RADIOISOTOPE SAVINGS IN INDUSTRY AND AGRICULTURE

Benefits and savings achieved in industry and agriculture were described by leading experts from six different countries at a public discussion organized by the Agency on 24 September 1963, during the last IAEA General Conference. The speakers were:

Dr. Glenn T. Seaborg, Chairman, Atomic Energy Commission, USA;
Professor V.S. Emelyanov, Deputy Chairman, State Committee for the Utilization of Atomic Energy, USSR;
Dr. Charlie Fisher, Director, Radioisotope Department, Saclay, France;
Dr. A.R. Gopal-Ayengar, Director, Biology Group, Atomic Energy Establishment, India;
Dr. G.C. Laurence, President, Atomic Energy Control Board, Canada;
Dr. J. L. Putnam, Deputy Head, Wantage Research Laboratory, Atomic Energy Authority, United Kingdom.

Dr. H. Seligman, Deputy Director General of the IAEA in charge of Research and Isotopes, acted as moderator.

The opening statements of the speakers, which were followed by some questions and answers, were as follows.

GLENN T. SEABORG

It is satisfying to know that radioisotopes are now at work, paying their own way, in many uses throughout our nation. The contribution of these versatile by-products of the atomic age to our health, welfare and economy continues to grow in many respects. Their manifold uses are now so thoroughly interwoven through our lives that their net worth is very difficult to measure precisely. Some of the most valuable contributions are those that are the least amenable to evaluation - at least in monetary terms. For example, tracer atoms are giving us a new understanding of the dynamic processes of nature. What is this worth? If this could be accomplished by more conventional techniques we might credit the difference in costs to isotopes. But in most applications tracer isotopes are performing unique functions. The medical diagnostic and therapeutic contributions of radioisotopes also defy assessment. What is it worth to save a human life?

The indirect and intangible savings from isotopes are also of importance in industrial applications. Research short cuts enabled by tracer atoms are yielding very substantial savings in industry, but they seldom show up on a company's balance sheet. Neither do the savings in scientific man-hours which are so important in nations' progress today.

The material saved by radioisotope process control devices, and the reduction in losses due to rejected products, are quite tangible and substantial. On the other hand, the excellent quality control that nuclear gauges permit may have a far greater value. The consistency of product assured by isotope gauges and radiography results leads to such worth-while values, not amenable to monetary assessment, as dependability and safety in a wide variety of items, such as tyres, boilers, pressure vessels, ships and airplanes - to name just a few examples.

We hesitate to speculate on how much economic gain might be attributed to just one of our oldest isotope applications - nuclear oil-well logging. Many entire oilfields have been found or rejuvenated with the assistance of these techniques.

However, in spite of these limitations, it is possible to make some assessments, and we do have some direct cost-saving data that may serve as a reference point for comparing the true value of radioisotopes from time to time. For example, the Atomic Energy Commission conducted such an evaluation in 1958. A private business research organization in the United States - the National Industrial Conference Board - was asked to contact every licensed industrial isotope user in our nation to determine directly accountable savings due to their utilization of isotopes. Simultaneously, the Atomic Energy Commission carried out a broader study which included estimates of indirect savings and consumer benefits. The private survey identified about $40 000 000 in annual direct industrial savings to companies, and the Atomic Energy Commission study, including the indirect savings, estimated at least $400 000 000 per year in savings to the over-all national economy. This tenfold difference seems reasonable, considering the difference in the approaches and scope between the two methods of making the estimate.

Industrial isotope licences and sales have more than doubled in the last five years. Based on the 1958 studies this suggests that present over-all annual gross savings, both direct and indirect, from the industrial use of isotopes in the United States may be approaching the $1 000 000 000 level.

Measuring isotope savings due to agricultural uses also involves some uncertainties. Although a definite saving of $11 000 000 can be attributed to the screw-worm fly eradication programme in the southwestern United States, for how many years do we credit this saving to the isotope account? Further, how does one calculate the financial gain from the isotope research findings showing where water and fertilizer economy can be realized? Distinguishing and measuring such savings on the nation's farms would involve considerable effort and extrapolation. Still greater difficulty stems from our nation's great agricultural productivity. What is the saving from added grain production in the context of the United States' unique excess storage problem?

Glenn T. Seaborg

Such problems rule out direct savings as a criterion for estimating the contributions of isotopes to agriculture. Accordingly, the survey sponsored by the Atomic Energy Commission of savings in this area was carried out on the broader, indirect basis. The survey conducted in 1959 by the Stanford Research Institute estimated that a minimum of $180 000 000 savings a year would accrue to agriculture in the United States through 1980 as research findings are put to use. Economies in crop and livestock production discovered through radioisotope research are already perceptible in a few places - for example in the healthier, more fruitful plant mutants now in limited use. But innovation in agriculture takes time, and the benefits of isotope research have yet to reach full application on our nation's farms.

The markets remain plentiful for all of the more common industrial isotope applications now in use. On this basis, we expect isotopes at least to continue the current rate of increase in benefits for the foreseeable future. However, based on new technology now moving towards commercialization, we may expect a marked acceleration in utilization with commensurate increased economic benefits during the next five years.

In particular, we should see substantial savings added from process use of radiation. This area has been slow in showing its true value because of the time-consuming research and development which is a prerequisite to such applications. However, some isotope radiation facilities are now "on-stream" producing or modifying various chemicals and plastics, and more are scheduled to follow soon.

Our programmes to develop radiation for pasteurization of some products and sterilization of other products will also enter the savings picture soon, and should contribute significantly in the next few years. In the case of food, the immediate goal of the Commission's initial effort is to demonstrate economic advantage in radiation pasteurization of fruit and fish. We think savings will accrue from extended shelf life, reduced spoilage, decreased shipping costs and expanded markets.

The food preservation programme illustrates how the Atomic Energy Commission works in concert with private industry and other government agencies to accelerate the benefits of nuclear technology. Much of our Isotope Development Programme effort necessarily involves development and extension of isotope technology at the laboratory stage. But to encourage private industry to pick up these developments and bring them to bear on the economy often requires that we carry them through to practical demonstration. We find this approach most fruitful if carried out in co-operation with the agency or private industry which will actually use the isotopes.

A further example is a device employed in the forward scatter of beta particles. This instrument has recently been carried by balloon into the upper atmosphere and has successfully telemetred back the true density of the rarefied air. The United States Weather Bureau is co-operating and co-sponsoring this work for obvious reasons. The industrial interest in the vacuum-sensing applications of the system has also been made clear.

We are also confident that the extensive isotopic power development programme now being carried on by the Atomic Energy Commission in co-operation with other government agencies will eventually find industrial uses, such as commercial space communication. In summary, then, the contribution of agricultural and industrial applications of isotopes in our nation has approximately doubled in the last five years, and we look for perhaps an increased trend in the next five years. We are encouraged by this picture, but we cannot be complacent in view of the very great untapped potential that remains.

VASILY S. EMELYANOV

The prospects afforded by the use of radioisotopes in industry as a result of the development of nuclear reactors can be likened to a large and very rich deposit of gold. The deposit needs only to be worked with skill; but in this case the gold prospectors must possess a great deal of knowledge, for their traditional skills are by no means adequate for work with radioisotopes.

The theme of today's discussion is "savings in industry and agriculture through the use of radioisotopes". That the use of radioisotopes results in savings - sometimes very substantial - is by now well known, although it is often difficult to estimate the exact amount saved. This point has already been referred to here, notably by Dr. Seaborg. In the Soviet Union, radioisotopes are used by many organizations in the most varied branches of science and technology, and which are concerned with different spheres of human endeavour.

In metallurgy, isotopes are used to follow the movements of materials in blast furnaces, in order to ensure an even flow of the materials within the furnace and a uniform distribution of furnace gases. Efficient operation of the furnaces is thus guaranteed, and in the long run this will make it possible to institute automatic control of the whole process and to obtain a correspondingly high level of productivity from smelting plants. In plate and strip rolling for pipe production, radioisotopes are used to measure thickness. The method enables the thickness of the metal to be checked without reducing the speed of the rolling process, and this in turn leads to increased productivity of the rolling mills. The quality of castings of metals and alloys can also be controlled with the help of radioisotopes. In the Soviet Union, they are also widely used in welding.

The chemical industry, too, is using radiation sources more and more extensively for the mechanization and automation of production processes. Isotopes can be used to ensure correct proportioning of the powdered and liquid components which go into a factory's products. Pressure, density, levels, temperatures and many other factors can be controlled.

In geological exploration, isotopes provide an exceptionally keen and sensitive eye, as it were, which helps the geologist to find useful minerals. In the Soviet Union, neutron logging has been especially valuable in petroleum prospecting, for it has not only led to the discovery of new petroleum deposits, but has enabled many abandoned oil wells to be returned to operation.

Biology, medicine and agriculture are among the many spheres of endeavour in the Soviet Union which have profited by the extensive use of radioisotopes. In pure scientific research, isotopes provide an invaluable experimental tool, permitting delicate biochemical processes to be observed and understood in a way which research workers of the past would never have dreamed possible; but in addition isotopes are now used in many experiments of immediate practical significance. We can determine how to apply fertilizers most effectively to the soil, by marking them with radioisotopes. Irradiation of grain destroys pests and preserves the grain. Irradiation of seed before sowing increases the yield of certain crops, and sometimes the useful portion of the plant can be increased by irradiation. Our research has shown, for example, that the sugar content of sugar beet, the carotin content of carrots, and so forth, can be increased. To be sure, the use of radioactivity in agriculture and in biological research is an extremely complex matter, as many different factors are simultaneously at work; this is something that must not be overlooked.

V.S. Emelyanov

One of the characteristic features of our recent work with radioisotopes has been their use in conjunction with other achievements of contemporary technology. The use of radioisotopes is an important contribution towards the automation and mechanization of many industrial processes. We have been making a special effort to introduce automation in types of work where human labour is especially unpleasant and burdensome - for the extraction, crushing, and transport of ores and coal, for example, we are introducing automatic machines. In one of the new large mining combines in the Ukraine - the Krivorozh iron-ore combine - hundreds of machines have been installed for the grinding and crushing of the iron ore; and these machines, which control the ore supply and direct it on its path from one mechanical device to the next, are based on the use of radioisotopes. In work such as this radioisotopes serve as strict and relentless checkers, which release human beings from unpleasant and exhausting labour.

It has now become hard to enumerate the fields in which radioactivity is being used with success;

indeed, it would be easier to state where it is not being used - although even this is not easy, because areas in which isotopes are not being used are becoming harder and harder to find. The Latvian Soviet Socialist Republic provides a good illustration of how isotopes are being used in the Soviet Union today. Latvia is a small republic, but isotopes are used in more than 70 enterprises, including the coal mines, cement and sugar factories, plywood factories, as well as factories making gramophone records, radio equipment and even confectionery. About a month and a half ago I visited a pastry factory where radioisotopes automatically check and regulate the temperature of the ovens which produce the pastry. This surely is one of the most peaceful spheres of human activity.

It is hard to estimate in figures the enormous benefit brought by the use of isotopes. However, the fact that they are being used in more and more new fields speaks for itself. We have tried to calculate the savings arising from the use of radioisotopes and our calculations, though far from complete, have yielded figures of hundreds of millions of roubles per year.

I should like to mention one more example of how isotopes can be turned to good use - an example that has just come to my mind. In the Soviet Union's textile and cinematograph film manufacturing industries, isotopes have gained extraordinarily wide favour as a means of removing static electricity. The difficulties which used to be caused by the accumulation of static electricity on parts of the machine are thus being banished, and the productivity of the machinery accordingly increased.

In conclusion, let me emphasize once more that the use of radioisotopes is a highly promising achievement of physics and radiochemistry. I should like to encourage the International Atomic Energy Agency to devote even greater efforts to furthering its development.

CHARLIE FISHER

For my part, I should like to refer mainly to the need - if the use of radioisotopes is to be rapidly expanded - to ensure good relations between the national bodies which are in general the producers of the radioisotopes and the many users who, between them, represent a wide range of problems. I should like to tell you something about our experience in France where atomic energy activities are rather highly centralized.

Conventional information media, lectures and technical publications are used to familiarize engineers who have ordinary engineering training with the special techniques involved in using radioisotopes; special courses are also given. However, if the use of radioisotopes is to be rapidly expanded, it would appear that the most direct way to rapid results is by the contacts established with the specialized technical bodies or the manufacturers of radioisotope equipment; having, at the same time, within the national organization (in France the Commissariat à l'énergie atomique), a study group, specialized in radioisotope applications, to whom users can go with their problems and discuss the particular uses in which they are interested.

There is such an enormous range of possible applications that most of the development work on radioisotopes must be transferred as quickly as possible outside the national atomic energy commissions: an expert in radioactivity cannot at the same time be an expert in metallurgy, an expert in public works

Charlie Fisher

and an expert in hydrology. Hence the need for establishing close contacts between the different technical branches. In France certain applications have long since passed entirely into private hands, e. g. gamma ray radiography and the use of different types of gauge for measuring thickness, levels or density. These techniques represent by far the greater part of the applications, and through them are obtained the major savings that are due to the use of radioisotopes.

However, it has appeared necessary to direct part of the centralized work of the Commissariat to other sectors where developments are taking place, and I should like to give you a few examples.

In hydrology and hydraulics, radioisotopes offer the ideal way of following the course of underground water, measuring the flow of rivers and tracing the movement of sands. It is obviously difficult to put a value on what is gained in this way, and a great deal of technical progress will be necessary for the extension of these applications.

We have taken up the study of specific types of gauge, and especially gauges which use radiation to stimulate the rays which identify the presence of a given element and so permit a kind of non-destructive analysis.

Activation analysis is another technique from which great things are expected, and a good deal of research and development is being carried on. The elements to be investigated are made radioactive so that their presence can be detected and measured; the technique is highly sensitive and permits rapid analysis in cases which it would be extremely difficult to handle by the ordinary chemical methods.

Finally, research connected with the use of radiation from large sources is concentrating on the development or improvement of methods of dosimetry, measurement and protection so as to develop a kind of technology for industrial facilities.

To show you how we work with industry in France, I may tell you that there is a group of large-scale chemical firms who utilize radiation effects. The Commissariat had several tens of thousands of curies of cobalt placed in the facility constructed by this group. This quantity has grown with time and thus collaboration has been established between the Commissariat and private interests with a view to the joint operation of their common facilities.

Something similar has been done in regard to activation analysis in order to provide industrialists with laboratories which can do activation analyses on a purely routine basis.

As a result of all this, the number of radioisotope users is growing steadily at the rate of about 20 per cent each year, mainly in connection with the very common uses of radioisotopes; it always takes some time before very novel types of gauge or new tracer uses enter into current practice.

A study made in France on savings made thanks to the use of radioisotopes gives the following results for 1961. What Dr. Seaborg refers to as direct savings amounted to 40 million francs, of which 90 per cent is accounted for by gamma radiography or gauges. We found it would be very difficult to make an estimate of the savings regularly made thanks to the use of tracers, but individual tracer applications are known which provide savings of the same order of magnitude.

My personal view is that a great deal has still to be done in developing radioisotopes and their uses, and I hope that, through co-operation with the Agency, this development will be large-scale, since the potential applications are almost unlimited.

A. R. GOPAL-AYENGAR

After referring generally to the great versatility of radioisotopes and the important contributions they were making to improved production and enlarged knowledge, Dr. Gopal-Ayengar said that the subject of savings in agriculture by the use of radioisotopes was of special significance to India, whose economy was predominantly agricultural. He pointed to the great savings resulting from the eradication of the screw-worm fly in the United States by the sterile male technique, and to the important savings which might be effected if knowledge gained through radioisotopes were to reduce the incidence of coccidiosis - a parasitic disease of poultry, cattle and sheep. He continued:

The sterile male technique has found many useful applications. Studies have been made under the East African Tsetse Organisation of Uganda and the London School of Tropical Medicine and Hygiene on one of the most dangerous insects - the tsetse fly, which has made about 4½ million square metres virtually uninhabitable. The sterile male technique has also been used for the control of the Mediterranean fruit fly, which infests a variety of fruits.

Control of insects in flour, grain and meal is also of considerable importance. Insect infestation results in a tremendous loss of stored flour, grain and cereal products. The granary weevil, flour beetle and the lesser grain borer are perhaps the most damaging insects to flour, prepared cereal products and grains. In the USA the loss due to insects is estimated to be $4 000 000 000 in addition to the cost of insecticides and fumigants, used in the order of 300 million pounds per year. Moreover, chemical fumigation may be effective on larval or adult insects but not on the insect eggs, unless fumigation is repeated to destroy insects hatched from eggs. Gamma radiation from a cobalt-60 source has a great advantage over chemical fumigation in that it sterilizes the eggs as well as the adult insect. Radioisotopes have become indispensable in giving us knowledge of the biochemistry and physiology of insects, migration and living habits, feeding habits, and mode of action of DDT and other insecticides.

Radioisotopes have found considerable use in the selective breeding of dairy cattle. Through studies involving an isotope of iodine (iodine-131) an attempt is being made to correlate thyroid function with the level of milk production. This information is used as a basis for selecting heat-tolerant strains of cows for breeding.

Let us now take the savings in agriculture from plant nutrition, plant physiology and plant mutation studies. Measured by increased productivity, the economic benefits ultimately derived from agricultural research are of considerable value. An estimated one half of the world's inhabitants now suffer from hunger, and world population is increasing with great rapidity. There are several hazards which can thwart agricultural production. Control and eventual elimination of causes of production losses are the goal of many research projects, and an estimate of potential savings in agriculture and industry can be made which (in spite of inadequate statistical information) is indeed considerable. Fundamental research using nuclear tools has devised successful measures to combat these losses. The problems of agricultural losses due to diseases are being solved by creating disease-resisting mutants, by controlling or eliminating disease-carrying insects and by learning more about nutritional requirements. The problems of losses due to weeds are being solved by soil studies and by developing newer and effective herbicides.

A.R. Gopal-Ayengar

In plant physiological studies there are considerable savings, as also from fertilizer applications. Using radioisotope tracer techniques, fertilizer and soil studies have helped to determine different plant requirements under varied conditions. Knowledge of the proper kind, amount and placement of fertilizer for different plants under different conditions has helped new practices in root and foliar feeding. Study of the mode of entry, distribution and action of plant regulators has developed information used to prevent pre-harvest drop of fruit, and to control flowering and fruiting. Herbicides - one of the important discoveries of agriculture - have been developed with the help of tracer techniques. These discoveries have direct bearing in increasing agricultural productivity. For example, by efficient utilization of phosphate fertilizers, an increase in the yield of sugar-beet, barley and potatoes by 20 per cent, and that of alfalfa by 50 to 75 per cent, will bring annual benefit to the tune of several million dollars from these crops alone.

Applications in food industry are also important. Although the economics of radiation preservation of foods is still at an early stage of development, it appears that the process is useful and practical. Several applications of radiation and radioisotopes have received recognition. Some of these aim at preventing losses of stored food through weevils and other insect pests, extending the shelf-life of fish, poultry, meat and vegetables, inhibiting potato sprouts, and replacing conventional methods of sterilization and pasteurization which cause extensive degradation of essential nutrients. As a public health measure, radiation can be used for the control of food-borne diseases such as tuberculosis, anthrax, brucellosis, salmonellosis, etc., as well as infections produced by animal parasites such as tapeworms and infections produced by fungi and protozoa.

The use of radiotracers to measure water flow and to study bed movement in rivers provides data for the design of dams, and therefore contributes a great deal towards the welfare of a nation as a whole, rather than contributing from a commercial point of view. Data obtained by the use of radioisotopes on movement of silt in various ports - I am referring here particularly to certain experiments carried out in the ports of Bombay and Cochin - have resulted in the sites for the dumping of dredged silt being altered, which has reduced the cost of maintaining the shipping channels. Savings resulting from reduced siltation can only be assessed after many years. Similar experiments are being conducted in the River Hooghly, the estuary of the River Ganges, which are likely to provide valuable data for improving navigation.

The movement of silt in the ports of Bombay, Cochin and Karwar and the estuary of Calcutta has been studied with the help of scandium-46 and gold-198. With scandium-46, which has a half-life of 84 days, it has been possible to study movements throughout the year, and data have been obtained to suggest suitable sites for dumping dredged silt. This has brought about considerable savings, estimated at over a million rupees. It is hoped that similar studies which are in progress to improve the navigation channel in the River Hooghly will effect considerable savings for the Calcutta port as well.

The use of radioisotopes in India is increasing rapidly, as can be seen by the number of consignments utilized for industrial purposes. These have increased eightfold during the last three years. They are being used in steel mills, in sheet metal rolling mills and for industrial radiography. Direct financial gains from the use of radioisotopes are estimated to be about 2 000 000 rupees.

In conclusion, Dr. Gopal-Ayengar referred to the Indian population problem, and the need to utilize any factor which might help to eliminate waste and step up productivity.

G. C. LAURENCE

The oldest applications, the most developed, the most important applications of radioisotopes have been those which have required fairly strong sources.

I am thinking, of course, of the treatment of cancer and of the use of radium in the inspection - the radiographic inspection - of castings and other objects in industry. The most promising new developments at this time seem to be in the irradiation of organic materials, such as in the sterilization of medical supplies, the treatment of foodstuffs to prevent the growth of sprouts and destroy parasites and bacteriological contaminations, and many other applications, which have been mentioned by my colleagues on the panel. All of these applications require very strong sources of radiation - i.e. blocks of radioactive material that emit radiation strongly. For this reason, our scientists in Canada have been giving most attention to these applications which require the strong sources. Another reason, I expect, for their interest in these applications is probably that heavy-water-moderated reactors are particularly suitable for the production of these highly concentrated radioactive sources, not only because their neutron flux is fairly high, but also because there is ample space in these reactors to expose materials in this high flux.

G.C. Laurence

Before 1951, the most powerful radioactive sources that we had available for industrial inspection and for the treatment of cancer were of radium, and it was only rarely that they were as strong as one curie; but in 1951 a source of 1000 curies was produced at Chalk River in our NRX reactor and supplied to Dr. Ivan Smith in London, Canada. That was the first cobalt bomb. Nowadays, cobalt units which contain sources of up to 9000 curies are being produced both for therapy and for industrial radiography and other uses in industry. These numbers mean very little perhaps to the layman, but to the radiologist who had been using only one curie of radium before the War they are most significant. They enable him to treat many more patients during the day, and to treat them with much better control of radiation. They have a similar advantage in industry, because they make it possible to complete the radiography of castings, weldings and other objects much more quickly than was possible some years ago. For the treatment of cancer as well as for radiographic inspection in industry it is important not only that the source be strong, but also that it be highly concentrated - concentrated in a small volume. When a concentrated source is used in cancer therapy, it is easier to confine the radiation to the diseased regions, and in this way reduce undesirable exposure to healthy tissues around the tumour. Also in industrial radiography highly concentrated sources are desirable. They produce radiographic images of much sharper definition - they make clearer pictures. The cobalt-60 sources which are now being produced in our NRU reactor have concentrations of up to 1100 curies per cubic centimetre. Cobalt-60 is used for the radiography of large castings of steel, iron and copper. For smaller objects iridium-192 is used, because its radiation is less penetrating, and therefore detects small flaws in objects much more easily. Other isotopes which have even less penetrating power are suitable for the radiography of thin sheets of metal or for castings of light alloys of aluminium and magnesium.

It is very difficult to describe in dollar value the savings that are made possible in industrial radiography. Very often no other methods of inspection are available by which it is possible to find hidden defects in objects without destroying them. The most important saving, of course, is by avoiding the losses which might result from costly accidents caused by the failure of structural parts that are defective. For this reason industrial radiography is a mandatory requirement in many kinds of manufacturing construction, and its use is increasing rapidly.

For some purposes, such as irradiation of agricultural produce, it is not necessary that the radioactive source be concentrated in a small space. It is often desirable to distribute a large number of radioactive sources over the walls of a small box in which objects to be irradiated can be placed. For such purposes it is more economical to use cobalt-60 that is not so highly concentrated. Weaker concentrations of cobalt-60 are available in forms which can cost as low as one dollar per curie. A large irradiator containing an arrangement of this kind is now being built which will be used for the irradiation of medical sutures and will contain 60 000 curies of cobalt-60. Apparatus of this kind can be used for many applications, such as the sterilization of medical supplies and the treatment of agricultural produce to destroy parasites and diseases.

One very promising application in this field is the prevention of the growth of sprouts in potatoes. When potatoes are stored for several months before they are consumed they germinate - i.e. sprouts grow, and draw nourishment from the potato, and this causes changes which are detrimental to the potato as food. It has been demonstrated that this can be prevented by irradiation. A large unit for the irradiation of potatoes was built and mounted on a trailer, so that it could be moved about the country. It contains 18 000 curies of cobalt-60. The potatoes in this machine are moved in buckets by a conveyor system. About 1000 kilograms of potatoes go through in one hour, during which they receive an exposure of 8000 roentgen. This exposure is sufficient to prevent the sprouting of the potatoes. Last year this trailer was moved from place to place across our country - moved a distance of about 64 000 kilometres. About 400 tons of potatoes were irradiated. Sprouting was prevented and the irradiation had no harmful effect on the quality or on the attractiveness of potatoes as food. This demonstration has been so successful that it is expected that much more extensive use will be made of it in Canada in the future.

The possibility of using similar equipment for irradiation of perishable fruit, such as strawberries, is being investigated in collaboration with our Department of Agriculture and also the Department of Agriculture of the United States. Other uses are in the sterilization of sea food - shellfish of various kinds, and lobsters - as well as bacon and prepared meats. The method will be used at first with the more expensive foods, like those that I have just mentioned, because the exposures required for many of these purposes are somewhat higher than that required to prevent sprouting in potatoes. For a thorough sterilization to destroy all bacteria in some foods, three to four million roentgen may be required, and the cost at present may be up to $40 per ton of food irradiated. But in some foods much smaller exposures are quite useful and quite within the economic range. The exposures required to destroy parasites such as weevils in rice, and other insects and larvae in grain generally, are smaller and the costs correspondingly lower. Twenty thousand roentgens is effective in controlling trichinosis in pork and tapeworm in beef. Exposures at present costing a few dollars per ton will increase from one week to several weeks the time for which meats or sea food can be kept at moderate temperature on the shelf without serious deterioration.

The success already achieved in preventing sprouting in onions and potatoes, and in increasing shelf life of many other foodstuffs, is giving us confidence that, as the costs of these radioactive materials gradually come down, and new applications are found, the use of radioactive materials for food preservation will become of very great importance.

J. L. PUTNAM

It is evident that some of the main gains of the type we have been considering - some of the easily accessible gains - accrue from the use of isotopes in industry, that is by industrial countries. To determine how much material you are saving in a manufacturing process simply by measuring the amount used before and after employing an isotope technique, and to put a money figure against it, is much easier than to assess how much it may be worth to make the whole of an unproductive arid zone agriculturally productive. I am not an agriculturalist, so I would not know what is involved in doing this, but I do know that a greater interest is being taken all over the world in hydrological problems. Even in Britain, where we may be considered to suffer from no shortage of water, the conservation of water is being taken much more seriously. Isotope methods are being used hydrologically to determine the flow of our rivers and the available water supplies, especially in our centres of population.

Turning then to the industrial savings, I would like to say that most of the applications which you have heard described we employ as well. In Britain too the number of users has approximately doubled over the last five years, since we made the last economic survey. For example, in the use of isotope gauges for process control, there are now about 1000 gauges used by industrial concerns in the country, compared with 600 in 1958. The sort of saving made - particularly in the paper industry - is shown by an example given by one paper manufacturer. He claims that he saves 300 kilograms of paper and fifteen minutes of operating time every time he changes the basic weight - i.e. the thickness of the material he is producing. This manufacturer is saving some $14 000 to $20 000 a year on each machine, which means that each machine pays for itself in something like six months. Figures like this are fairly easy to quote in the hope of convincing manufacturers that they should use isotope techniques to their own advantage, because manufacturers understand financial gains of this kind and are usually ready to make them.

What is less easy to assess is the way in which isotopes may to a very great extent benefit the economy of the country, and a number of people have estimated that the ratio between these financially assessable savings and the real economic advantage to the country is something like a factor of ten. An example of this is in the coal industry in Britain, on which we still depend to a certain extent. The coal industry has enjoyed a period of mechanization and improvement over the last few years, with the striking result that it has made a profit for the first time in a very long period. One of the contributory factors has been the development of new machines for mining coal. Two of these new machines - the Midget Miner and the Collins Miner, which are particularly useful for difficult seams of coal - both rely on automatic control by the use of radioisotope gamma ray gauges. They are controlled in this way so that they cut coal to within about one inch ($2\frac{1}{2}$ cm) of the shale or rock on which it is lying, which would still further debase the value of the coal. This method ensures that the coal is not mixed with shale, which might otherwise be cut if there were not this automatic control.

J.L. Putnam

Another point is the transfer of advantage from the user of isotopes to other people. In fact, the advantages of isotopes as used in research are very often passed on in this way, so that the eventual beneficiaries are not the users of the isotopes, but the people who use their products. For example, two oil firms researching with radioisotopes on lubrication problems in our country were able to speed up the research in the wear-rate of engine components to such an extent that in six months they were able to develop new oil additives with greatly improved properties, which would otherwise have taken eight to ten years to produce. It is plain that with these new oil additives the life of a motor-car engine is increased by a factor of something like four. Now, economists will be able to question the validity of this as an advantage to the motor-car manufacturer who would like to sell more engines, but to the eventual user it represents an improvement in the standard of living.

There are other ways in which improved quality and improved precision in manufacture can be turned to advantage, and I am not sure that they are being completely turned to advantage yet. One of these is in the production of metal sheets of precise thickness. The greatest advantage can only be obtained from this if the designers of equipment and machines using these metal sheets specify more closely the thickness of sheets which they require for production. For example, in car manufacture one can now safely use a thinner gauge of sheet for the car body, thus making the car lighter without the danger that underweight sheets (produced because of wide tolerances) may make the car unsafe. The quality is improved, and so again the user benefits.

It is true also that, where the application of isotope techniques speeds or makes easier a manufacturing process, the cost of the process to the producer is reduced. In a competitive economy - and I believe in other economies as well - it is inevitable that this reduction in the cost of production will eventually find its way to the consumer in the shape of a reduced price - or at least prevention of increase in the price of a better article - so that again the standard of living is put up, and in fact many of these industrial savings do not show up as financial savings. In the last survey we made, one user of gamma radiography actually reported that he was making a loss by using isotope techniques as compared with previous techniques, because whereas before he did not test his products, now he did, and it cost him money to do it. But how much he was gaining in goodwill, and how much the user of the product was gaining in a safer and more reliable product, is not, of course, recorded in the statistics of this survey.

Finally, I would like to mention that the standard of living (which is, I admit, somewhat outside the scope of this discussion) does itself have repercussions on productivity. Medical applications do in fact have an important economic aspect, not merely because happy workers are more productive workers, but if the worker's time in hospital and sick time are reduced, he is freer and able to produce more per year of man effort. Improved techniques of diagnosis using radioactive iodine and the reduction of post-operative infection by the use of sterilized hypodermic syringes (which are now coming into use in large quantities from the two large plants erected in the United Kingdom) are typical of the methods contributing to this improvement.