principle of a bubble sextant is shown diagrammatically in Fig. 4. By means of a lens and prism (not shown), which are fixed above the bubble lens, the horizon can also be seen in the field of view, as well as the bubble, so that the instrument may be used as an horizon sextant if required.

The problem of the rapid calculation of sextant observations appears to have been solved completely by the cylindrical slide-rule due to Mr. Bygrave. With a slide-rule about 7 in. long results can be obtained in three or four minutes' time which are accurate to within about three minutes of arc. With larger patterns greater accuracy in obtained.

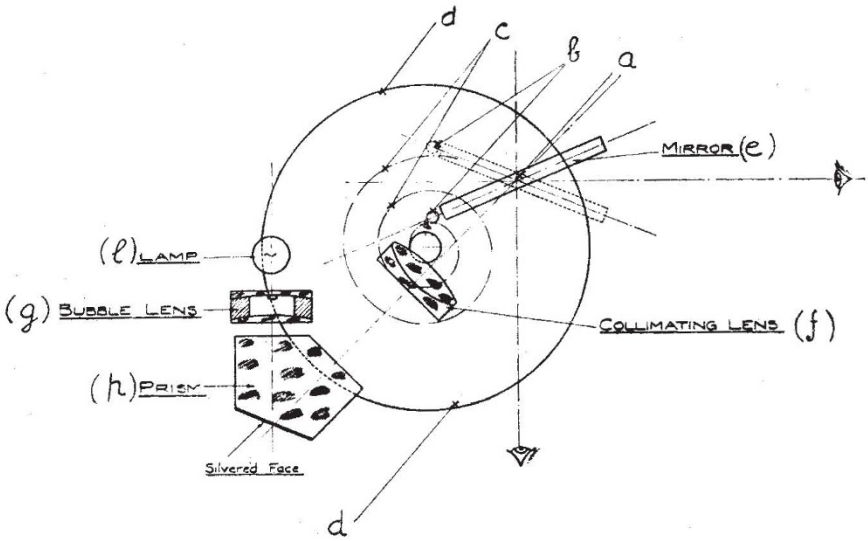

FIG. 4.—R.A.E. bubble sextant Mark II. *a*, axis about which clear mirror *e* is moved by pin *b* resting on cam *c* fixed to drum *d*. Image of bubble in lens cell *g* seen by reflection in *e* through lens *f* after further reflection in prism *p*. Bubble illuminated at night by lamp *l*.

The accompanying illustrations are from a lecture on "The Design of Instruments for the Navigation of Aircraft," read to the Royal Geographical Society by the author on May 10 last, and published in the *Geographical Journal* for November.

Industrial Research Associations.

VI.—The Glass Research Association.

By Edward Quine.

THE Glass Research Association has been established for investigation into the problems of the glass industry in accordance with the scheme of the Committee of the Privy Council for Scientific and Industrial Research. The association received its Certificate of Incorporation on August 11, 1919, and held the first general meeting on October 14 following.

The objects of the association are to conduct scientific and technical investigations relating to glass and its manufacture, and to disseminate among members technical and other information bearing on these subjects and on the production of articles made wholly or partly of glass.

The rate of development of the glass industry in this country is largely influenced by difficulties in the matter of technique, works organisation, production and equipment, and, in order that the industry may attain a high degree of efficiency, it is necessary for investigations to be directed towards overcoming these difficulties, in addition to investigations of fundamental principles and search for new knowledge. To ensure that greater economy in production and more satisfactory products may be obtained, improved methods must be introduced, and the works practice of the industry brought into line with the advanced methods found operative in other countries. Until recent years no comprehensive research work relating to the industry had been carried out in this country, but the need for a deeper and more extensive knowledge of the fundamental facts underlying the various processes of manufacture is now appreciated. The association is consequently endeavouring to secure that the fundamental principles and their application shall be thoroughly investigated by systematically conducted researches, so that, side by side with the modernising of works practice, and the introduction into the industry of the scientific control of the various operations, new knowledge may be acquired which may ultimately lead to industrially valuable developments.

The investigations of the association cover the problems of all sections of the glass industry other than those of optical glass, research work in which is being undertaken by the British Scientific Instrument Research Association.

The membership of the association is limited to British corporations and British subjects carrying on business in connection with the manufacture of glass, and other trades and industries allied therewith or accessory thereto. Individuals ineligible for membership or not desiring admission as members, who are interested in the glass industry and willing to subscribe to the objects of the association, may be admitted by the council as

associates. At present there are 135 members and seventeen associates.

The management of the association is vested in the council with an executive committee; the council consists of a majority of elected members together with a limited number of members co-opted because of their special knowledge and experience, and members nominated by the Department of Scientific and Industrial Research. The chairman of the first council is Mr. George E. Alexander, whose support and direction have been largely responsible for the successful establishment of the association.

The organisation and direction of research work is entrusted to a director of research, and the association has appointed to this post Mr. R. L. Frink, formerly of the Frink Laboratories, Lancaster, Ohio, U.S.A., who took office on March 1, 1920.

The director of research works in close consultation with seven research committees, which have been appointed by the council to survey the field of research in relation to glass and the glass industry. The terms of reference of these committees are :—

(1) Chemical and physical properties of glass (at all temperatures). (Chairman : Dr. W. Rosenhain.)

(2) Fuels, refractories, furnaces. (Chairman : Mr. S. N. Jenkinson.)

(3) Glass-making materials, glass-founding—temperature measurement and control; annealing and finishing other than decorative and marking operations. (Chairman : Mr. C. C. Paterson.)

(4) Glassware-forming operations—hand and mechanical; glassware-making machinery. (Chairman : Mr. J. Forster.)

(5) Lamp-working. (Chairman : Mr. F. Cossor.)

(6) Design, lay-out, and equipment of glass factories. (Chairman : Mr. R. S. Biram.)

(7) Glass decorative and marking operations. (Chairman : Mr. E. J. Purser.)

The programme of research covers a wide range of subjects, including investigations into the following problems :—

(1) The dependence of fusibility, range of viscosity, colour transparency, brilliancy, refractivity, heat conductivity, expansibility, electrical conductivity, tensile and crushing strength, hardness, brittleness, elasticity, working properties in the blow-pipe flame, resistance to chemical action, and devitrification upon the chemical composition of the glass.

(2) The examination and treatment of clays and bricks, the composition and methods of manufacture of refractory materials, the firing of pots, and investigations in regard to refractory materials.

(3) The design, construction, and operation of furnaces, tanks, pot arches, lehrs, kilns, glory-holes, etc.

(4) The relative value and efficiency of coal, coke, oils, tar, and other combustible mixtures, gas and gas-producers for various types of furnaces and lehrs, and the investigation of electrical methods of heating.

(5) The most suitable raw materials by means of which to introduce certain chemical elements in the best and most economical forms.

(6) Methods of batch mixing.

(7) Measurement and control of temperature during founding, chemical and physical changes during founding, determination of most suitable rates of charging and founding different types of glass, effect of furnace gases upon the various types of glass during founding; methods of aiding the fining process.

(8) Examination and improvement of the methods and conditions under which molten glass can be conveyed to the forming apparatus; moulds and their treatment; mechanical processes of forming glass.

(9) Investigation of annealing temperatures, rates of annealing, effect of annealing on physical and chemical properties; methods of detecting and measuring strain.

(10) Cracking off, grinding, etching, enamelling, decorating, graduating and marking, lamp-working machinery, and other mechanical processes of finishing.

(11) Ventilation of works.

(12) Efficiency and health of operators as related to industrial operations.

Apart from the general problems of the industry, members of the association may, on terms to be decided by the council, have special information given to them by the director or staff of the association, or may have special investigations or researches made for them.

In March, 1920, the association secured the lease of 50 Bedford Square, W.C.1, and these premises have been equipped as offices and laboratories, in which eight research assistants are carrying out intra-mural investigations. Difficulties have been met with regard to the equipment of these premises, thus causing much delay in the work; but now the required equipment is being rapidly assembled.

The full activities of the association have as yet been of short duration, but during this period it has consummated agreements and arrangements with certain of its members whereby it has been made possible to construct an experimental tank furnace for the development of certain types of glasses, and a method of their formation into chemical, table, lighting, and other classes of ware, which, it is hoped, will effect not only a great economy in cost of manufacture, but also increase the production. The construction of a new type of lehr is also contemplated under a similar arrangement, and it is hoped that the results of this work will assist in solving, or even solve completely, many of the technical problems in the annealing of various classes of ware at a greatly reduced cost in construction and operation, and at the same time place annealing under more scientific and positive control. Moulds for forming glassware, their composition, construction, and methods of

use are being studied, and the results will shortly be experimentally applied in the works of members.

A number of improvements and inventions, for some of which applications have been made for patents, are being completed, and will in due course be placed in operation. These improvements and inventions include a method of cooling tank-furnace walls, an instrument for indicating and recording viscosity of glasses under practical working conditions, temperature-control apparatus, furnace-controlling instruments, paste for moulds, etching and acid polishing solutions, instruments for classification of colour values of glasses, and others of minor importance.

It has been the policy of the association so far as possible to utilise existing facilities in scientific institutions, and in accordance with this policy the National Physical Laboratory is proceeding with researches on behalf of the association, and it is contemplated that during the coming year the volume of researches at this institution will be considerably increased. Investigations are also proceeding at the Department of Glass Technology, University of Sheffield. Negotiations are pro-pressing with universities and institutions which are specially equipped and adapted to investigate specific problems on behalf of the association.

The association is completing a working agreement with the British Refractories Research Asso ciation whereby large-scale researches into the fundamental principles underlying the manufacture of refractories for the glass industry and their industrial application will be carried out by the British Refractories Research Association working in consultation with a joint committee formed of members of both associations and the Directors of Research.

Working arrangements have been made with the British Scientific Instrument Research Association whereby problems common to both associations will be investigated jointly, this association co-operating with the British Scientific Instrument Research Association to the fullest possible extent.

The council has considered the advisability of conducting research investigations into psychological and physiological problems affecting organisation and productive operations of the industry, and, believing that such investigations will be of great benefit both to the operatives and to the manufacturers, has referred this matter to the appropriate research committee for action.

Apart from work to be undertaken by associations and scientific institutions and at factories of members on behalf of the association, arrangements have been made for men of science who have specialised in certain branches of scientific investigation as applied to this industry to undertake researches.

Extensive investigations on "The Bloom and Dimming Effect upon Lamp-working Glass" have been made on behalf of the association by Mr. J. H. Gardiner. A first report has been received which has led to fruitful suggestions for further investigations, which are proceeding. A valuable contribution has been made to the association by Messrs. F. Twyman and A. J. Dalladay upon "Methods of Differentiating Cords in Glass," and further work is being done on this subject in the laboratories of the association.

A vast amount of work lies before the association, and, while realising the limitations of universities in their relation to industrial research and appreciating their services to industry in furnishing both ideas and trained investigators, the council is, in its endeavours to solve such of those problems of the glass industry as lend themselves to investigations along academic lines anxious for the close co-operation of those universities and scientific institutions having equipment and facilities available, and it is hoped that as its work progresses the association may become the centre of scientific and industrial research into problems of the glass industry for the Empire.

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The Quantum Theory.

PROF. MAX PLANCK was awarded the Nobel prize for physics this year, and his address [1] on the occasion of receiving it makes extraordinarily interesting reading. He describes in some detail the way in which he was led to the discovery of the quantum, and to anyone engaged in research the description will be very encouraging, for it shows through what darkness the mind of a great discoverer must grope, and what false tracks he will follow, before he sees the light of the truth. At the time of his discovery few physicists would seem to have appreciated the fundamental importance of the unknown relation connecting the energy of radiation with its wave-length and temperature, perhaps because this relation can be obtained only by a denial of some of the chief articles of their scientific creed. Thus the late Lord Rayleigh had already stated correctly the radiation formula as it ought to be—and as it is for the longer wave-lengths; but he does not appear to have attempted to explain its hopeless failure in the region of the visible spectrum and beyond. The rival formula was that of Wien, far less sound theoretically, but giving good agreement with observation in the visible spectrum.

Planck started on Kirchhoff's idea that if he could find the emission and absorption for a single ideal radiating substance, the true radiation formula would result. He naturally worked on dynamical principles, and inevitably got a result equivalent to no result at all, for it led to the

[1] "Die Entstehung und bisherige Entwicklung der Quantentheorie." Von Max Planck. Pp. 32. (Leipzig: J A. Barth, 1920.) Price 4 marks.