RADIOISOTOPES AND GLASS

A SYMPOSIUM on the subject "Radioisotopes and Glass" was held by the Society of Glass Technology at the Department of Glass Technology of the University of Sheffield on November 27. Dr. W. M. Hampton was chairman of the morning session, followed by the president of the Society, Mr. C. E. Ramsden, who took the chair in the afternoon.

In an introductory lecture, Mr. J. L. Putman (Atomic Energy Research Establishment, Harwell) directed attention to the dual nature of the discussions, in dealing with both the services which radioactive techniques can offer to the glass industry and the demands which the handling and measurement of radioactive materials make upon glass. He mentioned the use of glass for containers and remote-control manipulative equipment for use with radioactive solutions, the use of lead glass as a transparent screening material for operations with high gamma-ray intensities and the use of discoloration as an index of high gamma-ray doses.

Following a brief review of the nature and properties of radioisotopes, Mr. Putman indicated the main ways in which these materials could be used, as radioactive tracers in solid, liquid or gaseous form, as sources of radiation in non-contacting thickness and density gauges, and as dissipators of unwanted electrostatic charges on insulators. A particular note was made of the special role of glass in the construction of Geiger counters and other radiation detectors.

Mr. E. W. Jones (Isotope Developments, Ltd.) spoke on "Glass Level Measurement in Furnaces". After a brief review of orthodox measurements of glass level, he pointed out the advantages of a radioactive system which does not require access to the inside of the containing vessel.

He referred to an early French design using radium as the source, and described a more recent British installation for monitoring the level of molten glass in the feeder to a bottle-making machine. In this model, which operates through two brick and refractory walls each $9\frac{1}{2}$ in. thick, encased in $\frac{3}{8}$ -in. steel, a cobalt-60 source of activity 200 mc. is used in conjunction with a water-cooled, all-metal Geiger counter as detector. Indications of changes in glass level up to $\pm \frac{1}{4}$ in. are obtained, with a sensitivity of about ± 0.01 in. Gradual radioactive decay is compensated by increasing the electronic sensitivity, so that the cobalt-60 source (much cheaper than radium) can be used over a period of five years. About one hundred such instruments are now installed, but only a few employ the desirable feature of automatic control by servo adjustment of the screw feed.

Mr. Jones outlined other possibilities for using simple level gauges to operate high-level warning systems, on batch silos and hoppers, and also mentioned the possibilities of using thickness gauges for the inspection of bottles and sheet glass.

Dr. R. E. Bastick (Chance Brothers, Ltd.) described the "Development of Glasses for Use with Radioisotopes and other Sources of Radiation", with particular reference to their uses for screening. He outlined the calculation of lead equivalent and showed that experimental determinations of this are

in agreement within 1 or 2 per cent. Lead equivalents up to 0.6 were reported for some lead glasses.

Dr. Bastick then discussed the coloration of crown and flint screening glasses by large doses of radiation and showed results of doses up to 10^7 r. on flint glass and the subsequent fading observed. The use of cerium oxide as an additive to inhibit coloration was described, with data showing the inhibitory effect of various quantities of cerium dioxide in flint glass at a total dose of 10^7 r.

Neutron absorbing glasses containing oxides of cadmium and boron were described, and the dependence of absorption coefficients on neutron energy was shown.

A brief account of the use of a lead glass scintillator in a Cerenkov counter was given, and the use of cobalt loaded borosilicate glass for gamma-ray dosimetry was described.

In discussion on this paper, the special property of quartz glass in withstanding gamma-radiation up to 10^6 r. without coloration was mentioned, and the purple coloration produced by radiation when 4-6 p.p.m. of aluminium is incorporated was proposed for dosimeters which show little or no fading. It was also noted that denser glasses required smaller concentrations of cerium dioxide to inhibit coloration (for example, plate glass requires 2 per cent, while lead glass needs only $\frac{1}{4}$ per cent).

Mr. J. L. Putman (Atomic Energy Research Establishment, Harwell) then presented a short paper on the "Determination of Selenium in Glass by a Radioactivation Method", an investigation made in collaboration with the British Glass Industry Research Association. He remarked that in finding the retention by glass of selenium added as a decolorizer, colorimetric methods were not applicable because of their dependence on the chemical form of the sample, and chemical analysis was cumbersome. In the method described the simultaneous neutron irradiation, in a reactor, of glass samples with and without the selenium additive was followed by comparison in a differential gamma-ray spectrometer, which subtracted the response of one sample from another, leaving only the gamma-ray spectrum due to selenium-75. Determination was thus specific for the element and largely independent of other impurities. Concentrations of 19.5 p.p.m. were measured with an estimated accuracy of ± 5 per cent. The applicability of the technique to analysis of other constituents and to the use of non-radioactive tracers was suggested.

In the afternoon, Mr. B. E. Moody (United Glass Bottle Manufacturers, Ltd.) described an "Investigation of Glass Flow in Furnaces by Radioactive Tracers". To trace the flow through furnaces handling 90 tons a day, over a period of 12-14 days, phosphorus-32 was chosen as the tracer, thus avoiding radiation hazards from the high activity of radioactive glass in the furnace, since it emits only beta particles. The tracer was in the form of neutron-irradiated ground phosphate glass compatible with the melt, and contained 51 per cent phosphorus pentoxide. After a delay of one week to allow radioactivity of potash and alumina constituents to decay, the phosphate glass contained 2 mc./gm. of phosphorus-32. It was added to the feed of one or more

of three batch chargers over a period of $\frac{1}{2}$ hr. From 35 to 350 mc. of phosphorus-32 was used in an investigation, 175 mc. being found to be the optimum activity.

Samples were taken at intervals from the output of three bottle-making machines fed by the furnace and measured with an end-window Geiger counter. By using a metal iris to limit the area inspected by the counter and by using glass samples thicker than 3 mm., it was established that the shape of the samples did not critically affect the results, and pieces of bottles were conveniently used for measurements.

It was found that tracer added to one of the outside batch chargers appeared almost uniformly in the three bottle-making machines, indicating good mixing and absence of streaming in the furnace. After a delay of $7\frac{1}{2}$ -10 hr. for amber glass and 5-6 hr. for flint, radioactivity began to appear in the product, reaching a maximum in about 24 hr. This was followed by a nearly exponential decay, leaving only 1.4 per cent of the labelled glass after 12 days and undetectable activity after 14 days. Apart from the expected initial delay before marked constituents appeared in the product, agreement with the 'curve of perfect mixing' was fairly good. Some subsidiary peaks in the curve of activity versus time were unexplained, but some were believed to be due to the recycling of active cullet.

Mr. R. F. Barker (Pilkington Brothers, Ltd.) gave an account of an "Investigation of Glass Flow in Furnaces by Radioactivation Methods". The furnace described was producing 6.4 tons per hr. of soda lime silica glass and had a capacity of 1,350 tons. Measurements were required over a period of several weeks. The long half-life and high activity required in a radioactive tracer made the use of radioactivity in the furnace undesirable. Hence an inactive material which could be made radioactive by the subsequent neutron irradiation of samples was used. Tantalum was chosen because of its high neutron cross-section and the desirability of the gamma-emitting tantalum-182 formed on neutron irradiation, the half-life (110 days) of which was longer than that of any activity induced in the normal constituents of the glass. The tracer was in the form of $3\frac{1}{2}$ kgm. of tantalum peroxide.

Tests were made on three of five machines fed by the furnace, and 200 samples, each containing 5 gm.

of powdered glass, were irradiated in a reactor at Harwell. After a delay of five weeks to allow short-lived activities to decay, measurements were made with a scintillation counter, using a single-channel pulse amplitude analyser to distinguish the tantalum-182 gamma rays. A minimum transit-time of 4 hr. was found, in agreement with other data. The tracer was at a maximum after 100 hr. and its decline was followed over a total time of 520 furnace-hours. Moderate agreement was found with W. M. Hampton's theoretical curve for perfect mixing, but Mr. Barker directed attention to significant departures from this curve near the time of injection.

In a second paper, on "The Assessment by Tracer Methods of Mixing during Sand Treatment", Mr. R. F. Barker described experiments made in collaboration with the Isotope Division, Harwell, using sand labelled by immersion in a solution of barium-140 and subsequent heating at 500° C. The adhesion of the radioactive material was already established under conditions of abrasion and washing with water. The daughter isotope lanthanum-140 (40 hr.) reaches equilibrium with the barium-140 (12 days) and measurements were made of gamma rays from the lanthanum.

Ten pounds of labelled sand, carrying 100 mc. of barium-140, were mixed with 5 cwt. of inactive sand in a cement mixer and added to a hopper feeding the washing plant. The progress of the radioactive material through the washing plant and grader was registered by recording meters placed outside the steel pipes carrying the sand slurry. A survey was made of the horizontal distribution of radioactively labelled sand in the storage bin (capacity 2,000 tons). At this stage the labelled sand was found still to be fairly localized. Further monitoring of the sand leaving the bin and in the railway transit wagons showed that mixing was introduced by the method of loading.

Finally, timed measurements were made of the radioactivity of glass drawn off from the tank furnace. From an analysis of these results the distribution of a particular sample of the original sand in the finished product was assessed.

The papers were followed by lively discussion. The proceedings of the symposium will be published in the *Journal of the Society of Glass Technology*.

J. L. PUTMAN

MELTING AND DIFFUSION

THE second symposium on "Melting, Diffusion and Related Topics" was held at the National Research Council Laboratories, Ottawa, on October 21-22. The meeting was sponsored by the Low Temperature and Solid State Physics Group of the Division of Pure Physics, National Research Council of Canada. As in the previous symposium, reported in *Nature* (177, 23; 1956), the object was to bring together workers with varied approaches to the subject and, by limiting the number of formal contributions to twelve, to encourage informal discussion.

In the previous symposium the melting process itself was a major topic of interest. In contrast, the programme on this occasion was concerned chiefly with processes having only a general bearing on melting, the direct approach being temporarily

abandoned in favour of seeking clues from the solution of associated problems.

Among the papers concerned with measurements in the region of melting was one by D. L. Martin (National Research Council), who reviewed existing information concerning specific heat anomalies in the region of melting; he showed that both anharmonicity and lattice defects have been invoked in explanation but argued that little conclusive evidence exists as to their relative importance. N. H. Nachtrieb (Institute of Metals, Chicago) dealt with diffusion in liquid and solid pure metals and in alloys; the analysis of his measurements showed a clear relation between melting and diffusion parameters, but also underlined the restricted nature of purely thermodynamic arguments. Diffusion was also considered