INDUSTRY BENEFITS FROM RADIOISOTOPES

The most rapid contribution which atomic energy makes to the economy of a country is by the industrial applications of radioisotopes. In research they may be used to reveal unique information about the nature of chemical processes, or as a fast and cheap tool to provide information more quickly or more accurately than could be obtained by other means. In manufacturing they are used to control and regulate many processes, thereby improving the quality of the product or making better use of raw materials. And in product control they offer many possibilities of non-destructive testing, thereby ensuring that products of inferior quality do not reach the market.

All these methods are frequently described in scientific and technical literature, and their applications are encouraged by many national and international organizations. Nevertheless, industry seems at times somewhat reluctant to apply these methods for its own profit.

The International Atomic Energy Agency since its inception has always sought to promote the industrial use of radioisotopes. Among other ways, it has arranged scientific conferences on various aspects of the question, and has selected and published general information.

Industry's attitude to any innovation, however, is the same the world over - viz. does it pay? The Agency, therefore, decided to collect information on the economic benefits derived from the use of radioisotopes in industry, described in terms of "savings". It arranged for an international survey of these benefits, and at the same time for the collection of information on how radioisotopes are being utilized today.

In April 1962 the Agency invited selected Member States to participate in the survey, and in response national governments collected detailed information from industrial organizations in their countries in the fields of prospecting, mining and manufacturing. The radioisotope techniques were grouped under the heads of radioisotope gauging, industrial radiography, ionization applications, tracing, massive irradiation and miscellaneous applications. The national reports from the participating countries recently reached the Agency, which is preparing a comprehensive report on radioisotope use and economics.

In order to assess the contents of the various reports and to establish the best means of interpreting and presenting the material, the Agency convened a Study Group in Vienna from 16 to 20 March 1964. About 60 participants from Member States and international organizations discussed the reports, the latest developments in isotope utilization, and how the use of isotopes in industry could be further encouraged.

The survey was prepared with care, as there have been few precedents to guide such an investigation on such a scale. Although its main purpose is to make an economic assessment, it has neccessarily had to start with the consideration of techniques, and information was collected both on technical and economic aspects.

Basis of Survey

National estimates of radioisotope savings in industry in the past have been based on widely different assumptions and methods. Even in the same country, the results of different estimates have varied by as much as a factor of ten. It was necessary to ensure that all the estimates for the survey were prepared in a standard manner; one of the main objects has been to achieve uniformity so that valid comparisons may be made. In consequence, the basis of the survey is perhaps rather narrow - for example only a limited number of industrial firms can calculate savings with reasonable precision, although as many as possible were brought into the survey.

It was also necessary to adopt a rather strict working definition of "savings". They were taken to mean "a measurable difference in costs between the method used prior to the introduction of radioisotope techniques and the new radioisotope method". For this purpose, "direct savings" are defined as raw material savings, finished product scrap savings, labour savings, etc., and "indirect savings" means avoidance of shut-downs, better process control, etc. In addition, questions were prepared to allow for calculation of "potential savings", which could be realized by an industrial category if all firms were to use radioisotope techniques to the same extent as those making estimates. Finally, "customers' savings" and "intangible savings" were not to be credited in the survey.

National bodies endeavoured to cover the whole field of industrial utilization so as to reach some estimate of national totals. They also made a few investigations in depth, and quoted a number of specific "case studies" of routine applications. These provide a background for the more detailed treatment of data, by providing the national bodies with first-hand knowledge of such matters as accuracy of nuclear and alternative gauges, operational experience of X-ray and radioisotope sources in radiography, and so on. Some of these findings are of considerable direct interest in illustrating the impact of the new techniques on particular industries.

The response by industry was on the whole quite good, but although much valuable and detailed information was collected on technical aspects, the economic information was rather scanty.

At the Study Group meeting, this was attributed by W. Rudoe (UK) to the absence of any one point in a normal industrial organization where the information required is centralized. The technical people, he said, do not know sufficient about the economics and financial side of the firm, and the financial people do not know enough about the technical aspects. However, all the countries which gave savings figures emphasized that the assessments were conservative, being confined in the main to directly measurable benefits, and making virtually no allowance for the indirect benefits, assessment of which presented difficulties.

The Canadian report noted that savings were difficult to estimate, as the availability of such information depends so much on the methods and details of book-keeping in the various industries and companies. The report adds that figures of dollar savings are incomplete and can reasonably be doubled, or more. "Apart from the methods of book-keeping which may make the recording of savings difficult, there are many cases where savings themselves are not obvious, as for instance the case of static eliminators where, under certain atmospheric conditions not uncommon in Canada, production becomes virtually impossible without the use of eliminators."

Although the survey proved that the direct cash savings resulting from the industrial use of radioisotopes are very substantial, these in many cases are outweighed by far by other benefits such as improved quality in the product.

The Agency's final report will be published in a couple of months and will give the over-all results of the survey. Meanwhile, some of the highlights of the national reports and of the meeting are worth recording.

Some Typical Cases

Gauging is the commonest of all industrial applications of radioisotopes today. It is employed to determine thickness of sheet material, the thickness of a coating such as paper or textile coated with plastic or abrasive, or steel plated with tin, the density of materials of constant thickness such as liquids or slurries in a pipe-line or tobacco in cigarettes, levels of solids or fluids in containers, bins or tanks, the elemental composition of certain materials, and the density of materials in large bulk, such as concrete, soil and rock strata.

Gauging is usually employed with continuous or semi-continuous processes. For industrial sheet materials, such as paper, plastics or metal strips, it replaces contact gauging, or periodical sampling of the material. Contact gauging is not practicable with certain products such as paper in the wet stage, or sheet metal which vibrates violently.

The isotope gauge gives a more precise control of the operation, which can thus be performed within closer tolerance and often with a lower average value than before. This means that less raw material is required for a given output. The interruptions and loss of output caused by sampling are avoided, and the gauge gives immediate warning of any departure from maximum tolerance, so averting waste production. Where production is frequently changed over to new specifications - as in paper-making - the isotope gauge permits a more rapid and precise adjustment of the machine to the new requirements.

Where level gauges are used, less supervision is usually required, with a saving in labour. There are some processes - notably in the chemical industry - which would not be possible without this aid. Gauges also make an important contribution to safety, by ensuring that the level of liquids in tanks is not too high or too low.

One of the most important gains from the use of isotope gauges is the improvement in the quality of the product which results in many cases. The Study Group meeting was told of some cigarette manufacturers who found when they installed density gauges that they could reduce the amount of tobacco used, because the cigarettes were more even in quality. They deliberately elected not to do so, however, preferring to pass on the whole of the benefit to the customer in the form of improved quality.

The investment in radioisotope gauges is often recovered in a few months. Poland reports a chemical company which installed level gauges on liquid ammonia separators, which paid back the investment in four months, and a metallurgical company recovered in three months the cost of thickness gauges installed on cold rolling mills. In the United Kingdom, a paper mill uses four transmission-type basis weight gauges, each using 25 millicuries of thallium-204. The total investment was £10 750, and running costs are small. When weight is changed on the machine the valve controlling the quantity of feedstock is re-set, and this used to be done by the operator, using his experience. His judgment proved at fault, and the sampling and weighing had to be repeated until the correct weight was established. One sampling, cutting and weighing operation might take about five minutes; during this time some five hundredweight of paper would be produced which might have to be scrapped. This weight change on two machines would cause at least £25 000 loss of production per annum which was avoided by the use of the isotope gauge. Other economies which cannot readily be calculated are the maintenance of correct weight thanks to the ability to spot changes immediately. This saves paper which might otherwise be rejected, and the saving is of the order of £35 000 per annum. The total saving of £60 000 implies that the investment in the gauges is amortized in just over two months.

One British chemical firm used a level gauge to determine the liquid profiles in absorber towers in operation. This revealed positions of flooding, so that chemical engineers were able to modify the towers to increase the throughput. It not only saved the building of two new towers at a capital cost of about £100 000 each, but enabled throughput to be increased six months earlier than would have been possible by building new ones - a gain of some £50 000. Thus a single gauge application saved the firm £250 000. The same firm uses a variety of density or level gauges with an estimated total annual saving of £300 000, for an annual investment of £5000.

In the glass industry a British firm making moulded glass containers uses level gauges to control the supply of raw materials into the furnace. The gauge operates an automatic control system to maintain a constant level in the furnace. Although the gauge works through about two feet of brick and refractory the control is normally better than 1/32 inch. This enables more accurate control of glass feeder temperature, and a constant weight of glass is delivered to the moulding machine, so increasing the uniformity of the product. The main advantage is that there is no interruption or interference with feeder operations; most other methods require some form of probe to be inserted. The total investment is £2650, annual costs £200, and annual savings estimated at £190 000.

In the United States, a potash manufacturer used radioisotope gauges to measure the density of salt solutions, and reported annual labour savings of $25 000, raw material savings of $20 000 and ten per cent increase in productivity worth $25 000. The gauge cost less than $900 a year.

£ 50 000 a Year for £ 7000

Ionization

Applications of radioisotopes based on the interaction of radiation with gases is useful in a variety of industrial applications, which were summarized at the meeting by C.G. Clayton (UK). He noted a continuous increase in the use of radioisotope smoke detectors, which have been approved by fire insurance committees in a number of countries. Gas chromatography is being applied in a wide range of industries and gas chromatographic columns incorporating ionization detectors are used in plant process control. Considerable extension of these uses may be expected, but meanwhile static charge elimination is the most important industrial application.

Belgium reported an important printery which publishes a monthly magazine of about 60 pages, some in four colours. Static electricity on the paper caused some deviation of the sheets, particularly significant when they were engaged by the colour cylinders and the folding-machine. This led to considerable rejections - up to 30 per cent - on account of printing out of register or faulty folding. A radioactive static eliminator brought the number of rejects down to the normal 3 to 4 per cent.

A British manufacturer of cellulose acetate yarn and plastics uses a radioisotope detector in gas chromatography as an aid in recovering solvents used in the process. The optimum economic working of the process depends on maintaining the correct balance between solvent recovery efficiency, steam consumption, and the rate of replacement of carbon-activated charcoal on which the solvents have been adsorbed. The isotope method saved £50 000 a year on a recovery plant with annual operating costs of about £250 000. The total investment of £7000 in isotope equipment includes 56 fire and smoke detectors, and running costs are £100 a year.

Massive Irradiation

Treatment of medical supplies is the most important application in this field, and P. Lévêque (France) considered that this use would continue to grow. The new methods of radiation sterilization have upset established ideas of preparation, such as the development of more compact packages. Sterilization of sealed packages also brought complete changes of manufacturing methods, such as the disposable plastic syringe. Close co-operation thus became essential between the manufacturer and the irradiation specialist.

Many applications of irradiation had been proposed, he said, but the industrial applications had so far been restricted. He listed eight industrial plants in the world, and of these five use accelerators and three gamma irradiation from cobalt-60. These applications are, however, on a significant scale, and include the production of polyethylene and ethyl bromide, the sterilization of goat hair used in carpet manufacture, and sterilization of medical supplies.

Although irradiation had helped the development of new chemical processes, chemists have usually quickly found ways of making products with equivalent qualities by very much cheaper, purely chemical processes. The possibilities of preserving food by radiation are being watched with interest, he added, and one might shortly expect practical results.

Radiography

Direct comparisons are difficult between gamma radiography, using radioisotope sources, and alternative methods such as X-rays and ultrasonic testing. Each has its own special advantages, so that to a large extent they must be regarded as complementary rather than competitive. Gamma radiography, however, is the only feasible method when inspection has to be carried out in places inaccessible to other forms of equipment - for example in a small tube.

For most materials in most factories, X-rays are better than radioactive sources for the same quality of result. With very thick materials, however, conventional machinery gives insufficient penetration, and then cobalt-60 sources compete advantageously because of their low capital cost. When only a few radiographs are made in a year, the long exposure times which usually make gamma radiation less efficient become unimportant, and panorama radiography will then be cheaper than X-rays, mainly because of decreased capital cost. Many small foundries prefer to test their daily production by overnight exposures in this way.

A British manufacturer of pressure vessels continuously uses eighteen cobalt-60 sources from 0.3 to 3.2 curies. The vessels must withstand the most severe conditions of temperature and pressure, and radioisotopes are used for two main purposes. The major purpose is to check the quality of the casting produced and to provide guidance on technique so that future products may be free from blemishes; the second is to ensure that castings leaving the foundry are of sufficient standard to pass right through the factory without interruption, no matter what further tests and inspections may be made.

Savings are then made in the following ways:

It was reported that no unsound castings are produced, thus saving labour and foundry materials;

Consequent saving of labour spent in producing castings rejects;

Minor faults in castings can be repaired while they can still be heat-treated, etc.;

Saving in machining time spent on producing bad castings;

Production programme can rely on quantities at the end of the cycle being identical with those at the beginning - hence more efficient production; and

Customer complaints and replacement of faulty parts eliminated.

The total investment is £52 000 and annual running costs £6000, but the annual saving is estimated at £500 000.

In a great many establishments, however, calculations of direct money savings are regarded as of minor or no importance. The benefits sought are the increase in the quality and reliability of the product, the objectives being customer satisfaction and safety in use.

Tracing

This embraces a wide field, as there is a great variety in the techniques in use, and also in the specific applications. There are many research applications of value to industry, such as investigation of chemical reactions, and wear studies. Radioisotope tracing has become an important aid to process control by such expedients as flow measurements, determination of wear in furnace linings, rapid location of pipe blockages and leaks, and checks on the completion of mixing processes. Industrial products can also be readily "tagged" for identification and age determination. Over a wider field, isotopes have proved their value for studies of ground and surface water, of air and water pollution, and of movement of sand or silt in rivers and estuaries.

The particular form of tracing known as activation analysis offers a method of great sensitivity, and holds the possibility of routine non-destructive analysis being carried out purely by means of radiation, no chemical processing whatever being involved. If this goal is attained, it will permit of rapid and continuous analyses "on stream" without any interference with production, and this would establish much closer control over production operations. An American company producing semi-conductor material determined trace impurities by this method and was able thereby to eliminate several manufacturing steps. The saving in time and equipment was estimated at $150 000 annually.

A French oil refinery established a radioisotope test bench for wear studies on automobile engine parts. The investment was 50 000 francs, and the annual savings 60 000 francs. Furthermore, results were obtained in a month which would have required more than a year by other methods. A preliminary study was made for a breakwater in a French harbour, and it was found that the length could be shortened by 200 metres, with a saving in construction cost of eight million francs. This was accomplished partly by studies of scale models and partly by radioisotope hydrological studies.

Future Applications

Some other radioisotope applications are being developed for specialized purposes, such as the nuclear batteries used to supply power in space satellites and weather stations. Isotope light sources may also prove useful for railway signals. But these do not, at present, seem likely to have any great industrial significance.

Looking to the future, E. E. Fowler (USA) told the Study Group that there was likely to be a steady extension of established industrial applications, which would be encouraged by the increased sensitivity of techniques and by the greater variety of radioactive preparations now available, which were also of greater purity.

Over the next ten years, he did not expect to see a large growth in the use of radiography, as no important new technology or new markets appeared to be emerging. The use of gauges appeared to be close to saturation point, but there could still be some extensions into new applications, and gauges of greater penetration could be developed. Tracing offered the greatest opportunity for expansion; it could be applied to many problems of industrial significance, and the rapid techniques of radio-analysis now being developed could have many industrial applications.

The economic contribution of radioisotopes should continue at about the same rate, apart from any major technical changes which might take place. The most likely field for such change was process radiation, which could open up "a new dimension in radioisotope use". It was being used for the production of chemicals and the modification of materials, Dr. Fowler continued, but instead of using radiation as an adjunct to established processes, the trend now was to look for products unique to radiation. Food preservation by radiation could be a major development. The United States had devoted a considerable effort to this, and the next decade might see important practical results emerge.