Miscellaneous

A survey of the existing knowledge of magnetic materials at radio frequencies has been published[3], and at the suggestion of the Board the further determination of the characteristics of such materials has been undertaken by the British Electrical and Allied Industries Research Association. The application of the cathode-ray oscillograph in various branches of radio technique has been further developed. Apparatus employing this instrument has been devised for use in the form of a simple visual direction finder which could be used as a collision preventer at sea. It has also been utilised as a course setter and course deviation indicator and as a new form of compass depending on the reflection of the electron beam by the earth's magnetic field. These instruments have been publicly demonstrated on several occasions during the year.

The arrangements for the publication in the "Wireless Engineer" of the abstracts of the radio literature of the world, prepared primarily for the use of the staff of the Radio organisations of the Department, have been continued. Many expressions of appreciation of the scope and usefulness of these abstracts to radio research workers and engineers in general have been received during the year.

In particular the Institute of Radio Engineers of America has signalised its appreciation of the Abstracts by making a generous and unconditional gift of £100 to the Department towards the cost of their preparation.

(1) APPLETON, E. V., NAISMITH, R., and BUILDER, G. Ionospheric Investigation in High Latitudes. *Nature, Lond.*, 1933, **132**, 340.

(2) COLEBROOK, F. M. Valve Oscillators of Stable Frequency. A Critical Survey of Present Knowledge. *Radio Research Special Report No.* 13. H. M. Stationery Office (1934). Price 1*s.* 0*d.* net.

(3) COLEBROOK, F. M. Magnetic Materials at Radio Frequencies. A Critical Survey of Present Knowledge. *Radio Research Special Report No.* 14. H.M. Stationery Office (1934). Price 6*d.* net.

(4) MCPETRIE, J. S. A Determination of the Electrical Constants of the Earth's Surface at Wavelengths of 1·5 and 0·46 m. *Proc. phys. Soc. Lond.*, 1934, **46**, 637.

(5) SMITH-ROSE, R. L. The Electrical Properties of Sea Water for Alternating Currents. *Proc. roy. Soc.*, 1933 (A), **143**, 135.

(6) SMITH-ROSE, R. L. Electrical Measurements on Soil with Alternating Currents. *J. Instn elect. Engrs*, 1934, **75**, 221.

(7) SMITH-ROSE, R. L., and MCPETRIE, J. S. The Measurement of the Electrical Constants of Soil by a Lecher Wire Method at a Wavelength of 1·5 m. *Proc. phys. Soc. Lond.*, 1934, **46**, 649.

(8) TAYLOR, MISS M. The Appleton-Hartree Formula and Dispersion Curves for the Propagation of Electromagnetic Waves through an Ionised Medium in the Presence of an External Magnetic Field. Part 2. Curves with Collisional Friction. *Proc. phys. Soc. Lond.*, 1934, **46**, 408.

(9) WILKINS, A. F. Measurements of the Angle of Incidence at the Ground of Downcoming Short Waves from the Ionosphere. *J. Instn elect. Engrs*, 1934, **74**, 582.

DENTAL INVESTIGATION

THE investigations at the National Physical Laboratory during the past year have been mainly devoted to the preparation of an amalgam, made with a dental alloy and pure mercury, which would show no initial contraction on setting but an expansion of not more than 4μ (1·6/10,000 in.). This object has been achieved by the careful standardisation of all processes accompanying the preparation of the amalgam. Tests have been carried out packing first steel " teeth " and then composition " teeth "(1).

Several conclusions have been drawn from the results obtained which are of practical importance. In particular, mixing the alloy and mercury in a pestle and mortar is undesirable since the pressure on the pestle and the time of mixing determine very critically the subsequent setting of the amalgam. Tests carried out proved that the mixing process is the most important factor affecting the setting of an amalgam. The rubber thumb-stall method of mixing, when standardised, gives most satisfactory results, and by mixing in this

manner the small initial contraction on setting is completely eliminated. This contraction occurs repeatedly in amalgam mixed under standard conditions with a pestle and mortar, and cannot be removed. The results of the work have now been published in the British Dental Journal[1].

The best composition for dental alloys is being studied, including the study of the pure silver-tin binary alloys and also those to which varying proportions of copper and zinc have been added. At the same time the investigation into the constitution of the ternary silver-tin-mercury alloys has been carried to a further stage and the results obtained, together with those obtained from experiments in the setting of amalgam of various composition, will throw light upon the cause of the setting of amalgams.

The work at the Chemical Research Laboratory has been mainly directed to the continued study of various types of synthetic resins and other plastic materials with a view to discovering a satisfactory non-metallic substitute for dental vulcanite, and efforts are being made to secure a further improvement in styrol resin which has shown the most promising qualities of the various substances examined[2]. The investigation undertaken to develop satisfactory dental lutes and cements has been discontinued for the present. A report has been published giving an account of the preliminary investigations undertaken and of the development of modern dental cements[3].

The draft specification for the production of standard dental plasters has been still further revised, and a list of suggested standards for dental plasters has been prepared. A review of the materials for denture bases which have so far been used or examined has been written up for publication.

[1] GAYLER, M. L. V. Some Factors Affecting the Setting of a Dental Amalgam. Part I. *Brit. dent. J.*, 1933, **54**, 269. Part II. *Brit. dent. J.*, 1934, **56**, 605.

[2] GIBSON, C. S. Plastics and Their Use in Dentistry. *J. Soc. chem. Ind., Lond.*, 1933, **52**, 669.

[3] HOLT, S. Dental Cements. *Brit. dent. J.*, 1934, **57**, 57.

ILLUMINATION RESEARCH

THE work on the effect of size of window, and of the colour and reflection factor of walls and ceiling, on the daylight illumination of deep rooms with various degrees of outside obstruction is being continued; suitable selenium rectifier cells have now been developed for use in the investigation. Experiments with prismatic glass and outside mirrors for the improvement of basement illumination are

being arranged. A report has been presented on the tests which have been carried out over a period of years on the effect of exposure under " city " conditions on the transmission of various types of glass. Methods of preparing average standard tables of adequate daylight in rooms, for the assistance of architects, are being considered.

Work on the glaring effect of coloured light sources and the " time effect " of glare is continuing; and a glaremeter has been designed by the aid of which it is hoped that quantitative measurements of glare in actual street lighting installations may be practicable, which may ultimately lead to the inclusion of suitable provisions in the British Standard Specification for Street Lighting. A report giving the results of measurements of the brightness difference threshold (contrast and sensitivity under various conditions) is being published.[4]

A report on the work on glare from motor-car headlights is being prepared for publication, explaining how the amount of glare from headlights can be quantitatively determined.[5] This should enable the designer of headlights to determine beforehand the effect of any proposed modification of design; and it is hoped that it will ultimately lead to agreement on a form of distribution of light within the headlight. A considerable amount of work has been done on the use of coloured light in fogs, and a report has been presented. Investigations on the visual efficiency of the luminous discharge lamp are being set on foot.

A final report on the dock lighting investigations undertaken by the Illumination Research Committee has been published, making recommendations for the best method of lighting cranes in docks[3].

A scheme is under investigation for the calculation of the illumination required for any industrial process from a knowledge of the various elements concerned, such as size, movement and contrast. A preliminary investigation in which one variable (size) only has been taken into account has given encouraging results; and a further series of investigations on the relation of size and illumination is being put in hand.

Representatives of the British Colliery Owners Research Association and of the Mines Department have discussed problems of mine lighting with the Illumination Research Committee: and further co-operation is being arranged.

The investigations in progress for the British Standards Institution on the fundamental properties of glassware have now been brought to a conclusion. Further samples of glass have been examined and measurements of average size and concentration of particles by means of an interferometer microscope have been carried out. An account of the work has been published [1, 2]. The colorimetric examination of artificial daylight units on behalf of the British Standards Institution has been completed, and a report communicated to the Institution. Spectral energy distribu-

tion measurements of the light transmitted by artificial daylight fittings are in progress.

Daily measurements of daylight have been continued at Teddington and Edinburgh, and arrangements are being made for taking further measurements in an industrial area. An analysis of the records taken at Teddington in the north octant has been submitted; measurements are now being taken in all four octants.

(1) DUNBAR, C. Particle Size and Concentration in Opal Diffusion Glasses. *J. Soc. Glass. Tech.*, 1933, **17**, 411.

(2) DUNBAR, C. An Interferometer Microscope. *J. sci. Instrum.*, 1934, **11**, 85.

(3) PRESTON, J. S. Industrial Lighting. Part II. Lighting of Cranes. *Illumination Research Technical Paper No.* 15. H.M. Stationery Office (1934). Price 3*d*. net.

(4) STILES, W. S., and CRAWFORD, B. H. The Liminal Brightness Increment for White Light for Different Conditions of the Foveal and Parafoveal Retina. *Proc. roy. Soc.*, 1934 (B), **116**, 55.

(5) STILES, W. S., and DUNBAR, C. The Evaluation of Glare from Motor Car Headlights. *Illumination Research Technical Paper No.* 16. H.M. Stationery Office (1934). (*In the press.*)

LUBRICATION RESEARCH

Journal Friction

THE Report on the observations with one lubricant over ranges of speed, load, temperature and clearance is in preparation. Certain discrepancies in the results have led to investigations of the accuracy of finish of the journal and bush, and of the distortion due to load and temperature. These factors imposed a limit on the accuracy of the measurements of aspect angle and eccentricity which covered the discrepancies found. Preparations are now in hand for a less extended series of observations under such conditions that the sources of error which have been discovered will be eliminated. Owing to the increased accuracy of these further observations it is hoped that they will provide an experimental basis for the design of whole bush clearance bearings intended to operate under conditions of fluid film lubrication.

The observations obtained during the investigation of the seizing temperature of oils have now been analysed and a report is in preparation.

For purposes of comparative tests with stainless steel and mild steel journals a sample of stainless steel which had proved to run unsatisfactorily in ring oiled bearings was obtained and a series of observations showed that the friction losses were higher than with a mild steel journal under similar conditions. The journals were then repolished using the same method for both journals and under

these conditions the friction of both journals was similar. The effect observed previously appeared, therefore, to be due to a difference in surface condition. Since it appeared to be desirable to be able to measure the surface roughness, a special apparatus was designed which proves to be suitable for the purpose and with small modifications is suitable for measuring the roughness of any form of surface. A description of this apparatus will shortly be published. Tests have been made to determine the speed at which fluid friction ceases, but these do not show any inferiority on the part of stainless steel. An investigation is now to be made with a ring oiled bearing in order to ascertain that the stainless steel journal will take up the oil fed by the brass ring as readily as a mild steel journal.

Oscillating Bearing Experiments

A report on tests of one oil at various loads, speeds and temperature has been presented to the Committee and further tests have been made using B.P. paraffin and mixtures of the same with palmitic acid. The object of these tests was to compare the results with Hardy's experiments on the static friction of these substances. The results show that under the conditions of the oscillating bearing test, B.P. paraffin is not " reversible " although the mixtures are practically so. They confirm Hardy's results in that small additions of palmitic acid reduce the friction but differ in that the optimum reduction in friction is produced by 2 per cent. of acid instead of 1 per cent. as found by Hardy. Attempts have been made to determine the friction of palmitic acid alone, and these show that the friction is of the order of 0.1 instead of zero as observed by Hardy. Since the friction appeared to be very variable as the direction of motion was reversed it appeared probable that the effect of speed might be great. The speed has been reduced from 1 cycle per minute to 1 cycle in 4 hours but without showing a decrease in the friction. It has been found, however, that the chemical action of the acid upon all the apparatus including the steel shaft and bush is very rapid so that it is not possible to run for more than a few hours without repolishing the surfaces. This may account for high friction observed.

In order to ascertain the effect of small quantities of water upon the seizing temperature of oil, a number of samples of one oil have been thoroughly dried and after admixture of known quantities of water these will be tested as soon as can be arranged. A standard rubber bearing for water lubrication has been obtained for test as soon as a machine is free.

Oxidation of Oils

The experiments on the oxidation of oils carried out in conjunction with the Air Ministry Laboratory have been continued

It has been found that the larger part of the increase in seizing temperature is due to improved surface conditions of the bush although it is probable that the optimum surface finish cannot be produced without the presence of oxidation products in the oil. The high seizing temperature of 310° C. obtained in the previous investigations for the new Mobiloils of the Vacuum Oil Co. Ltd., has been reproduced without the aid of a preliminary "running in" with doped castor oil. Pre-oxidized M.B. run in this bush gave the same seizing temperature within a short time and a fresh sample of M.B. also gave the same result within a few hours. From this it appears that when once the optimum surface finish is obtained very slight oxidation of the oil is sufficient to produce the high seizing temperature. The experiments are being continued with other oils.

A study of the boundary lubricating value of mineral oils of different origin has been prepared for publication.

NOTTAGE, M.E. Study of the Boundary Lubrication Value of Mineral Oils of Different Origin. *Lubrication Research Technical Paper No. 2. (In the press.)*

ATMOSPHERIC POLLUTION

DURING the year a new method for obtaining an indication of sulphur pollution in the air has been adopted by the Atmospheric Pollution Research Committee as suitable for use in the investigation of atmospheric pollution. This has been developed at the Building Research Station and consists in the exposure under standard conditions of cylinders coated with a preparation of lead peroxide which is attacked by atmospheric sulphur dioxide with the formation of lead sulphate. The cylinders are exposed for a month before removal for analysis and replacement by fresh cylinders. With the co-operation of the Committee, trials of the method have been in progress at a number of centres since August, 1931. After consideration of the results so obtained, the method has been recommended to the co-operating authorities and it is now in use at 27 stations.

Further tests have been carried out in connection with smoke measurement, in which various alternative methods have been submitted to comparison.

The Committee have been instrumental in encouraging the production of a new instrument for daylight measurement, suitable for use in routine observation, which is now in process of development. This consists essentially in an arrangement whereby light which falls on a scattering lens passes through suitable filters into a photo-electric cell. The resultant current is used to charge a condenser and when the charge reaches a certain amount the condenser is discharged and an ordinary four-figure counter is caused to move forward one unit.

The investigation of atmospheric pollution has now been in progress for nearly twenty years, and as a result there is a con-

siderable accumulation of data bearing on the subject, more particularly data collected with the aid of a standard deposit gauge. In order to ascertain the full significance of the information, a statistical analysis has been begun during the year.

The Investigation of Atmospheric Pollution. Report on Observations in the Year ended 31st March, 1933. Nineteenth Report. H.M. Stationery Office (1934). Price 5*s*. 0*d*. net.

Fabrics Research

Reference is made elsewhere (p. 3) to the dissolution of the Fabrics Research Committee. A report describing the concluding stage of the various researches will be published when certain large scale tests of methods, suggested in the course of laboratory investigations, for fireproofing fabrics have been completed.

Industrial Respirators

Further work on the production of a suitable respirator for use in industry as a protection against the inhalation of dust has been undertaken. The respirator to which reference was made last year proved to be satisfactory for use in a large proportion of the industries in which dust may be a danger to health, but in certain cases it was found that the vision of the worker was impeded by projecting portions of the respirator to an extent which might seriously affect his efficiency. A new design which it is believed will overcome this disadvantage, without diminishing the efficiency of the respirator, and which is also likely to be cheaper to manufacture than the previous type, is now being developed. It is hoped that the work will be completed during 1935.

Considerable progress has also been made with the work which, as stated last year, is being carried out with the financial and technical co-operation of the Association of British Chemical Manufacturers, on the detection in the atmosphere of small quantities of toxic gases, such as may occur in industrial processes. Methods for detecting a number of such gases have been developed and are now being tested under industrial conditions before being definitely specified. It is hoped shortly to commence work on the second part of this programme, which aims at the standardisation of performance tests for respirators for use in industry as a protection against such gases.

X-Ray Analysis

THE work at the National Physical Laboratory under the supervision of the Committee on Industrial Applications of X-Ray Analysis has been continued throughout the year. Further progress has been made in the use of X-ray methods for detecting and explaining the changes which occur when tungsten magnet steels are subjected to various heat treatments, of which some account was given in last year's report. The research is being extended to other steels, such as those containing cobalt. X-ray methods for determining the size of the individual crystallites in transformer steels and their freedom from internal strain have been developed; and it has been clearly shown that the most important requirement in the production of a steel of low hysteresis loss is that internal strain should be reduced to a minimum; the grain size is by comparison of secondary importance.

Among other problems dealing with steels an X-ray study has been made of the structural changes resulting from the surface hardening of steels by the nitriding process.

Detailed investigations on the effect on structure of cold work have been carried out. It is shown that the first result is the breaking up of the crystallites of the material; this is followed by lattice distortion, and in some cases by the production of fibre structure.[2] Subsequent heat treatment of cold worked specimens shows that the fibre structure can persist after the strain due to lattice distortion has been removed. Among the cold work processes examined have been drawing, rolling, torsion, longitudinal extension, etc.

The examination of various materials at the request of the Research Association of British Paint, Colour and Varnish Manufacturers has been continued. The most important materials examined have been a series of lead chromes. The X-ray results showed that the stability of the compound depended on the particular crystal modification present in the material.

Systematic X-ray studies of the structure of tooth enamel and dentine have been carried out on behalf of the Medical Research Council during the year. The various types of enamel have been classified, on the basis of the X-ray results, according to the amount and nature of the fibre structure which characterises the enamel and distinguishes it from the dentine. Comparison with clinical data suggests that the classification has a direct bearing on the tendency of the tooth to decay. More detailed investigations are now proceeding.

Test work has been carried out for various industrial firms during the year, and assistance has been given in other investigations in progress at the National Physical Laboratory. Work has been continued on the measurement of orientation of natural and artificial sapphires used for jewel bearings, to relate the wear of the jewel

with the nature of the crystal plane on which the pivot rests. Other work undertaken has included X-ray studies of the structure of opal glasses and of the effect of the annealing of gauge steels and its bearing on the creep of these steels.

(1) WOOD, W. A. Selective Lattice Distortion in Wires Under Torsion. *Nature, Lond.*, 1933, **131**, 842.
(2) WOOD, W. A. Lattice Distortion and Fibre Structure in Metals. *Nature, Lond.*, 1933, **132**, 352.
(3) WOOD, W. A. Effect of Lattice Distortion and Fine Grain Size on the X-Ray Spectra of Metals. *Phil. Mag.*, 1933, **15**, 553.

SCIENTIFIC GRANTS

SINCE the opening of the Royal Society Mond Laboratory in February 1933, to which reference was made in last year's report, the main work carried out under Professor P. Kapitza has consisted in the installation of low temperature plants. The Laboratory now possesses a liquid nitrogen and air plant with an output of 25 litres per hour, and a hydrogen liquefier with an output of 4 litres per hour which will operate on commercial hydrogen. These plants work regularly and supply various Departments of the University with liquid air, nitrogen and hydrogen. A liquefier which produces $1\frac{1}{2}$ litres of liquid helium per hour has also been developed. This plant was designed and built in the Laboratory, and its main feature is that liquefaction is achieved by an adiabatic process made possible by the invention of an expansion engine working on a new principle.(1) This plant is at least ten times more efficient than any standard plant based on the application of the Joule-Thomson effect. Besides this cryogenic work, research has been carried out on the magnetic properties of metals. Observations have been made on the magneto-striction of bismuth in transverse fields, and on the change of resistance of metals in magnetic fields at a temperature close to absolute zero.

Research work has been continued during the year at the School of Applied Geophysics in the Imperial College. The construction of the second electrical prospecting instrument mentioned in the last report has been completed. Laboratory tests have proved its behaviour to be very satisfactory, and it has been used to investigate the alternating magnetic fields in the neighbourhood of model ore bodies. A description of the instrument has been published,(2) and a commercial model, which is now being used in field trials, has been constructed. The data obtained in the work on the distribution of equiquadrature lines in alternating current flow have been examined with a view to publication of these results. As an outcome of Professor Rankine's investigations regarding the

construction of a magnetic torsion balance, which he made the subject of his presidential address to the Physical Society, a magnetometer for measuring paramagnetism and diamagnetism has been designed and constructed. A description has been published,[3] and new improved models are now in the course of construction. The work on the piezo-electric accelerometer has been continued and improvements have been made in the amplifier and string galvanometer used as accessories. Tests of the new arrangement are in progress.

Elsewhere in this report (Appendix IV) will be found statistics of the awards made to individuals during the year. A list of the papers published by recipients of grants, which have been brought to the notice of the Department during the year, is given in Appendix VI.

[1] KAPITZA, P. Liquefaction of Helium by an Adiabatic Method without Pre-cooling with Liquid Hydrogen. *Nature, Lond.*, 1934, **133**, 708.

[2] BRUCKSHAW, J. McG. An Instrument for Electrical Prospecting by the Inductive Method. *Proc. phys. Soc. Lond.*, 1934, **46**, 350.

[3] RANKINE, A. O. The Measurement of Magnetic Field Distortion. *Proc. phys. Soc. Lond.*, 1934, **46**, 1.

RESEARCH ASSOCIATIONS

As in previous years a brief account is given below of the work of Research Associations during the year. The summaries are based on statements prepared by the respective Research Associations and consequently vary somewhat as regards form and manner of presentation.

The British Cast Iron Research Association

(Licensed on 24th May, 1921)

The chief result of research work carried out during the past year promises to be of considerable industrial interest and of general metallurgical importance. By a process worked out in the Association's laboratories, it has been found possible to refine the graphite of normal or coarsely graphitic iron without any change in ordinary composition and without superheating to yield the graphite in the finest possible form. Furthermore, it has been found possible by a further process to recoarsen graphite, so that without any change in composition a common No. 3 pig iron has had its graphite reduced in size to so-called supercooled graphite, a process resulting in an improvement in mechanical properties of the order of 50 per cent., and then, to complete the cycle, the graphite has been recoarsened to its original condition. Hitherto it has been practicable to refine graphite only to a limited extent, either by superheating the melt, or by a reduction in the total carbon content of the metal. This work will explain the superior properties of cold blast irons compared with hot blast irons. Work is continuing on the application of the principle to white and malleable irons, and details will be available in due course. The process will have repercussions on the method of producing pig irons, as well as the inoculated high strength irons referred to in previous reports.

During the year the Association has installed and begun to operate a 24-in. bore cupola melting furnace of the balanced blast design patented by the Association. This furnace, which has an output of about 2·5 tons per hour, has been installed in the works of a member not far from the Association's headquarters. Satisfactory progress continues to be made on the installation of the balanced blast cupola in members' works and over fifty are either in operation or under construction. Successful installations are running in Australia and America.

The principal development in sands and refractories work has been the issue during the year of a comprehensive research report

on recommended methods for testing and control of foundry moulding sands. This report, as Special Publication No. 2, has also been made available by the Council to all interested at a small charge. A report has also been issued on the properties of oil-bonded core sands with special reference to the large number of commercial materials now available for bonding.

During the year an interesting experiment was carried out, extending the work done in the past by the Association in arranging meetings of members to discuss work in progress. Members were invited to a study course held at headquarters, including lectures by the staff, laboratory demonstrations and a works visit, extending over a period of three days. The course was highly successful, one hundred and seventy members attending, and arrangements are contemplated for making this a regular feature of the year's work.

The Association has also taken the initiative with respect to the establishment of a novel type of highly specialised school for the higher training of those engaged in, or likely to be engaged in, responsible work in the industry. This projected school takes the form of a full-time course for one year, governed by a body representing the industry. Various trade associations, research associations and technical institutions connected with the industry have already promised to support this venture; and it is hoped to raise from these sources and the industry sufficient to qualify for a grant from the Board of Education to enable the school to be opened in October 1935.

The British Iron and Steel Federation
Iron and Steel Industrial Research Council

(Established 1st January, 1929)

The past year marked the completion of the first five-year period of work of the Iron and Steel Industrial Research Council.

Definite practical results have already arisen, directly or indirectly, out of the work, such as an improvement in coke quality, reduced fuel consumption, higher outputs, increased yields, and a general higher productive efficiency in practice. These results may be largely attributed to the greater degree of technical co-operation within the industry which has arisen as the result of control of research activities by committees drawn from technical personnel.

The development of co-operative research, however, has not led to a reduction in research work by individual firms. A survey made during the past year indicates that apart from collective research expenditure under the direction of the Research Council, individual firms in the industry are spending nearly £200,000 per annum on their own special research problems, and this amount is rapidly increasing. As all technical research officers in the industry

are actively co-operating in the work of the Research Council, not only is the range of experience and information available to the Council rapidly extending, but there is a constantly increasing stimulus to investigation on a national basis of problems of interest to the industry as a whole.

A number of new features of interest have arisen out of the work of various committees of the Council during the past year. The fundamental work of Professor W. A. Bone for the Blast Furnace Committee on the inter-action between iron ore and reducing gas under blast furnace conditions has reached a stage of considerable practical interest. This work has shown that whilst with temperatures up to 650° C. and from 850° C. upwards there is an increasing velocity of reaction between ore and reducing gas, there is a range of temperature, between, say, 650° and 850°, at which a definite lag in the reduction rate occurs. These results could hardly have been anticipated from thermodynamical considerations, but could be accounted for on the assumption that the mechanism of the reaction between ore and gas in the higher range of temperatures is different from that at lower temperatures. From a practical point of view the observation is of great significance, and probably plays an important part in determining the reduction efficiency of the blast furnace process. It is proposed in the near future to make a complete exploration of British blast furnaces under different conditions, to determine the extent of the 650–850° zone, under varying conditions, and the conditions of gas composition and ore reduction in the shaft of the furnace. Preliminary tests made during the past year already indicate that such an investigation would give results of practical importance.

Among other interesting features of the studies under the control of the Blast Furnace Committee are results obtained by the Midland Coke Research Committee, which suggest that the coking properties of weakly coking coals can be increased by the addition of certain types of oil—a matter of national significance, in view of the increasing shortage in some of the British coal-producing districts of coal of good coking quality.

The British Refractories Research Association, working in conjunction with the Blast Furnace Committee, is at present examining the possibilities of a standard specification for blast furnace refractories. Co-operative work between refractory manufacturers and blast furnace managers on this Committee has led indirectly to an improvement in refractories and to increased life of blast furnace linings.

Studies are being made by three Coke Research Committees (Midland, Northern and Scottish) on the use of small size blast furnace coke in the open grate. Excellent results have been obtained, particularly by the Scottish Committee, in a specially designed grate.

The Open Hearth Committee has continued its studies of factors

governing efficiency in steel-making practice. In the course of this work, an examination has been made of the extent of air infiltration into open hearth regenerators using a very simple new method which consists of the use of a large tin funnel, in the stem of which a small Pitot tube was fixed. The wide end of the funnel is held against the part of the regenerator wall selected for examination, and the differential pressure set up by the flow of air along the stem of the funnel is measured by a very sensitive micro-manometer. This method is one which is capable of application to a study of furnace problems in a number of industries.

The work of the Heterogeneity of Steel Ingots Committee, which involves studies of an industrial and fundamental nature, has thrown light on the factors governing maintenance of quality of steel produced in the open hearth process.

A problem which is receiving attention, but which has not yet been satisfactorily solved, is the measurement of high temperatures in the open hearth furnace and in liquid steel.

The Corrosion Committee has completed the setting up of observation stations at 14 centres at home and abroad, representative of widely varying climatic conditions. This Committee, which is working in close collaboration with other organisations studying this important problem, published a report of its work during the year.

Research committees connected with the steel and tinplate trades have for some time past been investigating factors governing quality in steel sheets. This work, which is under the direction of Principal Edwards at University College, Swansea, has given results of considerable significance. It has been shown that annealing furnace and rolling mill practice both play an important part, and consideration is being given to the possibility of modifying existing practice in the South Wales area with a view to improving the quality of sheets still further.

Work of national interest in another direction is being done by the Sheffield, Rotherham and District Smoke Abatement Committee, whose investigations indicate distinct possibilities of making steel products of Sheffield quality with less smoke emission than has been possible in the past.

Although the investigations of many of the research committees under the Council are entirely different in both their purpose and scope, many of them are interdependent, and results obtained by one committee frequently have an important bearing on investigations made by others. The co-ordination of all this work by the Research Council has resulted in a rapid acceleration of progress. This applies also to researches outside the control of the Council; the investigations of many of the organisations under the general control of the Department of Scientific and Industrial Research are frequently of considerable importance in iron and steel production. The work of the National Physical Laboratory, the Fuel Research

Station, the Building Research Station and the Food Investigation Board have all in one way or another been of great practical value to various branches of the iron and steel industry. In some cases joint investigations are in progress with these organisations, and in others co-ordination is secured through the Department.

The British Non-Ferrous Metals Research Association

(Licensed on 5th December, 1919)

During the past year changes in organisation of staff and work have been put into operation with the object of utilising as fully as possible the advantages of the Association's Headquarters in London. Better co-ordination of the research staff as a team has been secured and has been facilitated by the strengthening of the staff following the removal of certain extramural researches to Headquarters.

In the early years of the British Non-Ferrous Metals Research Association its researches were carried out in established laboratories in the Universities, the National Physical Laboratory, the Research Department, Woolwich, and in members' research laboratories. Such a policy at that period was undoubtedly the right one and has been abundantly justified by its results.

This first period is now being succeeded by a second, with promise of still greater activity, in which the majority of the Association's researches will be carried out by its own staff in its own laboratories, with many advantages in increased service to members to be gained by the employment of a permanent staff who are specialists in different types of scientific work. This policy does not indicate any lack of appreciation of the value of extramural research, nor any intention to abandon such work. Extramural research on a considerable scale is, indeed, still in progress, and for special kinds of work demanding equipment and experience not available in its own laboratories the Association intends always to utilise the facilities of the great metallurgical and other scientific laboratories at Teddington, Woolwich, and the Universities.

Several of the major researches which have been in progress for a number of years have either been completed recently or will be completed in 1934, in so far as active experimental work is concerned, and new researches have been planned or started. A new research dealing with the relation of ingot structure to rolling properties has been planned and active work to be carried out partly at the Research Department, Woolwich, and partly at Headquarters will be started immediately. A research on the corrosion of copper (copper water service pipes, etc.) will be undertaken as a resumption and extension, covering a wider field of preliminary investigation, of the problem of " green staining " occasionally met with in the use of copper pipes in water services. The question of

bismuth in copper has received a considerable amount of attention during the year, firstly with regard to its determination by chemical and by spectrographic methods, and secondly with regard to its removal in fire-refining. The subject of the final removal of the very small amount of bismuth which may remain in fire-refined copper has assumed sufficient importance to warrant a systematic investigation of the problem at all stages in the extraction and refining process. This investigation will involve considerable experimental work as well as collection of information and experience from all quarters. The effects on the properties of the copper of the small amounts of bismuth in question, if not removed, have been considered in an important section of the investigation mentioned below.

For a number of years the research on the effect of impurities in Copper, which has been carried out at the National Physical Laboratory, has been one of the highest importance. It is realised on all sides that this research has provided an enormous amount of reliable, authoritative data, and that, although much further work might profitably be carried out in this subject, time might now be given for the industry to assimilate and utilise the results obtained. It has accordingly been decided that the present research shall be terminated, the outstanding investigations rounded off, and a Summary Report prepared on the work of the research as a whole.

The important research on brass strip ingot casting which has been carried out at the Research Department, Woolwich, and has now been definitely completed, has had highly important practical results and has been of great value to the brass industry. The completion of the research has been fittingly marked by the publication of a book, " The Casting of Brass Ingots," by R. Genders and G. L. Bailey, summarising the main results of the work.

Another major research carried out in the Research Department, Woolwich, on properties of lead has also reached the stage of completion. The work has advanced our knowledge of lead and its alloys to a notable degree and valuable practical results have followed, for example, the introduction of the BNF ternary lead alloys. Although in its present form this research has been completed, further research on lead and lead alloys is being considered.

The completion of a definite stage in the research on aluminium castings at the end of 1933 made it a convenient time to transfer this research to Headquarters. The results of the investigations carried out in the University of Birmingham by Dr. I. G. Slater working with Professor Hanson have not only made available a great deal of useful information on the subject of gases in aluminium and its alloys generally, but have led to the provision of a simple and inexpensive treatment which is proving an effective degassing process.

The subject of corrosion of metals has always formed an important part of the Association's research activities. The termination

of the investigation of the effects of tarnish on the polished surfaces of metals and of the effects of various methods of removing tarnish completes thirteen years of continuous research on the subject of atmospheric corrosion. The condenser tube corrosion research, which for so many years before being placed under the control of the Association was carried out under the auspices of the Institute of Metals, continues to provide information of the utmost value to the manufacturers and users of condenser tubes. Much valuable work has been done during the year on the investigation of the effect of minor constituents of cupro-nickel tubes and of variations in the composition of aluminium brass tubes. Changes in character of sea water and their effects on corrosion have also been studied, and attention is being paid to a type of pitting action which is becoming increasingly important in practice. The laboratory work has been transferred to the Association's Laboratories, but the experimental condenser remains in the Royal School of Mines where Sir Harold Carpenter and the College authorities very kindly continue to provide accommodation and facilities for tests. By the transfer to Headquarters of the central activities of the condenser tube corrosion research the Association now has a strong section in its own laboratories capable of dealing with problems of corrosion as they arise.

Other researches which are in progress and continue to provide valuable practical results include those dealing with metallurgical applications of the spectroscope, effects of frost on water pipes, alloys for high temperature service, galvanising and zinc coatings, and electro-deposition.

During the year two books have been issued by the Association and are on sale to the public. One of them on brass casting, published in January, 1934, has already been referred to, the other "Metallurgical Analysis by the Spectrograph," by D. M. Smith, was published in October, 1933. Both of these books have been favourably received, have aroused widespread interest and are in good demand. This method of making the results of an important research or series of researches generally available, when the information is no longer reserved for the use of members only, is likely to be still further developed in the future.

Members are availing themselves to a steadily increasing extent of the facilities provided through the Development Department for the discussion of their problems with scientific officers in close touch with research. Such discussions assist manufacturers considerably in the solutions of their immediate difficulties and in appreciating the directions in which they can make use of the results of scientific work, while at the same time frequently indicating useful lines for the prosecution of further research.

An essential activity of the Development Department is the maintenance of contact with members of the Association. Further steps have been taken during the year to ensure that all members

are kept fully informed at frequent intervals on the work which is in hand in the Association's Laboratories, and are thus in a position to offer useful help and criticism at an early stage of the work.

The work of the Association's Information Department and Library continues to show a steady increase in volume, notably in the library loan services to members, the extended critical survey of technical literature of which the main results are reflected in the monthly *Bulletin*, the preparation of prompt translations of outstanding foreign metallurgical papers, and of the issue and distribution of the research reports and other publications arising from the whole of the Association's activities. The Technical Enquiry service, which is co-ordinated by the Development Officer and draws upon the experience of all staff, is becoming more widely known and utilised among members. The number of enquiries showed an increase of practically 50 per cent. over the previous twelve months.

The year was notable for the resumption of more numerous membership enrolments than in the last year or two and there is every prospect that the second phase of the Association's activities now begun will meet with increasing recognition from industry and fully justify the heavy and continuous work carried on since 1920.

The British Refractories Research Association

(*Licensed on 15th March*, 1920)

The formulation of standard specifications follows the progress of research. It is interesting, then, to note that the Institution of Gas Engineers, which has fostered research on refractory materials for the past twenty-five years or so, introduced recognised standard specifications for firebricks in 1912. As the result of experience, modifications were suggested, and revisions made in 1922 and 1925. There can be little doubt that the application of these standard tests resulted, amongst other things, in a great improvement in the texture of firebricks, and gave an impetus to a fuller appreciation of the constitution, and peculiar properties of silica products.

About a year ago, the Refractory Materials Joint Sub-Committee of the Institution of Gas Engineers, and the Association seized an opportunity to reconsider the specifications in the light of recent investigations, and an increased knowledge of the properties of refractory materials. The results of these deliberations have now been embodied in a completely revised edition of " Standard Specifications for Refractory Materials for Gasworks," which has recently been published.

For the past four years investigations on the properties and behaviour of blast furnace linings for the Blast Furnace Refractories Sub-Committee of the British Iron and Steel Federation and the B.R.R.A. have been proceeding. On the basis of these researches,

it is confidently expected that the committee will be able to complete a satisfactory scheme of standard tests and specifications for the approval of the iron manufacturers and brickmakers.

In the standard testing of refractory materials, the refractoriness test is, probably, the first consideration. In this, an attempt is made to measure the resistance of materials to the influence of very high temperatures. This test, however, gives little or no indication of the conjoint influence of pressure and temperature, a state of things more often encountered in industrial usage than the effect of temperature *per se*. For a considerable time, it has been suggested that provision should be made in a scheme of specified tests for the determination of the refractoriness-under-load characteristics of refractory materials. The investigations carried out by the Association between 1923 and 1927 added considerably to our knowledge of these characteristics. However, before a suitable test can be specified, much more research will have to be done. Consequently, at the request of the Institution of Gas Engineers, a comprehensive investigation has been undertaken, and is already producing valuable guiding data.

Several advances of practical importance in the field of drying claywares, and a consideration of the design of dryers have recently been reported. The drying of a clay body under constant conditions of temperature and humidity takes place in two periods. In the first one, the rate of drying is constant, while in the second the rate falls off continuously with the decreasing moisture content of the clay. Investigations over a comprehensive range of temperatures and humidity have demonstrated, in these cases where the air flowing over the clay forms the only source of heat, that, during the first period, the clay assumes the wet bulb temperature of the air, and that the rate of drying is proportional to the wet-bulb depression. During the second, or " falling-rate " period, this simple relationship breaks down, the temperature becoming a factor of increasing importance as the moisture content of the clay decreases.

Experiments on the effect of temperature on the greatest safe rate of drying claywares have also been carried out. By drying fireclay blocks at various temperatures, and controlled rates, it has been found that there is a temperature at which a clay can be dried at the greatest rate without cracking. At both lower and higher temperatures the tendency to crack is more evident. The storage of moulded clay shapes, under humid conditions, as distinct from the storage of plastic clay, increases the resistance to cracking during drying and, consequently, the rate at which they may be dried. The effect of the addition of an acid coagulant to a clay on its drying properties was mentioned in last year's report.

The most common method of failure of saggars, used in pottery firing, is by " cracking across the bottom." It has been shown that, in many cases, the cause of bottom cracking lies in the fact that the sides of a saggar generally dry at a greater rate than the

bottom. Permanent plastic deformation of parts of a wet clay body can result from drying strains, causing cracks to appear when the shrinkage of the clay is practically complete or the finished article to be badly strained.

An outstanding feature of the study of the drying of claywares is the very pronounced variations in the rates at which various clays may be safely dried. With the object of throwing some light on this point, and on the mechanism of drying, an apparatus has been devised and constructed for measuring the flow of water through plastic clay. The principle involved is the restriction of the clay between two permeable pistons, water being passed through the whole. Under the experimental conditions, the moisture content of the clay is controlled by the pressure applied. To obviate the effect of the variation of the viscosity of water with temperature, the whole of the apparatus is contained in a thermostat.

Some of the other investigations included in the present research programme are (1) the properties and behaviour of refractory materials used in the construction of blast furnaces, gas retorts, steel furnaces, and in the manufacture of pottery saggars; (2) the mechanism of the attack of slags and alkali vapours on silica bricks and firebricks; (3) factors influencing the texture of refractory materials; (4) composite chrome refractory materials; (5) the influence of the setting of claywares in kilns on the efficiency of the firing operation.

The British Electrical and Allied Industries Research Association

(*Licensed on 22nd September*, 1920.)

Surge Phenomena

Overhead transmission lines and the apparatus connected thereto are frequently subjected to high voltages of a transient character, known as surges. These may be set up by lightning, by switching operations or by abnormal operating conditions, and to ensure continuity of supply, a knowledge of their causes and characteristics and the best methods of protection against such surges is necessary. The Association has devoted considerable attention to the study of the problems involved, and, in co-operation with and with the support of the Central Electricity Board, has put in hand a comprehensive programme of research on the occurrence of surges, the factors controlling their propagation on overhead lines and methods for minimising their harmful effects.

Earthing

The Association has continued its investigations into problems connected with earthing of electrical plant and apparatus. It has

been found that shocks may sometimes be obtained from earthed apparatus and a theoretical investigation has been made to determine the circumstances in which this is possible. To ensure that the current through the body, in the event of contact with defective apparatus, shall be limited to safe values, the relationship between the resistance of the earth electrode, the fault resistance, and the resistance of the human body has been determined.

When an earth current, due to fault conditions, passes through an electrode, the surrounding soil is dried and the resistance of the electrode increases. In certain cases the increase may be so large that the electrode ceases to be efficacious in protecting the circuit or personnel. The Electrical Research Association has prepared a report on this subject, in which different types of electrode are compared under various conditions of operation and further experimental investigations are being made under practical conditions of operation in the field.

Flameproof Lighting Fittings

In many industries inflammable dusts, such as flour, sugar, coal or sawdust, or inflammable cellulose films may be deposited on lighting fittings and so give rise to a fire hazard. In order to discover the extent of the danger the Electrical Research Association has commenced an investigation in which the effect of the deposition of these materials on flameproof and dustproof lighting fittings is being determined experimentally.

Dielectrics

The Association is continuing the important researches into the fundamental properties of dielectrics and at the same time is devoting attention to the practical aspects. This work has already borne fruit in the form of improved products and the results are made available to the public by the issue by the British Standards Institution of British Standard Specifications, based on information supplied by the Association, which ensure that materials complying with the requirements of the Specifications are of good quality. One striking instance showing the benefit to industry of improved products is that of enamelled wire, such as is used in the manufacture of electricity meters and other measuring instruments. One of the leading manufacturers in this country has stated that failures, due to faulty wire, in a certain class of finished products before shipment, formerly approximating 20 per cent., have now been reduced to a figure of less than 1 per cent.

Underground Cables

With the increasing use of electricity it is important to ensure that the mains should carry the maximum current without injury,

in order to reduce the costs of transmission. To secure that the best use is made of cables, a knowledge is required of the thermal properties of the ground in which they are buried. The Electrical Research Association is studying the problems involved and has developed a method for the determination of the thermal resistivity of the ground by direct test on a cable route, while the influence of moisture on the thermal properties of the soil is also being studied.

Steels for Use at High Temperatures

During the year a Conference of representatives of manufacturers and users has been held, and as a result of the support obtained, the Association has been able to plan on an adequate scale, in co-operation with the British Iron and Steel Federation, a further important series of researches into the creep and corrosion properties of carbon and alloy steels at high temperatures. Such knowledge is essential if increased efficiencies are to be obtained by the use of higher pressures and temperatures as is the tendency in modern power engineering practice.

Electric Circuit Breakers

During the year, the work on fundamental research on arcing phenomena has been continued and many important researches are in progress. Improved arc rupturing devices covered by patents taken out by the Association are now in commercial production in this country, while a licence to manufacture in Germany under the E.R.A. Gas Blast Patent has been taken by one of the leading manufacturers in that country.

In connection with test records taken by means of the cathode ray oscillograph, the Association has developed a special electron trip which ensures that a number of larger scale cathode ray records of different transient phenomena, each occupying, say, 1/100,000th of a second and recurring at irregular intervals spread over a time of several hundredths of a second duration, can be taken on one photographic plate.

In the study of arc and tank pressures a novel pressure recorder has been developed which operates on small changes of electric capacity and is sensitive enough to follow rapid diaphragm movements due to pressure oscillations, which may thus be recorded by an ordinary oscillograph on the film recording other phenomena. The range covered is from zero to 1,000 lb. per sq. in. without the necessity for making any change of diaphragm. The instrument is capable of recording changes of capacity of the order of a few millionths of a microfarad.

Plugs and Sockets

Comparative tests have been completed on British standard round and American flat-bladed electrical plugs and sockets, which

have confirmed conclusions forecast by earlier work and demonstrated the superiority of the British design. Reports on the subject have been furnished to the British Standards Institution and to the Institution of Electrical Engineers.

The British Scientific Instrument Research Association

(Licensed on 23rd May, 1918)

A demonstration model of the apparatus, devised by the Association, for measuring the thickness of iron plates, to which reference was made in last year's Annual Report, was included among the exhibits on the Department's stand at the Shipbuilding and Engineering Exhibition held at Olympia during September, 1933. The apparatus attracted a considerable amount of attention from shipbuilding firms, gas supply corporations and other potential users, and the Exhibition afforded an excellent opportunity of finding out the more important requirements of the industries likely to be interested in apparatus of this type. Commercial models designed to meet these requirements are in process of development by a member of the Association, and it is expected that one or two models will be put on the market early in 1935.

The torsional changes which occur when suspension fibres made of drawn wire or rolled strip are subjected to changes of temperature have been investigated, and heat treatments have been worked out by which the zero positions taken up by loaded fibres made of a number of different metals can be rendered substantially independent of temperature changes within wide limits. Microscopic examination of the heat-treated fibres has failed to reveal any changes in the structure of the metals which could be associated with the changes in the torsional behaviour of the fibres. With all the metallic filaments investigated, heat-treatments which are sufficient to produce structural changes observable under the microscope render the filaments useless as suspension fibres.

The effects produced on the state of polarisation of light, initially plane-polarised, when the light is reflected at the surface of a crystal or at a polished surface of glass, have been further investigated. The results obtained show that the bi-refringent properties of crystals can be determined conveniently in this way, and the method would appear to lend itself to the investigation of the properties of dichroic crystals. Important information regarding the effects produced by the " weathering " of polished glass surfaces has been obtained during the investigation.

The causes of fading of the coloured liquid used in alcohol-filled thermometers have been investigated, and methods by which the development of such fading can be very greatly retarded have been worked out.

A number of glasses of unusual composition have been made experimentally during the year, and some investigation has been made of their durability and other properties.

The defects which have been found to develop occasionally on silvered mirrors when exposed for long periods to temperatures of the order of 250° C. to 325° C. have been studied, and the heat-resisting properties of mirrors produced experimentally by various methods have been investigated. A technique has been worked out which, from the results obtained in the laboratories of the Association, should enable mirrors of high stability to be produced. Tests of commercial mirrors made by the method recommended by the Association are now in progress.

The investigation into the nature and causes of films which frequently develop in optical instruments, particularly when the instruments are used in tropical and sub-tropical climates, has been taken up again during the year. In some of the filmed instruments which have been put at the disposal of the Association for the purpose of this investigation, films of types which had not been previously examined by the Association were found. A report is to be issued describing the more important characteristics of the various types of films investigated, with recommendations regarding methods by which the development of filming may be avoided or considerably retarded.

Among investigations of a definitely *ad hoc* type, the following may be mentioned as typical:

A number of resistance coils which had broken down in use were examined and the combination of conditions which appeared to be essential for breakdown to occur was discovered. Methods of avoiding this combination of conditions were recommended.

Marking inks have been worked out which are stable at temperatures of 600° C. to 750° C. when applied to glasses and burnt in at temperatures between 450° C. and 650° C.

A number of materials, including greases, oils, fabrics, etc., have been examined to determine whether they were suitable for use in instruments or in instrument cases, and in many instances alternative materials, free from objectionable properties found in the samples submitted, have been recommended or made up and supplied.

THE RESEARCH ASSOCIATION OF BRITISH PAINT, COLOUR AND VARNISH MANUFACTURERS

(*Licensed on 1st September*, 1926)

During the year 1933–34, the Association has produced a notable series of papers on various subjects, ranging from the mechanical properties of films to the hiding power of paints, the precipitation of iron oxides, cellulose lacquer, dispersion of pigment dyestuffs, colour scales for oils and varnishes, identification of synthetic resins, and tung oil.

Much of this work has a direct bearing upon immediate practical issues. It will not result in dramatic changes in methods of manufacture or large savings in money, but it will help forward that steady improvement in technique which is a matter of considerable importance to the industry.

Systematic investigations of the mechanical properties of films dealing with their tensile strength, their extension under steady load and their behaviour under alternating stress have opened up an entirely new region of experimental work on the study of paint and varnish materials, the significance of which has not yet been fully appreciated. There is no doubt at all that the properties of elasticity, plasticity, toughness and adhesion of films are all concerned in the performance quality of films in service. These qualities can also be related, at least in part, to the liquid medium from which the film is produced, for the film is very much the child of the liquid medium in its molecular structure; it is thought that the study of physical properties of dried films in relation to the composition and constitution of the parent liquid will, sooner or later, relate manufacture to performance and service.

Investigations on the composition, crystal structure and surface activity of precipitated iron oxides in relation to the heat treatment which they had received have been continued. It has been shown that ferric hydrate produced by precipitation is invariably the monohydrate, and that if produced by oxidation of a ferrous precipitate its crystalline structure is orthorhombic, but cubic when produced directly from ferric salts. The changes which follow different treatment of the primary precipitate determine the pigment properties and colour of a valuable range of iron oxide pigments, ranging in colour from light yellow to deep red, and ranking among the most permanent pigments available.

Mention was made last year of a new method of determining hiding power by an instrument known as the " Transmeter." Quite a number of these instruments are now being regularly used in the industry both as a means of control and as a new method of investigation. This subject of the hiding power of paint and pigments is by no means finished, but it is satisfactory to be able to report not only that a great advance has been made scientifically in the study of the subject but that the principles involved have been reduced to practical terms.

Some attention has been paid to the problem of lacquer manufacture using material other than toluol and there is every indication that recent and foreshadowed developments in the production of solvents will have a marked effect on lacquer formulation.

In the last report reference was made to a considerable amount of work which had been done on the measurement of the colour of oils and varnishes with a view to developing rational scales for the colour evaluation of these materials. It has not been possible hitherto to express conveniently in any system what is really

required, namely, a graded series of colours for specification purposes. The schemes outlined as a result of this work provide the first real attempts to establish colour scales for industrial use fulfilling these general requirements. The particular recommendations relate to colour scales for oils and varnishes, matching these materials within close limits both in brightness and in colour, the steps in the colour scales having a definite and known quantitative relationship to one another. The scientific authority for the work is found in the Guild trichromatic system of colour measurement; coloured glasses are used as the means of expressing the standards which can be assembled from the ordinary Lovibond Tintometer glasses.

The work on tung oil has been chiefly concerned with the significance of the heating tests and a recommended new procedure has been developed which has since been incorporated in the revised British Standard Specification for tung oil. During the year also, an increasing number of samples of Empire grown tung oil have been examined and reports thereon have been published in the Bulletin of the Imperial Institute. It may be accepted that the programme for the Empire development and cultivation of tung oil is proceeding satisfactorily and the oil produced, although not yet in commercial quantities, is proving true to type and of excellent quality.

The Institution of Automobile Engineers Research and Standardisation Committee

(*Established 1st July*, 1931)

During the past year, the activities of the Research and Standardisation Committee of the Institution of Automobile Engineers have been concerned almost entirely with the wear and tear of motor vehicles.

Research is being continued at the Chiswick Laboratory on cylinder wear, which is probably the most important cause of deterioration in engines, entailing unnecessarily high oil consumptions and expensive service and replacements. The solution of this problem alone would, literally, save the users of motor vehicles, *i.e.*, the public, millions of pounds per annum. During the year, the relative importance of a large number of factors in relation to cylinder wear has been determined and, although it is not claimed that a panacea has been found, sufficient has already been accomplished to enable both designer and user to mitigate cylinder wear. Earlier work had shown the importance of corrosion at low operating temperatures, and the various factors controlling this corrosion have now been studied. Certain remedies are under consideration and it is hoped that the coming year will see the successful conclusion of this investigation.

An allied investigation has been carried out which has shown the important influence of wear in different parts of an engine on the actual increase in oil consumption. In addition, the great influence of engine speed on oil consumption has been established.

The wear of valves and valve seats in engines is a matter of considerable concern to operators of commercial vehicles as it entails continued adjustments, servicing and replacements. Experiments have been carried out during the year which showed the great importance of exhaust valve temperature, and a study was, therefore, made of the influence of a large number of factors—relating to both design and operating conditions—on valve temperature. In this way it has been possible to show under what conditions valve temperatures are highest and to make definite recommendations for reducing valve temperatures. In addition, the wear resistance of a large number of different seat materials has been determined, some of which give very much better results than ordinary cast iron.

The British Cotton Industry Research Association

(Licensed on 7th June, 1919)

In many of the Annual Reports on the work of the Shirley Institute reference has been made to the steady increase in the demands of members for special help from the Research Staff. There is still no sign of a saturation point being reached in this respect, and during the last year more special problems of individual spinners, manufacturers and finishers have been received at the Institute than in any twelve months previously. In the face of this almost embarrassing recognition of the value of the Association to the trade, the difficulty of maintaining and extending fundamental research work has become even more acute than it was a year ago, but at the moment of writing there is happily every hope of increased financial support, which should justify the Institute in developing and extending the research work—now long overdue —on many fundamental problems.

There is, indeed, a pressing need for expansion in almost all branches of the Association's activities. To give only one further illustration of this—when the new experimental spinning rooms were opened in 1930, there were many members who said that the accommodation available was far more than could ever be efficiently utilised. Now, after only four years, the work is being hampered through lack of space for sufficient machinery adequately to deal with the numerous problems which arise—such as spinning tests on experimental growths of cotton from the Empire Cotton Growing Corporation, and the preparation of special yarns for research purposes. In almost every department a similar story could be told. There are, in addition, many entirely new fields of research, urgently needing to be explored, for which both the facilities and

the staff of the Institute are at present insufficient. It is hoped that in the next few months the much needed expansion will have become a reality, in which case some account of it may be available for inclusion in next year's Report.

The Wool Industries Research Association

(Licensed on 26th September, 1918)

Reference was made in last year's report to the co-operation of millowners in trying out on a large scale in the works the results of laboratory research. The past year has seen a consolidation of this development. Quite apart from laboratory work on wool and wool processes which is being actively pursued, research work is being carried on in mills of the members under practical everyday bulk conditions; e.g., wool scouring and worsted carding are being so treated. Already invaluable information as to the requirements and technique of commercial practice has been secured, which, in certain cases, has led to better control and to improved products. Similar experiments are being carried out in milling and felting, and in woollen carding and spinning. The Association's modifications of the woollen card are being adopted by the industry.

The report on the fastness of dyed fabrics to light and laundering has been completed and definite standards of fastness to these agencies are now available. Tentative standards of the fastness of dyed wool to milling are also proposed.

A study of the carbonising process for the chemical removal of vegetable matter in wool has led to the development of a simple and reliable new technique for the estimation of:—

(*a*) The possible damage to the wool;
(*b*) The residual acid.

With reference to (*a*) a method has been devised by which within 24 hours the extent and nature of damage or susceptibility to damage of a particular type of wool can be assessed. It is of great importance in assessing the resistance of wool fabrics to laundering, perspiration, and other deleterious influences encountered during wear and storage. This discovery reduces the time of testing from three weeks to one day.

The ionised oil processes for wool lubrication have been developed for woollens still further, and are being exploited for other branches of the industry under mill conditions.

The Association's work on atmospheric humidification and control of humidity in mills has been further developed to meet special practical requirements and the services of the staff are being increasingly sought by the industry.

There is again a steady increase in the demand for private

investigations and special enquiries of a technical nature. The number of problems submitted exceeded that of last year and affords evidence of the increasing confidence of the trade in the Association's work.

The protection of clothing, etc., against moths and mildew has been considerably advanced and practical results have ensued not only for mill practice, but for the household. The protection of furs under storage conditions has been successfully accomplished.

In addition considerable developments have ensued as a result of investigations of metallic stains occurring during processing. Having located the cause of many of the troubles, steps have been taken towards their elimination. The presence of lead on a fabric was traced to the use of solder for coating wire healds on the loom instead of pure tin. An improved back rail has been substituted for the older type by several firms in their looms.

Increasing attention has been paid to the determination of the acidity and alkalinity of the liquors used duing the various manufacturing processes, and methods of control and measurement now suggested have been adopted under mill conditions. The newer methods of determination of pH values have proved very advantageous.

A feature of the Association's influence on the industry is the increasing utilisation of the fundamental data obtained from the pure research of the earlier stages of its activity by the personnel of the mills themselves in order to explain and develop their technique in processing. Concrete examples of this are seen in the invention by certain members, in co-operation with the Association's staff, of combined scouring and milling machines, and further improvements in cloth finishing machines.

The Association's new process for producing unshrinkable wool, yarns, and fabrics, claimed to withstand the rigours of laundering, is being exploited under mill conditions. It is hoped to have materials available for the public early in 1935.

The new motor fabrics made from wool and rubber latex are now being introduced to the public. It is hoped that they will become popular.

The Linen Industry Research Association

(*Licensed on 10th September*, 1919)

In order to provide material for a full-scale factory trial, 117 acres of flax were grown, of which 105 were in Norfolk. This experiment will be completed within the financial year. The processes devised proved very satisfactory and the resulting flax fibre has been good in yield and quality. A number of members have already

bought considerable quantities of the flax fibre and good prices have been obtained averaging for Norfolk flax £77 a ton. A tank retting process has been devised and used for the better crops, called the Duplex ret, which gives results similar to the Courtrai double retting.

With regard to preparing, work has been continued on investigation of regularity of slivers using the apparatus previously developed for this purpose. The usual methods of varying the dimensions of machine components throughout preparing systems have been studied and analysed with a view to determining the physical principles involved; various formulae have been developed and the conclusions drawn are of interest. The problem of calculating the proportions of constituents in a mixture of flaxes has been investigated; graphical and mechanical aids for effecting the calculations have been developed.

In connection with spinning, investigation has continued of the behaviour in the reach of the spinning frame. An improved method of drying wet spun yarn has been worked out and reported to members. Work on the automatic maintenance of spinning troughs in a clean condition was brought to a stage suitable for extended works trials. Further progress has been made in the investigations having for their object the development of an improved process of spinning.

Arrangements have been made for the manufacture of the calculating machine referred to in the last annual report and a number of machines are on order for the use of member firms.

In connection with weaving, an attachment to impart a bunching motion to pirn winders of the cup type has been designed and patented. Work in connection with the dressing of warp yarns has been continued and the work on the measurement and recording of yarn tension during winding, dressing, and weaving has made progress. An improvement has been made in the design of the Jacquard self-twilling machine and a modified machine is now undergoing a factory trial. With the assistance of members, a large range of cloth samples was prepared to study the effect of some structural changes on the creasing of linen fabrics and this work is being continued.

During the year a method of preparing flax fibre for spinning by chemical treatments of " decorticated " unretted straw has received close attention. As a result of numerous experiments on a fairly extensive scale several difficulties met with in spinning the chemically prepared flax have been surmounted. Yarns have been spun in fair quantity from the fibre and weaving trials are in progress. The experiments are regarded as very satisfactory but it is not yet possible to say anything definite as to the costs of the process in full-scale operation.

The investigations carried out in connection with bleaching and dyeing are for the most part a continuation of those referred to in previous reports. After a prolonged search a method is at last

available which enables damage by acids to be distinguished from damage by oxidising agents in nearly all cases. As the method is successful with goods which have received a thorough alkaline boil subsequent to the treatment which caused the damage it is considered that it will be very generally applicable. A new method of estimating the degree of chemical degradation of cellulosic fibres, similar to the solubility number method but considerably more sensitive, has been worked out. An investigation was made of the action of various metals in causing damage during chemicking. The work on dyes has been extended to include a preliminary investigation of the behaviour of dyed materials in peroxide bleaching.

Work of an advisory nature, relating to special problems arising in practice, has continued to demand a considerable proportion of the staff's activities. There can be no doubt that this aspect of the Association's work is of growing importance and is felt by the trade to be of material benefit. The problems presented are many and varied and bring the staff into close contact with technical difficulties in practically all stages of production.

It has been possible to devote a fair amount of attention to finishing problems during the year and it is hoped that investigations now in progress on the beetling, calendering, and mangling operations will furnish results of some importance.

Recently the appearance on the market of materials containing composite yarns has focused attention on the devising of reliable methods of estimating the proportions of various fibres in a mixture.

Investigation of the behaviour of linen materials under repeated launderings has been undertaken and is only one illustration of the way in which the Association is following the behaviour of linen when it has been marketed and sold to the consumer. In this connection reference may be made to a particular form of damage which has recently been unduly prevalent. This occurs in dress goods and is not due to a fault in the cloth but has been shown to be caused by contact of the material with deodorants containing aluminium chloride.

The British Silk Research Association

(*Licensed on 17th September*, 1920)

The continued uncertainty in the silk industry with regard to the future of the silk duties, which was not resolved until June last, has militated against any improvement in the financial position of the British Silk Research Association. Despite the restrictions thus imposed, the Association has, however, continued the prosecution of systematic research besides investigating the numerous special problems submitted to it, and providing other information sought by members of the industry.

The British Launderers' Research Association

(Licensed on 19th July, 1920)

During the past year the work accomplished has been generally similar in character to that of the previous few years. There have been no outstanding departures from previous policy, though there have naturally been variations in detail.

The main part of the general programme has been devoted to work on improvement in methods and in plant design with the object of securing higher operative efficiency and at the same time conserving fabric life by eliminating the incidence of fabric damage in laundering. In addition a certain amount of fundamental work has been undertaken, which, while not likely to show its full value at an early date, will nevertheless provide a foundation on which to base future applied research.

Among the pieces of work of immediate and general practical value mention must be made of that on water reclamation, as the outcome of which a considerable economy in water consumption can be effected without the slightest detriment to washing efficiency. Processes for reduced water consumption have previously been designed for special cases, but such processes are not of general interest and in them necessity is balanced against efficiency. By the new method clean rinse waters are recovered from the later stages of one process and used in the early washing stages of the next process. The re-use of clean rinse water in this manner involves no sacrifice of efficiency and invites no criticism on hygienic grounds. By its use a 30 per cent. water economy may be effected: thus the process will in many cases lead to definite savings in wash-house costs, and prove of permanent value apart from its merits during times of water shortage.

There has, during the past year, been an extension of previous work on the measurement of efficiencies of different types of laundry plant. Such work, while in its first stages mainly statistical, is of great practical value. It leads not merely to improvements in existing machines and displacement of the less efficient ones, but also frequently makes possible the design of new machines of much higher efficiency. There has been too great a tendency in the past to assess laundry machinery merely in terms of productive capacity, and it is only slowly being recognised that thermal and mechanical efficiency have a definite bearing on overall results. As a development from the measurement of the efficiency of individual machines, considerable attention has been paid to a survey of the heat and power conditions existing in laundries of different types. Useful progress has been made in elucidating the factors governing the balance between power and heat requirements to be co-ordinated in the design of an efficient laundry power plant.

The utilisation of exhaust steam for the production of process steam renders power generation in almost every laundry an economical proposition. The study of a number of cases, in which full measurements of all the relative factors has been possible, has enabled general advice to be given to members as a whole, with the result that several have installed their own power plant, the performance of which has been fully up to expectation.

Turning to the more chemical side of laundry work, a large number of new products which have been suggested for use in the laundry industry have been examined with a view to their possible employment. There is evidence that some of these products have values in certain specialised operations but there is at present little indication that any new material of a revolutionary character is forthcoming.

In addition to the actual experimental work of which some few examples have been given there are other directions in which the Association has been particularly active and, although not in themselves subjects of research, they have undoubtedly been of considerable assistance in the application of the results of research to such a large extent that these activities may be considered as almost a branch of research itself. Of first importance is the method employed for interpreting the results of research work and applying them to the needs of the individual member. For some years past a proportion of the staff has been employed on visits to individual members with this object in view and the time has now come when almost every member has received one visit of this character. That these visits have done much to bring the laundry and the laboratory into closer contact, that they have shown members what research is and what it can do, that they have in this way done much to inculcate and foster the spirit of research among members themselves and that they have thus had far reaching results in the improvement of the general standard and outlook of the Industry there can be no doubt. Publications also assist in this direction, and while the scientific reports giving a full account of a completed piece of work are still issued to members when such a piece of work becomes available for report, the issue of a small publication at frequent intervals dealing with a variety of topics and written as far as possible in non-technical language has been attended with remarkable success.

In addition to this means of communicating the results of research, the Association has co-operated with the National Federation of Launderers in developing an educational system in the industry. A number of classes in laundry subjects have been formed throughout the country and while the lecturers in these classes are usually drawn from the staff of the Technical Schools giving instruction, the lecturers themselves are supplied with technical information on laundry work by direct contact with the Research Association.

Moreover, classes for laundry employees have been conducted by members of the Research Association's staff. Although this educational development is not a direct function of the Research Association, their willing co-operation has been given, and it is evident that work of this kind which commenced in a very small way a few years ago is growing very rapidly indeed.

Co-operation with educational authorities in this way is leading to important results; co-operation with bodies of another character is at least of equal importance, and in that connexion much time and thought has been spent in recent years on co-operation with the manufacturers of textiles. This subject was, however, fully discussed in the last report and little need be said beyond the statement that the foundations of this co-operation, which have been laid in the past, are now enabling a very promising structure to be erected.

It is very satisfactory to note that there is a growing tendency for the industry as a whole to appreciate that the Research Association may give useful assistance. This is evidenced by the considerable increase in the number of requests for technical information which are received. At the present time correspondence with members on subjects of this kind runs to well over 8,000 letters per annum. It is interesting to note that during the past year this correspondence was not limited to a small fraction of the total membership whose interest had been aroused, but that about 80 per cent. of the members had written to the laboratory for assistance at least once during the year.

The British Leather Manufacturers' Research Association

(*Licensed on 27th July*, 1920)

During the past year further important work has been carried out in the laboratories of the British Leather Manufacturers' Research Association, in collaboration with the New Zealand Department of Scientific and Industrial Research, on the pickling of sheep skins sent from New Zealand to this country. There are many defects in this type of raw material, some of which are caused prior to the pickling process, such as mottle, leopard grain, low grain, etc., and others, such as mould growth, which arise from unsuitable pickling.

The first type of defect is being investigated by means of experimental casks of pelts from New Zealand. These pelts are being tanned in tanneries in this country where the quality of the pickled pelts and also of the finished leather is assessed. Samples are also examined chemically and microscopically in the Association's laboratories. The results obtained are correlated with the details of the processes used in the freezing works in New Zealand.

The chief defect arising from unsuitable pickle liquors is mould growth. Previous work had shown that sheep skins can be efficiently pickled in liquors containing only sulphuric acid and sodium chloride, but, in order to prevent mould growth and to preserve the skin in good condition for a long period of time, the concentration of both acid and salt taken up by the skin must be rigidly controlled. When the pickling process is so controlled there should be few packs of pickled goods which are not suitable for storage for long periods. In large scale work, however, lapses in the rigid control of processes sometimes occur and research has been carried out in order to recommend a means of reducing the risk of mould growth on the pickled skins should the concentration of acid and salt accidentally fall below the optimum.

It was found that mould growth could be prevented by the addition of organic acids to the pickle liquors, but the fibre structure of the pickled pelt on storage, especially at increased temperatures, was not in every case as good as when the optimum concentration of mineral acid and salt had been used. If, however, certain disinfectants are present in the pickle liquor, mould growth is prevented and good fibre structure preserved during prolonged storage, even if the concentration of sulphuric acid falls considerably below the optimum. These disinfectants may be used in very low concentrations, *i.e.*, about 0·01 to 0·05 per cent. in the pickle liquor.

This work on pickled sheep skins is a part of a wider investigation in hand at present on tanners' raw materials in general. For example, work has been carried out on the disinfection of salted hides with sodium fluoride and the effect, if any, such a treatment would have on bi-products such as edible gelatin has been investigated.

Mould growth is an ever present source of trouble in all stages of the tanning process and research has been carried out with special reference to the defects in curried leather due to mould growth. In general, mould growing during the currying process is liable to roughen and pit the surface and the more solid constituents of the currying mixture are liable to collect in these pits or rough areas giving the appearance of a fatty spue. It has been shown that moulds cause the formation of free fatty acids, though it is difficult to say how far this is deleterious to the leather. If, however, the leather is in contact with metal, the free fatty acid will corrode the metal and the leather become contaminated with traces of the metal which act as a catalyst for the oxidation of fats and so cause the formation of a gummy spue. It has also been found that moulds may cause the formation of a gummy spue in the absence of such metallic impurities.

In order to overcome these troubles experiments were carried out to determine suitable disinfectants to add to leather during the shedding processes which would inhibit mould growth during storage and during currying. A number of suitable fungicides were found and the requisite concentrations determined.

A new method of examining the fibre structure of leather has recently been investigated, namely the method of X-ray photography. X-ray shadowgraphs do not give any information with regard to the quality of leather but X-ray diagrams of the molecular structure have opened up an entirely new field of investigation. The X-ray diagram of good quality leather shows a sharply focussed pattern, whereas for a poor leather the pattern is diffuse and indistinct. It is hoped that this work will be extended considerably in the near future and will enable information as to the condition of the fibres in a sample of leather, and the stage in the tanning process where fibre damage has taken place, to be determined with ease and accuracy.

An important line of research which is being continued is the assessment of quality in leather. Chemical, physical and microscopical examinations of leathers have been made and the various results obtained have been correlated so as to determine which are independent and which dependent factors in assessing the quality of a given sample of leather.

Besides these fundamental research problems, numerous smaller troubles have been studied, and the application of pure research results to members' individual problems has continued with much success. The " service " side of the Association's activities has been extended so that members may have greater facilities for understanding and applying in their own yards the results of the research carried out in the laboratories of the Association.

The British Boot, Shoe and Allied Trades Research Association

(*Licensed on 1st May*, 1919)

The business of the boot and shoe industry is to assemble materials which are the finished products of other industries and to unite them into articles of direct personal utility to each individual member of the community. Consequently the directness of its service is conspicuous to all. This manifestly gives emphasis to what must be the ultimate object of the shoe industry's research, namely, the improvement and development of the service rendered by the industry to the community. It is to be attained by the provision of footwear of continually advancing merit in qualities of fit, comfort, elegance and in " value for money."

The Association has always planned its programmes in an endeavour to fulfil this highest purpose, as successive issues of this Annual Report bear witness. And so there is found, in one year, a record of the Association's accomplishments in the field of foot measurement, last design and shoe fitting. At another time the selection, care and use of the wide variety of shoe materials indicate

directions in which progress has been made. Yet again, as in the report of a year ago, the advances of the moment had relation to production methods and factory efficiency. And so, in its turn, each avenue along which lies improved footwear service to the community has had its research counterpart referred to in these Annual Reports.

During the past year steady work has been done along the whole research front and much consolidation has been accomplished, while the dissemination and transfer into practice of results achieved has received special attention. Contact between the factories and the Association has been made closer by the employment of a contact, or service officer, whose whole time is occupied in visits to members' factories.

Research achievements which, perhaps, call for special mention on this occasion relate to the physical properties of leather. The Association is a pioneer in this field of investigation. A year ago the British Leather Manufacturers' Research Association section of this report included a paragraph on research into the quality of vegetable tanned sole leather, in which reference was made to the cooperation of this Association. The physical properties of the leathers included in that investigation were measured in these laboratories and they included those properties for whose measurement this Association has designed special instruments.

Four of the Association's instruments are now manufactured and on sale, *i.e.*, instruments for the determination of the density of leather, for the measurement of air permeability, and for the measurement of water permeability, together with another instrument (the "Lastometer") which performs a "cupping" test to show the strength and stretchiness of shoe materials.

During the year under review the Association has published in the scientific press four papers under the heading physical properties of leathers and shoe materials. One deals with thermal conductivities; a second is a statistical study of the physical properties in relation to one another and to the chemical characteristics; while the other two papers were read on the occasion of the annual meeting of the British Association for the Advancement of Science, Leicester, 1933, and dealt with the drying and wetting of leathers, also the testing of leather and sheet materials by distension under pressure and by the Lastometer type of test.

All this is research fundamental to improved footwear service; it brings that knowledge which improves the comfort of shoes by making them more hygienic and which enhances the efficiency of their production to make them either lower priced or better value for money.

The improvement in footwear service to the public has been a conspicuous feature of the years since the war; and the Association has had an important part to play in bringing about this manifest improvement.

The Research Association of British Rubber Manufacturers

(*Licensed 30th September*, 1919)

During the year, the Association has been restored to a normal basis of operation and the work of its Laboratory, Library, and Information Bureau, which was interrupted for a period on account of circumstances mentioned in the previous report, is now proceeding as before.

The joint investigation with the British Electrical and Allied Industries Research Association on ebonite has been advanced more particularly in connexion with the influence of the method of vulcanisation on the properties obtained, the action of oils on ebonite, and its electrical surface deterioration in light, whilst reports have been issued on various other aspects of the subject such as water absorption, ageing, and standardised test methods for mechanical properties. This work has already brought to light important differences in certain properties according to the method used for vulcanisation, and has yielded useful information on the production of ebonite to withstand the harmful action of oils.

The investigation of new raw materials has always formed part of the Association's research activities, and accordingly attention has been paid to a new type of raw rubber ("powdered rubber") recently introduced. Preliminary tests have been made on a small sample, and a more extended investigation is planned. The experiments have suggested novel methods of manufacture by the use of this material, which may lead to economies in the production of certain types of rubber articles and to the development of new uses for rubber.

The systematic investigation of the properties of rubber continues to receive attention. The work on the action of organic liquids on vulcanised rubber, which has been carried on for some years past, has recently produced interesting results indicating the lines to be followed in compounding rubbers to resist the swelling and weakening action of organic liquids such as petrol, mineral oils, benzole, etc. The coefficient of expansion of vulcanised rubber is important in connection with the production of accurately dimensioned moulded articles, and accordingly work has been carried out to develop a simple method of measuring this property and to investigate its dependence on the composition and degree of vulcanisation of the rubber.

Turning to matters of a fundamental rather than directly practical character, investigations have been carried out and published on the explanation and significance of the characteristic stress-strain curve of rubber, and on the effect of intensive drying of raw rubber on its solution viscosity, which indicate that changes in the molecular or colloidal structure occur during drying.

The study of methods of test for unvulcanised and vulcanised rubber is being carried on with the object of providing the industry with reliable standardised methods for process control and for the testing of finished products. Continuing the investigation of the indentation method almost universally used for hardness testing, the influence of various test conditions has been examined as a step towards establishing a standard test procedure. The investigation of the parallel plate method of plasticity testing has been advanced by the theoretical study of the behaviour of materials exhibiting various types of plastic flow. The results have greatly extended the utility of this method as an instrument of research on unvulcanised rubber stocks and other plastic materials.

The Association is collaborating with the British Electrical and Allied Industries Research Association in the investigation of impact strength testing and tensile testing of ebonite and other hard moulded dielectrics, and with the British Standards Institution in drawing up a new British Standard Specification for electrical rubber gloves.

With a view to increasing the usefulness of the Association, a Development and Advisory Section of the laboratory has been established as a unit separate from the Research Section. This will be concerned primarily with the development and testing of new processes and materials and with all problems involved in the practical utilisation of the results of the Association's scientific investigations. It is considered that by thus establishing a section of the laboratory to deal solely with matters of direct practical interest to manufacturers, the value of the Association as a means of improving the technical efficiency of the industry will be increased, whilst the Research Section will be left freer to devote itself to more extended investigations of a fundamental character.

The work on the Handbook of Physical and Chemical Properties of Rubber, under the Rubber Growers' Association's scheme for extending the use of rubber, has continued throughout the year under review and the book is now being set in type. In addition to the large amount of tabulated quantitative data on every aspect of rubber properties and manufacture, important sections have been added on recommended methods of analysis and testing, on specifications for rubber goods, and on the scientific and technical associations and institutions of the rubber industry throughout the world.

The Information Bureau resumed the Journal and Summary of Current Literature and is making up the arrears which accumulated during the interruption of its work in order to secure an unbroken sequence of references and indexes. The series of statistical circulars on United Kingdom rubber trade has already been brought up to date. In addition a number of circulars on scientific and economic subjects have been issued.

The patent situation in the rubber industry has become so complicated in recent years by the enormous number of patents

taken out for latex processes, accelerators, and antioxidants, among other subjects, and enquiries from members about patents have increased to such an extent, that it was decided to initiate a new monthly publication, " Rubber Patent and Trade Mark Review." This started in January, 1934, and is devoted to giving a complete index of patents, designs, and trade marks for the principal rubber producing and manufacturing countries. This periodical includes also special articles on patent and trade mark problems and a review of current articles on these subjects in connection with rubber, upwards of 700 references being given each month.

A second new periodical added to the Information Bureau's series of publications is " Rubber Economic Intelligence," issued monthly and designed to supplement the annual and ten-year trade statistical circulars by giving current monthly and quarterly returns for the chief rubber consuming countries. This journal was begun in October, 1933.

The Research Association of British Flour-Millers

(Licensed on 31st August, 1923)

Reporting on the milling and baking characters of typical wheats used by the industry has for many years been an important advisory activity of the Association. Although the work is of a routine character the reports, if issued quickly and frequently, help millers to take the fullest advantage of price differences and to avoid shipments of certain undesirable characters.

One of the most important groups of problems with which wheat and flour research has to deal is that connected with flour quality or baking quality. Why does one flour from one kind of wheat produce better bread, and dough of more satisfactory handling and fermenting character than another? Precisely what is meant by the term baking quality? How can a satisfactory dough be described? What are the actual changes brought about in a dough by the so-called chemical improvers or improvement processes? What happens during fermentation which causes a dough to ripen and thereby to produce satisfactory bread? What is dough ripening? Bread made from dough which is under- or over-ripe, that is from dough which has been insufficiently fermented or over-fermented, is not of satisfactory character.

The problem has been studied for many years by many workers, but our knowledge of the fundamentals of the problem has hardly advanced at all. This slow advance is probably due to the purely chemical character of the earlier work, whereas the problem in the first instance appears to be a physical one. During fermentation a dough assumes a sponge-like structure, the individual cells increasing in size owing to the pressure of gas generated within them by the

yeast. The cell walls are consequently in a state of varying strain, and it is their behaviour when in this condition (for example, whether they rupture easily or whether they stretch without rupture) that largely determines the quality of the resultant bread. In other words, the properties of dough which are of most immediate and direct importance in breadmaking are the purely physical ones of plasticity and elasticity. It is important to be able to measure these properties with precision and in particular to follow their changes during panary fermentation and to study their relation to the water content of the dough. Little progress in our knowledge of flour quality is possible until the individual physical properties of dough which collectively make up quality can be measured.

It is interesting that the same properties are important in soil science, for they are among the underlying factors in good tilth. In close collaboration with the Soil Physics Department of Rothamsted Experimental Station, methods for measuring the plastic and elastic properties of doughs have been developed. The precise rôles played by these physical properties in bread-making are not yet clear. There is evidence, however, that the degree of plasticity is of great importance during fermentation (where moderate stresses are applied for long periods), while elasticity is of dominating importance during the first few minutes in the oven (when larger stresses, caused by rapid expansion of the gas by the heat of the oven, are applied for short times). The problem, however, is further complicated by important effects introduced during the working of the dough by the application and release of stresses, effects such as work hardening, thixotropy and elastic after-effects, all of which probably play essential parts in dough ripening and in producing the final product —bread.

A very important chemical character of dough is its ability to produce carbon dioxide when acted upon by yeast. It is this continuous production of gas throughout panary fermentation which produces the highly vesiculated or sponge-like nature of dough and bread crumb. Flours from different wheats vary widely in their gassing power from poor to over-abundant. An inadequate "gasser" can be converted into a satisfactory one by various methods: either by incorporating some sprouted or frosted wheat (which are always good gassers) in the wheat mixture used for milling, or by adding highly diastatic malt extract or malt flour to the flour. It has been discovered in the Research Association's laboratories that the method of milling is no less important than wheat variety in determining gassing power, and may be possibly even more important. The problem of bringing this important flour characteristic completely under the control of the miller during milling operations is well on the way to solution.

Interesting investigations have also been completed on the dressing action of certain types of sieves and very marked improvements in their efficiency and dressing capacity have been effected.

The British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades

(Licensed on 4th December, 1919)

During the past year further progress has been made in those investigations of a foundational nature dealing with gelatin, pectin and starch.

Gelatin

The work on gelatin has now reached a stage where the information obtained in this foundational work can be applied to industrial problems. The first of these to be undertaken was that of the manufacture of marshmallows of which the gelatin is the most important ingredient. Commercial gelatins as supplied to the trade vary considerably in their physical properties, and the present investigation is designed to find out to what extent these varying properties affect the quality of the finished product. The process of manufacture has been studied at the same time, particularly with reference to the effects of temperature, time and speed of beating. When completed, the results will indicate the most suitable types of gelatin for use in the manufacture of marshmallows. Further, it is always possible that during the course of this work means of improving the results obtained with any particular type of gelatin may be discovered, which may lead either to improved products or economies in manufacture.

Pectin

Two reports on this subject have been issued to members giving the results of the earlier part of the investigation into the nature and properties of pectin. In the first of these the methods of determining pectin are examined and discussed; incidentally a new and rapid method of determining the quantity of pectin in a fruit or fruit product was described which should be useful for control purposes in factories. In the second report the chemical nature of pectin is discussed. The results of this part of the investigation prove quite definitely that pectin as extracted from fruit is not a simple substance like sugar, but rather resembles the natural fats in that it is a mixture of closely allied substances. Consequently, it may vary in its composition according to the kind of fruit from which it is extracted and to the method employed in its extraction. Attempts to establish a basic chemical formula for the constitution of pectins are therefore bound to fall short of completeness unless means can be found to separate the various components of the mixture of pectin as obtained by extraction.

It is anticipated that the results of this investigation should throw some light on certain difficulties met with in the making of some fruit jellies and indicate means of overcoming them.

A common source of trouble occurring in the making of some of these jelly products is the formation of bubbles in the jelly, which remain in the solidified product, thus detracting from its appearance. Premature setting of the jelly, *i.e.*, setting before it is filled out, is a frequent source of trouble not only in making jellies but also in the manufacture of jams. This premature set results in a curdled appearance of the product giving it a soft, unsatisfactory consistency. From the results already obtained in this investigation a means of curing the latter trouble can now be suggested. Some of these difficulties are characteristic of the extracts of certain fruits. Consequently, purified pectins are being prepared from these fruits and their chemical and physical properties are being studied with a view to finding an explanation and a remedy.

Starch

The foundational investigation of the various types of commercial starches on the market has not progressed so far as those referred to above, but some unexpected differences in the properties of these products have already been noted. Starch, like pectin, is a complex substance and its properties vary according to its source, and no doubt also according to the method of preparation. With regard to jellifying properties, for example, it has been found that starch from one source has double the jellifying power of that from another. It is obvious that a knowledge of these differences should enable a manufacturer to select the type which will give him the best result. As starch is used in the factory for a variety of purposes it is necessary to investigate its properties other than merely that of its jellifying power. This further investigation is now in hand.

Boiled Goods

Two reports on this subject were issued some time ago and two further reports during the past year. These goods are always liable to suffer from damp as the sugars of which they are mainly composed absorb moisture from relatively dry atmospheres. The moisture thus absorbed at first produces a sticky surface as the result of the dissolving of the sugar in the moisture. After a time the sugar so dissolved tends to crystallize out again, producing a soft grained surface. This graining then continues to penetrate the sweet until in time the whole of it is in this condition. In some cases where there is a high proportion of invert sugar or glucose the sweets become sticky at first, but no graining occurs. If left in a damp atmosphere unduly long, they will soften down to a treacly mass. The reports show how the composition of the sweets influences

not only the absorption of the moisture but their subsequent behaviour. They also indicate the steps which should be taken to control these actions as far as it is possible for the manufacturer to do so. Methods of packing are described which should enable the manufacturer to place sound goods in the retailers' hands, but unless the latter takes all the necessary precautions to protect the goods from damp in the shop even the most carefully made products will develop defects.

The introduction of waterproof wrapping materials has helped both manufacturer and distributor in this respect, but these wrapping materials are not all equally waterproof, as has been shown in work recently carried out by the Association. Even when the material has the highest waterproof qualities, there is still the difficulty of hermetically sealing the joints. Unless this is carefully done, moisture will eventually penetrate through the folds of the wrapper, producing the inevitable stickiness.

Another trouble associated with this type of sweet is that due to heat. In a heated atmosphere, such as that of a shop window lighted by gas or exposed to direct sunshine, these goods may soften and coalesce into a lump which becomes hard on cooling, making it difficult to separate the individual pieces. The ease with which this occurs is to some extent dependent on the composition of the article. The report suggests certain modifications of the composition where this is possible or desirable, *e.g.*, in goods for export to hot climates.

Acid Taste

The introduction of an acid flavour into confectionery sometimes leads to difficulties in manufacture. The subject has therefore been studied, and methods of overcoming these difficulties have been described in a report recently issued to the members of the Association.

Other Investigations

Several investigations are nearing completion and reports will shortly be issued. Two of these deal with the manufacture of toffees, and the viscosity of chocolate, its determination in the laboratory and in the factory. The influence of the various manufacturing operations on viscosity has also been dealt with and will be presented in a later report.

A number of other subjects are being dealt with, but the work is not yet sufficiently advanced to warrant the issue of reports. Among these may be mentioned a very important entomological investigation into the sources of insect damage to raw materials. Most raw materials used in the food manufacturing industries, *e.g.*, rice, wheat, and other cereals, also nuts and cocoa beans which are imported from abroad, are liable to be attacked by insects. It is

suspected that much, if not most, of this infestation occurs in the exporting countries; consequently, samples of these raw materials are being taken for examination at the plantations and at successive stages on the journey from there to this country. The help of the Directors of Agriculture overseas is being enlisted with a view to the development of preventive measures.

British Food Manufacturers' Research Association

(Licensed on 7th January, 1926)

In last year's Annual Report reference was made to an apparatus which the staff of this Association had devised for the purpose of determining the percentage of salt in cured meats. This apparatus has now been subjected to a thorough test conducted in conjunction with the Low Temperature Research Station, Cambridge, the work being carried out in connection with an investigation into the dry salt and tank curing of bacon. Papers giving the results of this work will shortly be published. These will illustrate the value of the apparatus in the study of problems in the curing of meat.

During the past year experiments have been carried out on similar lines with another type of apparatus, which offers very considerable advantages over the original, especially when it is used for factory control purposes. This newer apparatus makes use of an instrument which is already on the market, but is designed for other purposes. With some slight modifications, however, it can be made to suit this purpose. In its modified form it will be possible to read the percentages of salt direct from an indicator, the test taking merely a matter of a few minutes. As the reading can be taken by an intelligent workman, and as the apparatus is readily portable, it should prove most useful in controlling curing under factory conditions. It is believed that a modification of this instrument will have other uses, *e.g.*, it has already been found possible to determine the thickness of the fatty layers in bacon or pork. Carcases can be graded in this respect by its use.

Sterilization Problems

A report was issued during the past year giving the results of a lengthy investigation into the rate of penetration of heat into packages of various sizes and containing a variety of products. The information conveyed in this report has already proved most helpful to many of the members.

A new process of pressure sterilization has been tried out both on the laboratory and factory scales and appears to offer definite advantages over the usual process as carried out in this country. Some further work is necessary, however, before the process will be finally recommendated to members. In particular it is necessary

to test it from an economical point of view, and for this purpose measurements of steam consumption during processing must be made. Arrangements are being made to carry out these tests in a thorough manner.

Some other problems connected with sterilization have also been dealt with, and the investigation of the nature and extent of the bacterial contamination of raw meats, which has been completed, should prove of great value to the packers of cooked meat products.

Salt Tolerance of Bacteria

Work on this subject has been continued, and interesting results of importance to the curer have been accumulated. As was already known, there is a wide variation in the percentages of salt required to inhibit the growth of the various bacteria. Fortunately, some of the most objectionable forms appear to be the most easily suppressed.

The Printing Industry Research Association

(*Licensed on 21st November*, 1930)

Reference was made in last year's report to the investigation directed towards eliminating the warping of book covers, calendars, fancy boxes, showcards, etc., which consist of cloth or paper mounted on to "cardboard." Work on this topic has been continued and the causes of the warping, which were found to be more complex than was originally anticipated, have been established. The board itself is liable to distortion due to the cellulosic fibres absorbing water from the adhesives used in mounting, with a consequent swelling and re-orientation. For the same reason, cloth and paper expand on application of the adhesive and subsequently contract on drying out with the result that the board is subjected to stress. The magnitude of the stresses depends not only on the quality of the cloth or paper being mounted, but also on the relative humidities at the times of mounting and use. The extent of warping produced by these stresses is dependent upon the rigidity of the board which in turn is affected by its moisture content. A further factor in the warping is that stresses are set up by the contractions of the adhesive layer itself. It is impracticable to modify the properties of the board, cloth and paper to eliminate the warping and the most suitable means available is to use non-aqueous adhesives in the place of the customary glue or paste. A series of adhesives of this type have been developed and their use completely eliminates warping providing the articles are used under normal conditions. The adhesives are now undergoing tests in members' works to determine what modifications, if any, are necessary in order that they may be

used successfully in existing machines. Although non-aqueous adhesives are more expensive than those previously used, yet the additional cost of the finished article should be slight, since only a small fraction of the cost of the article is represented by the adhesive.

The Association in conjunction with the printing ink and paper making industries is undertaking a survey of the factors governing set-off with a view to an attack being made on what is perhaps the most serious source of waste in the industry.

British Colliery Owners Research Association

(Licensed on 29th December, 1924)

The investigations in connection with the occurrence of silicosis among underground workers in coal mines mentioned in the previous report have been continued. Tests have been carried out underground at a number of collieries in various parts of the country to ascertain the quantity and composition of the dust suspended in the air, but the accumulation of the required data is of necessity a slow process owing to the time taken to collect sufficient dust for analysis and for microscopical examination.

Some time has been devoted to investigating the possibility of further reducing dust production during wet drilling operations by means of various "wetting" agents. Whilst anomalous results were sometimes obtained the investigations indicate that the use of a small quantity of certain reagents causes more effective wetting of the fine dust particles which are not wetted by water alone and reduces the dust production.

During the period under review conferences between representatives of the Association and officials of the Medical Research Council and other interested bodies have been held with a view to co-ordinating the work which is being done in investigating the subject of silicosis.

The work in connection with underground illumination referred to in the previous report has been continued by the Birmingham Executive Board of Mining Research, the investigations being mainly concerned with the collection of additional data concerning the illumination given by the latest form of high candle power lamps.

Some work has also been carried out in designing an apparatus for the purpose of testing the degree to which light is cut off by air containing dust in varying concentrations and the difference in this respect between shale and coal dust. With this apparatus it is proposed to examine the possible advantage of the use of a yellow monochromatic light for underground operations.

Meetings have been held at the instance of the Department of

Scientific and Industrial Research with representatives of other bodies engaged in research into illumination problems so that the work of the Association may be linked up so far as necessary with that of the other bodies and thus prevent any overlapping.

Some considerable amount of work has been done at Birmingham with the object of evolving a cheap industrial method for the production of a gaseous fuel of high calorific value, suitable for carrying in compressed form on buses and possibly other forms of motor transport in place of petrol. Since the cost of compression is one of the chief items of expenditure in the application of coal gas for this purpose and since methane has approximately double the calorific value of the customary municipal gas supply it is clear that a practical method for the production of this gas or its concentration from coal gas should be of very great value. By the use of almost pure methane not only would the cost of compression be halved but of almost greater importance is the fact that for the same volume of gas stored in the cylinders double the mileage could be obtained. The work has included *inter alia* the investigation of methods for the concentration of methane from coal or coke oven gas by preferential absorption and other means and also the investigation of the feasibility of increasing the storage capacity of a cylinder by the use of an absorbent material.

APPENDIX I

LIST OF ASSESSORS TO THE ADVISORY COUNCIL AND OF MEMBERS OF RESEARCH BOARDS AND COMMITTEES OF THE DEPARTMENT

Throughout this list [1] *against members' names shows that they retired and* [2] *that they were appointed during the period of this report.*

Assessors to the Advisory Council

Department	*Assessor*
Admiralty.	Third Sea Lord: [1]Vice-Admiral C. M. Forbes, C.B., D.S.O.; [2]Vice-Admiral R. G. H. Henderson, C.B.
	Director of Scientific Research: [1]C. V. Drysdale, Esq., C.B., O.B.E., D.Sc., M.I.E.E., F.R.S.E.; [2]C. S. Wright, Esq., O.B.E., M.C.
Ministry of Agriculture and Fisheries.	H. E. Dale, Esq., C.B.
Agricultural Research Council.	Sir William C. D. Dampier, Sc.D., F.R.S.
Air Ministry.	Air-Marshal Sir H. C. T. Dowding, K.C.B., C.M.G. H. E. Wimperis, Esq., C.B.E., F.R.Ae.S., M.I.E.E.
Colonial Office.	Sir John E. Shuckburgh, K.C.M.G., C.B.
Development Commission.	Sir T. H. Middleton, K.C.I.E., K.B.E., C.B., LL.D.
Dominions Office.	Sir G. G. Whiskard, K.C.M.G., C.B.
Board of Education.	W. C. Eaton, Esq., C.B.
Scottish Education Department.	W. W. McKechnie, Esq., C.B.
Ministry of Health.	H. A. de Montmorency, Esq., O.B.E.
Home Office.	R. R. Bannatyne, Esq., C.B.
India Office.	Sir Louis J. Kershaw, K.C.S.I., C.I.E.
Medical Research Council.	E. Mellanby, Esq., M.D., F.R.C.P., F.R.S.
Post Office.	Lieut.-Colonel A. G. Lee, O.B.E., M.C., M.I.E.E.
Scottish Office.	P. J. Rose, Esq., C.B.
Board of Trade.	W. Palmer, Esq.
Board of Trade, Mines Department.	H. W. Cole, Esq., C.B.E.
Department of Overseas Trade.	C. E. G. House, Esq., M.B.E.
Ministry of Transport.	Sir C. W. Hurcomb, K.B.E., C.B.
University Grants Committee.	J. Beresford, Esq.
War Office.	Master-General of the Ordnance: [1]Lieut.-Gen. Sir J. R. E. Charles, K.C.B., C.M.G., D.S.O.; [2]Lieut.-Gen. Sir Hugh J. Elles, K.C.M.G., K.C.V.O., C.B., D.S.O.
H.M. Office of Works.	W. Leitch, Esq., C.B.

Building Research Board

Chairman: Sir Raymond Unwin, D.Tech., F.R.I.B.A.

[1]Sir Richard Allison, C.V.O., C.B.E., F.R.I.B.A. (H.M. Office of Works).
G. M. Burt, Esq., F.I.O.B.
Sir Clement D. M. Hindley, K.C.I.E., M.Inst.C.E., M.Inst.T., M.I.E.(Ind.).
B. L. Hurst, Esq., M.Inst.C.E., M.I.Mech.E.
A. E. Munby, Esq., F.R.I.B.A.
Sir Leopold H. Savile, K.C.B., M.Inst.C.E., A.I.N.A.
[2]G. B. Sharples, Esq., O.B.E., M.Inst.C.E.
C. J. Trollope, Esq., F.I.O.B.

Director of Building Research: R. E. Stradling, Esq., C.B., M.C., D.Sc., Ph.D., M.Inst.C.E.

Assessors:

[2]Colonel R. A. Boger (War Office).
[2]H. A. Lewis Dale, Esq., M.B.E., M.Inst.C.E., M.I.Mech.E. (Air Ministry).
[2]O. A. G. St. John Kneller, Esq., M.Inst.C.E. (Admiralty).
[2]R. G. Hetherington, Esq., C.B., O.B.E., M.Inst.C.E. } (Ministry of Health).
A. Scott, Esq., M.B.E., F.R.I.B.A., M.I.Struct.E. }
[2]H. Ryle, Esq., M.V.O., O.B.E., F.S.I., A.R.I.B.A. } (H.M. Office of Works).
[2]J. G. West, Esq., O.B.E. }
John Wilson, Esq., F.R.I.B.A., F.R.S.E. (Department of Health for Scotland).

Reinforced Concrete Structures Committee*

Chairman: Sir George Humphreys, K.B.E., M.Inst.C.E.

B. L. Hurst, Esq., M.Inst.C.E., M.I.Mech.E.
D. Anderson, Esq., M.Inst.C.E. } (Nominated by the Institution of Civil Engineers).
Oscar Faber, Esq., O.B.E., D.Sc., M.Inst.C.E., A.M.I.E.E., M.I.Struct.E. }
O. M. Ayrton, Esq., F.R.I.B.A. } (Nominated by the Royal Institute of British Architects).
A. Alban H. Scott, Esq., F.R.I.B.A. }
A. Burnett Brown, Esq., F.S.I., F.R.I.B.A. } (Nominated by the Chartered Surveyors' Institute).
O. Healing, Esq., F.S.I. }
L. Roseveare, Esq., O.B.E., M.Inst.C.E. } (Nominated by the Institution of Municipal and County Engineers).
A. S. Parsons, Esq., M.Inst.C.E. }
R. H. H. Stanger, Esq., F.C.S., A.M.Inst.C.E., A.M.I.Mech.E., M.I.Struct.E. } (Nominated by the Institution of Structural Engineers).
E. S. Andrews, Esq., M.Inst.C.E., M.I.Struct.E. }
R. E. Holloway, Esq., F.I.O.B. } (Nominated by the Institute of Builders).
E. Burt, Esq., F.I.O.B. }
H. C. Ritchie, Esq., M.Inst.C.E., M.Inst.W.E. (Nominated by the Institution of Water Engineers).
J. E. Swindlehurst, Esq., A.M.Inst.C.E., M.I.Struct.E. (Nominated by the Incorporated Association of Architects and Surveyors).
H. E. Steinberg, Esq., M.Inst.C.E. (Nominated by the Reinforced Concrete Association, Ltd.).

* Dissolved on completion of its work in 1933.

Standing Chemical and Weathering Committee

Chairman: Sir Herbert Jackson, K.B.E., F.R.S., F.I.C.

Sir Richard Allison, C.V.O., C.B.E., F.R.I.B.A. (H.M. Office of Works).
M. P. Applebey, Esq.
C. H. Desch, Esq., D.Sc., F.R.S., F.I.C.
J. J. Fox, Esq., O.B.E., D.Sc., F.I.C. (Government Chemist's Department).
A. W. Heasman, Esq., M.V.O., O.B.E. (H.M. Office of Works).
J. A. Howe, Esq., O.B.E.
A. E. Munby, Esq., F.R.I.B.A.
W. F. P. McLintock, Esq., D.Sc.
H. G. Thornton, Esq., D.Sc.

Structures Investigation Committee

Chairman: Professor C. F. Jenkin, C.B.E., LL.D., F.R.S., M.Inst.C.E.

Oscar Faber, Esq., O.B.E., D.Sc., M.Inst.C.E., A.M.I.E.E.
Professor A. J. S. Pippard, M.B.E., D.Sc., M.Inst.C.E., M.I.Mech.E., F.R.Ae.S.
Professor A. Robertson, D.Sc., M.Inst.C.E., M.I.Mech.E.
Professor W. N. Thomas, D.Phil., A.M.Inst.C.E., A.M.I.Mech.E.

Standing Committee on Heating and Ventilation

(*Joint Committee of the Building Research Board and the Fuel Research Board*)

Chairman: J. A. Macintyre, Esq., O.B.E., M.Inst.C.E.

C. G. Douglas, Esq., C.M.G., M.C., D.M., F.R.S.
A. C. G. Egerton, Esq., F.R.S.
Margaret Fishenden, D.Sc., F.Inst.P.
Ezer Griffiths, Esq., D.Sc., F.R.S.
W. W. Nobbs, Esq., M.I.Mech.E., M.I.H.V.E. } (Institution of Heating and
J. R. Preston, Esq., M.I.Mech.E., M.I.H.V.E. } Ventilating Engineers).
C. W. Price, Esq. (Home Office).
A. Scott, Esq., M.B.E., F.R.I.B.A., M.I. Struct.E. (Ministry of Health).
F. S. Sinnatt, Esq., M.B.E., D.Sc., M.I.Min.E., F.I.C.
B. H. Wilsdon, Esq.

Joint Committee with the Medical Research Council on Research in Heating and Ventilation

Chairman: C. G. Douglas, Esq., C.M.G., M.C., D.M., F.R.S.

R. B. Bourdillon, Esq., M.C., M.B. }
Professor A. V. Hill, F.R.S. } (Medical Research Council).
A. C. G. Egerton, Esq., F.R.S.
Margaret Fishenden, D.Sc., F.Inst.P.
Ezer Griffiths, Esq., D.Sc., F.R.S.
B. H. Wilsdon, Esq.

Joint Committee of the Executive Committee of the National Physical Laboratory and the Building Research Board on Architectural Acoustics

(*For membership, see page* 148).

Committee on Testing Work for the Building Industry

Chairman: Sir Raymond Unwin, D.Tech., F.R.I.B.A. (Building Research Board).

Lieut.-Col. E. Kitson Clark, T.D., M.Inst.C.E., M.I.Mech.E. (Institution of Mechanical Engineers).
Sir Christopher Clayton, C.B.E., Ph.D., J.P., M.P. (Institute of Chemistry of Great Britain and Ireland).
[1]Sir Murdoch Macdonald, K.C.M.G., C.B., M.Inst.C.E., M.P.
[2]Brig.-Gen. Sir Henry P. Maybury, G.B.E., K.C.M.G., C.B., R.E., M.Inst.C.E., J.P.
[1]Major E. C. P. Monson, F.R.I.B.A., F.S.I., M.I.Struct. E. (Institution of Structural Engineers).
A. E. Munby, Esq., F.R.I.B.A. (Royal Institute of British Architects).
[2]Major A. H. S. Waters, V.C., D.S.O., M.C., M.Inst.C.E., M.I.Mech.E., M.I.Struct.E.

Chemistry Research Board

Chairman: N. V. Sidgwick, Esq., O.B.E., Sc.D., F.R.S.

[1]C. Carpenter, Esq., C.B.E., D.Sc.
[1]Professor Sir H. C. Harold Carpenter, Ph.D., F.R.S.
[2]E. V. Evans, Esq., O.B.E.
Professor I. M. Heilbron, D.Sc., F.R.S.
Professor H. Raistrick D.Sc.
W. Rintoul, Esq., O.B.E., F.I.C.
J. D. Pratt, Esq., O.B.E., F.I.C.
Sir Robert Robertson, K.B.E., D.Sc., LL.D., F.R.S.
H. T. Tizard, Esq., C.B., F.R.S.

Assessors:

[1]C. V. Drysdale, Esq., C.B., O.B.E., D.Sc., M.I.E.E., F.R.S.E. (Admiralty).
[2]C. S. Wright, Esq., O.B.E., M.C. (Admiralty).
D. R. Pye, Esq., F.R.Ae.S. (Air Ministry).
G. Rotter, Esq., C.B.E., D.Sc., F.I.C., F.Inst.P. (War Office).
Director of Chemical Research: Professor G. T. Morgan, O.B.E., D.Sc., F.R.S., F.I.C.

Corrosion of Metals Research Committee

Chairman: Professor Sir H. C. Harold Carpenter, Ph.D., F.R.S.

F. P. Bowden, Esq., Ph.D.
Professor Sir William H. Bragg, O.M., K.B.E., D.Sc., F.R.S.
C. H. Desch, Esq., D.Sc., F.R.S., F.I.C.
J. J. Fox, Esq., O.B.E., D.Sc., F.I.C.
R. H. Greaves, Esq., M.B.E., D.Sc., F.I.C.
H. Moore, Esq., C.B.E., D.Sc., Ph.D., F.I.C., F.Inst.P.
Professor J. R. Partington, M.B.E., D.Sc.

Food Investigation Board

(This Board was reconstituted on a different basis after the conclusion of the period of the report, but in accordance with policy adopted during the period. For convenience of reference the new Board is given below, and the members of the Board during the period of the report are shown by an asterisk.)

Chairman: Sir Frank E. Smith, K.C.B., C.B.E., D.Sc., LL.D., Sec.R.S.

A. I. Anderson, Esq.
*F. F. Blackman, Esq., D.Sc., F.R.S.
*Sir Joseph G. Broodbank.
*†Sir J. Alfred Ewing, K.C.B., D.Sc., Sc.D., LL.D., F.R.S., M.Inst.C.E.
Professor W. N. Haworth, D.Sc., Ph.D., F.R.S.
*Professor T. P. Hilditch, D.Sc.
L. H. Lampitt, Esq., D.Sc., F.I.C.
*E. Mellanby, Esq., M.D., F.R.C.P., F.R.S.
Professor H. Raistrick, D.Sc., F.R.S.
F. A. Stockdale, Esq., C.M.G., C.B.E. (Colonial Office).
F. L. McDougall, Esq., C.M.G. (Representing the High Commissioner for Australia).
N. L. Wright, Esq., F.I.C. (Representing the High Commissioner for New Zealand).
F. J. du Toit, Esq. (Representing the High Commissioner for the Union of South Africa).
B. F. Wright, Esq. (Representing the High Commissioner for Southern Rhodesia).

Assessors:

J. C. Dawes, Esq., O.B.E. (Ministry of Health).
J. W. Dulanty, Esq., C.B., C.B.E. (Irish Free State).
Sir Robert B. Greig, M.C., D.Sc., LL.D. (Board of Agriculture for Scotland).
J. M. Hamill, Esq., O.B.E., M.D., D.Sc. (Ministry of Health).
G. Hogarth, Esq. (Fishery Board for Scotland).
H. G. Maurice, Esq., C.B. (Ministry of Agriculture and Fisheries).
Sir T. H. Middleton, K.C.I.E., K.B.E., C.B., LL.D. (Agricultural Research Council).
G. Scott Robertson, Esq., D.Sc., F.I.C. (Government of Northern Ireland).
Colonel R. T. Snowden-Smith, C.B.E., M.I.Mech.E. (War Office).
Y. N. Sukthankar, I.C.S. (India).
V. E. Wilkins, Esq., M.B.E., Ph.D. (Ministry of Agriculture and Fisheries).
W. A. Wilson, Esq. (Dominion of Canada).

Director of Food Investigation : E. Barnard, Esq., D.S.O.

Committee of Management, Low Temperature Station for Research in Biochemistry and Biophysics, Cambridge

Chairman: Sir William C. D. Dampier, Sc.D., F.R.S.

F. F. Blackman, Esq., D.Sc., F.R.S.
Sir Joseph G. Broodbank.
Professor A. V. Hill, O.B.E., Sc.D., LL.D., F.R.S.
Professor Sir Frederick G. Hopkins, D.Sc., LL.D., F.R.C.P., P.R.S.
C. G. Lamb, Esq., D.Sc.
Professor E. H. Lamb, D.S.C., D.Sc., A.M.Inst.C.E., M.I.Mech.E.
E. J. Maskell, Esq., Ph.D.
P. J. Wheeldon, Esq., O.B.E.

† Died 7th January, 1935.

Engineering Committee

Chairman: *Sir J. Alfred Ewing, K.C.B., D.Sc., Sc.D., LL.D., F.R.S., M.Inst.C.E.

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† Dissolved, April, 1934.

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Professor C. S. Gibson, O.B.E., Sc.D., F.R.S.
Professor T. M. Lowry, C.B.E., F.R.S.
E. L. Sheridan, Esq., F.R.C.S.I., L.D.S.I.

Electro-deposition Committee

Chairman:

W. R. Barclay, Esq., O.B.E. (British Non-Ferrous Metals Research Association).
R. H. Greaves, Esq., M.B.E., D.Sc., F.I.C. (War Office).
[2]Engineer Commander D. G. Hoare, R.N. (Admiralty).
Professor R. S. Hutton, D.Sc.
Engineer Commander The Hon. D. C. Maxwell, R.N. (Admiralty).
H. Moore, Esq., C.B.E., D.Sc., Ph.D., F.I.C., F.Inst.P. (British Non-Ferrous Metals Research Association).
D. R. Pye Esq., F.R.Ae.S. (Air Ministry).

Fabrics Research Committee†

Chairman: R. H. Pickard, Esq., D.Sc., F.R.S.
(British Cotton Industry Research Association.)

S. G. Barker Esq., D.I.C., F.Inst.P. (Wool Industries Research Association).
G. Barr, Esq., D.Sc.
W. S. Denham, Esq., D.Sc., F.I.C. (British Silk Research Association).
W. H. Gibson, Esq., O.B.E., D.Sc. (Linen Industry Research Association).
‡Colonel L. L. Hoare, D.S.O. (War Office).
R. G. Parker, Esq., F.I.C.
B. D. Porritt, Esq., M.Sc., F.I.C., F.R.S.E. (British Rubber Manufacturers' Research Association).
G. Rotter, Esq., C.B.E., D.Sc., F.I.C., F.Inst.P. (War Office).
Director of Scientific Research, Admiralty.
Director of Scientific Research, Air Ministry.

* Appointed Chairman 1st April, 1934, on retirement of G. C. Simpson, Esq., C.B., C.B.E., D.Sc., LL.D., F.R.S.

† Dissolved, February, 1934.

‡ *Ex-officio* as Chairman of the Technical Co-ordinating Committee on Textiles and Clothing.

Illumination Research Committee

Chairman: C. C. Paterson, Esq., O.B.E., M.Inst.C.E., M.I.E.E.

*Sir Frank Baines, K.C.V.O., C.B.E.
J. S. Dow, Esq.
B. P. Dudding, Esq.
[2]C. W. Glover, Esq., A. M.Inst.C.E., M.I.Struct.E., L.R.I.B.A.
Professor H. Hartridge, M.D., Sc.D., F.R.S. (Medical Research Council).
A. E. Munby, Esq., F.R.I.B.A.
Sir J. Herbert Parsons, C.B.E., D.Sc., F.R.S., F.R.C.S. (Medical Research Council).
G. Smith, Esq., M.B.E. (H.M. Office of Works).
J. S. G. Thomas, Esq., D.Sc.
D. R. Wilson, Esq., C.B.E. (Home Office).

Lubrication Research Committee

Chairman: H. T. Tizard, Esq., C.B., F.R.S.

A. C. G. Egerton, Esq., F.R.S.
Professor G. I. Taylor, M.C., F.R.S.
D. R. Pye, Esq., F.R.Ae.S.

Road Tar Research Committee

Chairman: Sir Robert Robertson, K.B.E., D.Sc., LL.D., F.R.S.

W. G. Adam, Esq.
Major F. C. Cook, D.S.O., M.C., M.Inst.C.E. (Ministry of Transport).
H. J. Gough, Esq., M.B.E., D.Sc., Ph.D., F.R.S.
W. J. Hadfield, Esq., C.B.E., M.Inst.C.E.
G. A. Hebden, Esq., M.I.Chem.E., F.C.S.
H. W. James, Esq.
J. C. Mann, Esq.
Professor G. T. Morgan, O.B.E., D.Sc., F.R.S., F.I.C.
F. S. Sinnatt, Esq., M.B.E., D.Sc., M.I.Min.E., F.I.C.
R. E. Stradling, Esq., C.B., M.C., D.Sc., Ph.D., M.Inst.C.E.
A. C. Tait, Esq.

* Died 25th December, 1933.

Steel Structures Research Committee

Chairman: Sir Clement D. M. Hindley, K.C.I.E., M.Inst.C.E., M.Inst.T., M.I.E. (Ind).

Commander W. R. Gilbert, R.N.
J. H. Humphryes, Esq., M.I.Struct.E.
J. E. James, Esq.
C. J. Kavanagh, Esq., O.B.E.
[2]J. S. Lewis, Esq., M.I.Struct.E., M.I.E. (Ind.).
J. D. Stitt, Esq., M.I.Struct.E.
(Nominated by the British Steelwork Association).

D. Anderson, Esq., M.Inst.C.E.
R. Freeman, Esq., M.Inst.C.E.
B. L. Hurst, Esq., M.Inst.C.E., M.I.Mech.E.
(Nominated by the Institution of Civil Engineers).

E. S. Andrews, Esq., M.Inst.C.E., M.I.Struct.E.
Professor C. Batho, D.Sc., M.Inst.C.E., M.I.Struct.E.
Professor Sir H. C. Harold Carpenter, Ph.D., F.R.S.
Oscar Faber, Esq., O.B.E., D.Sc., M.Inst.C.E., A.M.I.E.E.
G. Topham Forrest, Esq., F.R.I.B.A., F.R.S.E., F.G.S.
C. Gribble, Esq., M.Inst.C.E.
Professor C. E. Inglis, O.B.E., F.R.S., M.Inst.C.E.
Professor A. J. S. Pippard, M.B.E., D.Sc., M.Inst.C.E., M.I.Mech.E., F.R.Ae.S.
Professor A. Robertson, D.Sc., M.Inst.C.E., M.I.Mech.E.

Committee on the Application of X-Ray Methods to Industrial Research

Chairman: Professor Sir William H. Bragg, O.M., K.B.E., D.Sc., F.R.S.

Professor Sir H. C. Harold Carpenter, Ph.D., F.R.S.
A. P. M. Fleming, Esq.
W. H. Hatfield, Esq., D.Sc.
W. Rintoul, Esq., O.B.E., F.I.C.
Professor R. Robinson, D.Sc., F.R.S.
Professor G. I. Taylor, M.C., F.R.S.

Radium Beam Therapy Research Board

(*A Research Board of the Medical Research Council and the Department of Scientific and Industrial Research jointly.*)

Sir Frederick G. Hopkins, D.Sc., M.B., P.R.S.
(*Chairman,* nominated by the Royal Society).

Lord Dawson of Penn, G.C.V.O., K.C.B., K.C.M.G., M.D., P.R.C.P.
(*Vice-Chairman,* nominated by the Royal College of Physicians of London).

Sir Holburt Waring, C.B.E., M.S., P.R.C.S.
(*Vice-Chairman,* nominated by the Royal College of Surgeons of England).

Wilfred Trotter, Esq., M.S., F.R.C.S., F.R.S.
(Nominated by the Medical Research Council).

Lord Rutherford of Nelson, O.M., D.Sc., LL.D., F.R.S.
(Nominated by the Department of Scientific and Industrial Research).

Professor A. J. Hall, M.D., D.Sc., F.R.C.P.
(Nominated by the National Radium Commission).

Sir George Blacker, C.B.E., M.D., F.R.C.P., F.R.C.S.
(Nominated by the Radium Institute, London).

Professor J. C. McLennan, LL.D., F.R.S.

Sir Cuthbert S. Wallace, K.C.M.G., C.B., M.B., B.S., F.R.C.S., J.P.

APPENDIX II

ESTABLISHMENTS OF THE DEPARTMENT

Establishment.	Address.	Telephone No.	Telegraphic Address.
HEADQUARTERS OFFICE	16, Old Queen Street, S.W.1 ..	Whitehall 1632 ..	Resciendus, Parl., London.
NATIONAL PHYSICAL LABORATORY	Teddington, Middlesex	Molesey 1380	Physics, Teddington.
Radio Research Station ..	Slough, Bucks	Slough 380, Extn. 29 ..	—
Taximeter Testing Sub-Station	China Walk, Lambeth Road, S.E.11	Reliance 2171	—
GEOLOGICAL SURVEY AND MUSEUM:			
Head Office and Museum ..	Exhibition Road, South Kensington, S.W.7	Kensington 5227 ..	—
Northumberland and Durham District	Clarendon House, Clayton Street West, Newcastle-on-Tyne 1	Newcastle-on-Tyne 27815	—
Lancashire District	270, Oxford Road, Manchester 13 ..	Ardwick 1598	—
Yorkshire District	32, St. Mary's York	York 2644	—
Scotland	"Southpark," 19, Grange Terrace, Edinburgh 9	Edinburgh 42726 ..	—
BUILDING RESEARCH STATION ..	Bucknalls Lane, Garston, near Watford, Herts.	Garston 149	Research, Phone, Watford.
CHEMICAL RESEARCH LABORATORY	Coleshill Road, Teddington, Middlesex	Molesey 1380	Chemistry, Teddington.
FOOD INVESTIGATION:			
Low Temperature Research Station.	Downing Street, Cambridge ..	Cambridge 2400 ..	Lowtemp., Cambridge.
Covent Garden Laboratory ..	"The Cottage," Dudley House, Endell Street, W.C.2	Temple Bar 6600, Extn 41	—
Torry Research Station ..	Aberdeen	Aberdeen 1269	Resciendus, Aberdeen.
Ditton Laboratory	East Malling, Maidstone, Kent ..	Aylesford 7256	Resciendus, East Malling.
FOREST PRODUCTS RESEARCH LABORATORY	Princes Risborough, Aylesbury, Bucks	Princes Risborough 101	Timberlab, Princes Risborough.

FUEL RESEARCH:			
Fuel Research Station ..	River Way, Blackwall Lane, E. Greenwich, S.E.10	Greenwich 1220	—
Coal Survey Laboratories—			
Scotland	Royal Technical College, Glasgow	Bell 1811	—
Northumberland and Durham Area	Armstrong College, Newcastle-on-Tyne 2	Newcastle 26851 ..	—
Cumberland Area			
West Yorkshire Area ..	The University, Leeds	Leeds 22188	—
South Yorkshire Area ..	Portobello Street, Sheffield 1 ..	Sheffield 22480 ..	—
Nottinghamshire and Derbyshire Area	16–18, Shakespeare Street, Nottingham	Nottingham 41425 ..	—
North Staffordshire Area ..	N. Staffs. Technical College, Stoke-on-Trent	Hanley 4664	—
Warwickshire, Cannock Chase and South Staffordshire Area	St. Martin's St., Edgbaston, Birmingham	Midland 0596	—
Forest of Dean Area			
South Wales Area	School of Mines, Treforest	Pontypridd 26	—
ROAD RESEARCH LABORATORY ..	Harmondsworth. West Drayton, Middlesex	Colnbrook, 104	—
WATER POLLUTION RESEARCH—			
Mersey Laboratory	Dock Office, Liverpool	Bank 548	—

APPENDIX III

LIST OF EXISTING RESEARCH ASSOCIATIONS IN ORDER OF FORMATION

(The numbers in brackets against certain entries in column (6) refer to the explanatory notes printed on page 159).

Name. (1)	Address. (2)	Director and Secretary. (3)	Commencement of grant earning period. (4)	Number of completed years of work (at 31st July, 1934). (5)	Grant paid— (a) In respect of last completed year. (b) In respect of period given in col. (5). (6)
					£
British Scientific Instrument Research Association.	*Offices and Laboratories:* 26, Russell Square, London, W.C.1. *Tel. No.:* Museum 2656.	Harry Moore, Esq., D.Sc., A.R.C.Sc., F.Inst.P. J. W. Williamson, Esq., B.Sc.	1st July, 1918	16	(a) 7,002 (b) 137,846
Wool Industries Research Association	*Offices and Laboratories:* "Torridon," Headingley, Leeds. *Tel. No.:* Leeds 51047.	— A. Frobisher, Esq., B.Sc., F.S.S.	1st Oct., 1918	15	(a) 5,000 (b) 87,143
British Boot, Shoe and Allied Trades' Research Association.	*Offices and Laboratories:* 19, Bedford Square, London, W.C.1. *Tel. No.:* Museum 3945.	*Director and Secretary:* H. Bradley, Esq., B.Sc., D.I.C., A.R.C.Sc.	1st Jan., 1919	15	(a) 1,200 (b) 13,063
British Cotton Industry Research Association	*Offices and Laboratories:* Shirley Institute, Didsbury, Manchester. *Tel. No.:* Didsbury 2401.	R. H. Pickard, Esq., D.Sc., F.R.S. C. Packer, Esq.	1st July, 1919	15	(a) 9,750 (b) 155,790
Ditto (Rayon Dept.) ...	—	—	1st July, 1928	6	(a) 1,012 (b) 10,332

Linen Industry Research Association	*Offices and Laboratories:* The Research Institute, Lambeg, Co. Antrim, N. Ireland. *Tel. No.:* Lisburn 77.	W. H. Gibson, Esq., O.B.E., D.Sc., F.I.C., F.Inst.P. Miss E. W. Hill, F.I.S.A.	1st Oct., 1919	14	(*a*) 1,372 (*b*) 67,166
Research Association of British Rubber Manufacturers	*Offices and Laboratories:* 105/7, Lansdowne Road, Croydon. *Tel. No.:* Croydon 2305.	B. D. Porritt, Esq., M.Sc., F.I.C., F.R.S.E. Miss C. Henderson.	1st Jan., 1920	14	(*a*) 4,103 (1) (*b*) 40,456
British Association of Research for Cocoa, Chocolate, Sugar Confectionery and Jam Trades.	*Offices:* 22, Buckingham Gate, London, S.W.1. *Tel. No.:* Victoria 5729 *Laboratories:* 2 and 4, Dalmeny Avenue, Holloway, London, N. 7. *Tel. No.:* North 1048.	T. Macara, Esq., F.I.C., F.C.S. R. M. Leonard, Esq.	1st Oct., 1919	14	(*a*) 1,270 (*b*) 29,862
British Non-Ferrous Metals Research Association.	*Offices and Laboratories:* Regnart Buildings, Euston Street, London, N.W.1. *Tel. No.:* Museum 9972-3.	H. Moore, Esq., C.B.E., D.Sc., Ph.D., F.I.C., F.Inst.P. A. F. Ridley, Esq., F.L.A.	1st. Jan., 1920	14	(*a*) 6,773 (*b*) 78,824
British Refractories Research Association.	*Offices:* Drayton House, 30, Gordon Street, London, W.C.1. *Tel. No.:* Museum 0783. *Laboratories:* The Mellor Laboratories, Shelton, Stoke-on-Trent, Staffs. *Tel. No.:* Hanley 29119.	J. W. Mellor, Esq., D.Sc., F.R.S. H. Halliday, Esq., F.C.I.S.	1st July, 1920	14	(*a*) 1,500 (*b*) 26,580
Scottish Shale Oil Scientific and Industrial Research Association.	*Offices:* 53, Bothwell Street, Glasgow.	— *Secretary:* H. R. J. Conacher, Esq.	1st April, 1920	14	(*a*) — (*b*) 7,500 (2)

APPENDIX III—*continued.*

Name. (1)	Address. (2)	Director and Secretary. (3)	Commencement of grant earning period. (4)	Number of completed years of work (at 31st July, 1934). (5)	Grant paid— (*a*) In respect of last completed year. (*b*) In respect of period given in col. (5). (6)
					£
British Launderers' Research Association.	*Offices:* 17, Lancaster Gate, London, W.2. *Tel. No.:* Paddington 4384–5.	R. E. V. Hampson, Esq., D.Sc.	1st Oct., 1920	13	(*a*) 1,723 (*b*) 31,267
	Laboratories: The Laboratory, Hill View Gardens, Hendon, London, N.W.4. *Tel. No.:* Hendon 6111 and 6112.	J. J. Stark, Esq.			
British Leather Manufacturers' Research Association.	*Offices:* 8, St. Thomas' Street, London, S.E.1. *Tel. No.:* Hop 0175.	Miss D. Jordan Lloyd, D.Sc.	1st Oct., 1920	13	(*a*) 1,623 (*b*) 31,469
	Laboratories: 20, St. Thomas' Street, London, S.E.1. *Tel. No.:* Hop. 0900.	E. C. Snow, Esq., M.A., D.Sc.			
British Electrical and Allied Industries Research Association.	*Offices and Laboratories:* 15, Savoy Street, London, W.C.2. *Tel. No.:* Temple Bar 7907–9.	*Director and Secretary:* E. B. Wedmore, Esq., M.I.E.E., F.Inst.P.	1st Oct., 1920	13	(*a*) 7,877 (*b*) 114,378
British Silk Research Association.	*Offices:* 19, Russell Square, London, W.C.1. *Tel. No.:* Museum 8274.	W. S. Denham, Esq., D.Sc., F.I.C.	1st Jan., 1921	13	(*a*) — (*b*) 15,523
	Laboratories: The British Silk Research Laboratory, The University, Leeds. *Tel. No.:* Leeds 20251.	A. B. Ball, Esq.			

British Cast Iron Research Association.	*Offices and Laboratories:* 21–23, St. Paul's Square, Birmingham. *Tel. No.:* Central 1885	*Director and Secretary:* J. G. Pearce, Esq., M.Sc., M.I.E.E.	1st July, 1921	13	(*a*) 3,000 (*b*) 45,207	
Research Association of British Flour Millers.	*Offices:* 40, Trinity Square, London, E.C.3. *Tel. No.:* Royal 2398. *Laboratories:* Old London Road, St. Albans, Herts. *Tel. No.:* St. Albans 640.	E. A. Fisher, Esq., M.A., D.Sc., F.I.C., F.Inst.P. H. G. Hall, Esq.	1st July, 1923	11	(*a*) — (*b*) 23,582	
British Colliery Owners' Research Association.	*Offices:* General Buildings, Aldwych, London, W.C.2. *Tel No.:* Holborn 3326	*Secretary:* W. A. Lee, Esq., C.B.E.	(Licence issued by the Board of Trade on 29th Dec., 1924.)	9	—(3)	
British Food Manufacturers' Research Association.	*Offices:* 22, Buckingham Gate, London, S.W.1. *Tel. No.:* Victoria 5729. *Laboratories:* 2 and 4 Dalmeny Avenue, Holloway, London, N.7. *Tel. No.:* North 1048.	T. Macara, Esq., F.I.C., F.C.S. R. M. Leonard, Esq.	1st July, 1925	9	(*a*) 570 (*b*) 8,827	
Research Association of British Paint, Colour and Varnish Manufacturers	*Offices:* Tavistock House (North), Tavistock Square, London, W.C.1. *Tel. No.:* Euston 2474 *Laboratories:* The Paint Research Station, Waldegrave Road, Teddington, Middlesex. *Tel. No.:* Molesey 1063.	L. A. Jordan, Esq., D.Sc., A.R.C.Sc., F.I.C. J. B. Graham, Esq., M.C.	1st July, 1926	8	(*a*) 2,200 (*b*) 28,243	
British Iron and Steel Federation (Iron and Steel Industrial Research Council).	*Offices:* Caxton House, East Tothill Street, London, S.W.1. *Tel. No.:* Whitehall 4255–6.	E. C. Evans, Esq., B.Sc., F.I.C. M. S. Birkett, Esq., O.B.E.	1st Jan, 1929	5	(*a*) 5,000 (*b*) 28,166	

APPENDIX III—*continued*

Name. (1)	Address. (2)	Director and Secretary. (3)	Commencement of grant earning period. (4)	Number of completed years of work (at 31st July, 1934). (5)	Grant paid— (*a*) In respect of last completed year. (*b*) In respect of period given in col. (5). (6)
Printing Industry Research Association.	*Offices:* St. Bride Institute, Bride Lane, Ludgate Circus, London, E.C.4. *Tel. No.:* Central 3161.	G. L. Riddell, Esq., Ph.D., A.I.C. Miss D. P. Hewett.	(Licence issued by the Board of Trade on 21st Nov., 1930.)	3	£ —(4)
Institution of Automobile Engineers (Research and Standardisation Committee).	*Offices:* Watergate House, York Buildings, Adelphi, London, W.C.2. *Tel. No.:* Temple Bar 5025-6. *Laboratories:* 5, Bolton Road, Chiswick, London, W.4. *Tel. No.:* Chiswick 0444.	C. G. Williams, Esq., M.Sc. B. G. Robbins, Esq.	1st July, 1931	3	(*a*) 2,500 (*b*) 7,500 (5)

EXPLANATORY NOTES.

(1) This figure does not include an advance of £2,500 made to the Research Association of British Rubber Manufacturers for the year ended 31st December, 1929.

(2) The total amount of grant paid to the Scottish Shale Oil Scientific and Industrial Research Association was in respect of the first five-year period ended 31st March, 1925; the Association has since continued operations without further grant aid.

(3) The British Colliery Owners' Research Association is not in receipt of grant aid from the Department for its general operations.

(4) The Printing Industry Research Association is not in receipt of grant aid from the Department.

(5) The Research and Standardisation Committee of the Institution of Automobile Engineers took over the research work of the Research Association of British Motor and Allied Manufacturers as from 1st July, 1931, and that of the British Motor Cycle and Cycle Car Research Association as from 1st January, 1932.

APPENDIX IV

STATISTICS RELATING TO MAINTENANCE ALLOWANCES TO STUDENTS-IN-TRAINING, SENIOR RESEARCH AWARDS AND GRANTS FOR THE DEVELOPMENT OF SPECIAL INVESTIGATIONS

Explanatory note.—Maintenance allowances to students-in-training are normally made for two years, Senior Research Awards are tenable for three years, while grants for the development of Special Investigations may be made for one, two or three years according to the circumstances. The total number of awards in any category which are held in any year, therefore, represents the sum of those in the first year of award and those extending from the previous year, or years. It is to be noted in this connexion that Table 1, which gives the result of applications received for grants to commence in the year to which the Table relates, is thus limited to new awards made in that year. Table 2 compares the total grants held in the year with those held in previous years.

The cost of these grants during the Academic Year 1933–34 was £26,346 19*s.* 8*d.*

TABLE I

PARTICULARS OF APPLICATIONS RECEIVED IN RESPECT OF THE ACADEMIC YEAR 1933–34 (COMPARED WITH SIMILAR DETAILS FOR EARLIER YEARS)

—	Students-in-Training.			Senior Research Awards.			Grants for Special Investigations.		
	1931–32.	1932–33.	1933–34.	1931–32.	1932–33.	1933–34.	1931–32.	1932–33.	1933–34.
A.—Applications granted	85	63	95	5	6	4	35	23	34
B.—Applications refused	123	115	122	11	19	13	26	21	22
C.—Applications withdrawn or referred elsewhere	39	29	30	1	1	4	6	—	4

TABLE 2

PARTICULARS OF THE TOTAL NUMBER OF GRANTS HELD IN THE ACADEMIC YEAR 1933–34 AS COMPARED WITH PREVIOUS YEARS

——	1931–32.			1932–33.			1933–34.		
	Continued from 1930–31.	New in 1931–32.	Total.	Continued from 1931–32.	New in 1932–33.	Total.	Continued from 1932–33.	New in 1933–34.	Total.
1. Students-in-training	58	85	143	53	63	116	33	95	128
2. Senior Research Awards ..	10	5	15	12	6	18	7	4	11
3. Grants for Special Investigations.	16	35	51	14	23	37	8	34	42

TABLE 3

DISTRIBUTION OF GRANTS HELD IN VARIOUS BRANCHES OF SCIENCE

—	Students-in-training.			Senior Research Awards.			Grants for Special Investigations.		
	1931–32.	1932–33.	1933–34.	1931–32.	1932–33.	1933–34.	1931–32.	1932–33.	1933–34.
Chemistry	59	44	49	8	8	5	22	15	14
Physics	28	23	24	5	6	3	9	6	8
Mathematics and Astronomy	5	2	7	—	—	—	3	2	4
Biology	23	24	25	1	2	2	7	8	6
Geology and Mineralogy	3	2	5	1	1	—	3	1	3
Metallurgy	11	8	6	—	—	—	3	1	4
Engineering	14	13	12	—	1	1	4	4	3
Totals	143	116	128	15	18	11	51	37	42

APPENDIX IV

TABLE 4

INITIAL AFTER-CAREERS OF STUDENTS-IN-TRAINING WHOSE ALLOWANCES TERMINATED IN 1932–33, WITH TOTAL CORRESPONDING FIGURES FOR THE FIVE-YEAR PERIODS 1923–28 AND 1928–33

———	1932–33.	Total for 1923–28.	Total for 1928–33.
Scientific service under Government ..	4	72	28
Scientific service in industry	22	184	100
Proceeded to Senior Research Awards..	—	2	7
Engaged in connexion with Special Investigations	2	9	18
Scholarships	22	129	122
Unaided research work	3	26	18
University posts	12	119	63
Scholastic posts	5	43	23
Miscellaneous	8	37	39

APPENDIX V

SUMMARY OF THE EXPENDITURE OF THE DEPARTMENT DURING THE YEAR ENDED 31ST MARCH, 1934

Organisation.	Gross.	Receipts.	Net.
	£	£	£
Headquarters' Administration	26,127	2,336	23,791
National Physical Laboratory	209,052‡	90,365§	118,687
Building and Road Research	59,191	29,507*	29,684
Chemical Research Laboratory.. ..	25,705	3,541	22,164
Food Investigation	44,232	33,525†	10,707
Forest Products Research	39,745	5,834	33,911
Fuel Research	89,840	9,417	80,423
Water Pollution Research	11,819	6,366	5,453
Miscellaneous Programmes	9,279	5,470	3,809
Geological Survey and Museum ..	64,364	938	63,426
Grants for Research :—			
Research Associations	59,088	96	58,992
Grants to Students, etc.	26,040	190	25,850
	664,482	187,585‖	476,897

* Includes a payment of £21,520 from the Road Fund.

† Includes a grant-in-aid of £30,000 from the Empire Marketing Board.

‡ Includes the cost of work at the Laboratory for the Radio Research Board, the Food Investigation Board, etc.

	£
§ Outside bodies and firms, etc.	47,969
Air Ministry	36,237
Other Government Departments	3,736
Special Research Funds	2,423
	£90,365

‖ This total may be classified—

Fees for paid work for industry.. ..	59,774
Contributions from Industry to Co-operative Research	10,209
Other Government funds	99,705
Sales of by-products	12,759
Miscellaneous	5,138
	£187,585

APPENDIX VI

LIST OF PUBLICATIONS BY INDIVIDUALS IN RECEIPT OF GRANTS, BROUGHT TO THE NOTICE OF THE DEPARTMENT DURING THE YEAR

ABBOT, E. B.—

Optically Inactive Bornyl Fumarates. *J. chem. Soc.*, 1934, 711.

ALLSOPP, C. B.—

Refractive Dispersion of Organic Compounds. IV. *cyclo*-Hexene and 1 : 3-*cyclo*-Hexadiene. *Proc. roy. Soc.*, 1934 (A), **143**, 618.

ASTIN, S.—

Selenium Dioxide. A New Oxidising Agent. Part. IV. The Preparation and Properties of Ethyl Ketohydroxysuccinate. [With H. L. Riley.] *J. chem. Soc.*, 1934, 844.

BACON, F.—

Fatigue and Corrosion Fatigue with Special Reference to Service Breakages. *Proc. Instn mech. Engrs, Lond.*, 1933, **124**, 685.

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Cumberland—

36 N.E.

[1] A complete list may be obtained as explained on p. 181.

APPENDIX VII

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Lancashire—

83 N.E.
83 S.E.
91 N.E.
91 S.E.
92 S.E.
94 S.W.
100 S.W.
101 N.E.
102 N.W.
102 S.W.
108 N.E.
109 N.W.
112 N.E.

Northumberland—

N. 78 S.W.
N. 78 S.E.
N. 86 N.W.
N. 86 S.W.
N. 86 S.E.

Yorkshire—

218 N.E.
218 S.E.
219 S.E.
233 N.E.
233 S.W.
263 N.E.
263 S.E.
264 N.W.
264 S.W.
274 N.W.
275 N.E.
275 S.E.
276 S.W.
281 N.E.
281 S.E.
283 N.E.
284 N.W.

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N. 4 S.E.
N. 5 N.W.
N. 5 N.E.
N. 5 S.W.
N. 6 N.W.
N. 6 N.E.
N. 6 S.W.
N. 6 S.E.
N. 8 N.W.
N. 8 N.E.
N. 9 N.W.
N. 10 N.W.
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