Radio-isotopes in Australian Industry and Research

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INTRODUCTION

Radio-isotopes play a very prominent part in industry in the United States, the United Kingdom and other highly industrialised countries. These countries also use radio-isotopes, mainly as tracers, very extensively in basic and applied research, and in clinical medicine. Australian industry and research has been relatively slow to accept these new techniques, as illustrated by statistics in Table 1.

The relatively low figure for the U.S.A. can be explained by their national policy in radio-isotope production. In general, United States shipments from Oak Ridge are individually larger in quantity than the U.K. shipments. Many United States shipments are bulk supplies for commercial firms, who split them up for sale to the user in much smaller units. The United Kingdom organisations at Harwell and Amersham sell direct to the user, or in a form ready for use in almost all cases. Also, small shipments under general licence are not included in the U.S.A. data. If the U.S.A. figures were on the same basis as the United Kingdom data, the number of shipments per unit of population figure would be much larger than indicated in Table 1.

TABLE 1.—COMPARATIVE UTILIZATION OF RADIO-ISOTOPES IN RECENT YEARS.

Field of application	Number of Shipments Used			
	Australia (1/7/56-30/6/57) (a)	New Zealand (1/4/56-31/3/57) (b)	United Kingdom (1/4/55-31/3/56) (c)	U.S.A. (1/1/57-31/5/57) (d)
Medical	182	110	8,226	—
Industrial	41	23	1,684	—
Research	207		4,860	—
Total	430	132	14,770	6,019 (5 months only)
Shipments per million of population per annum	44	60	288	84

(a) Annual Report of Commonwealth X-Ray & Radium Laboratories, Melbourne, Australia for year ended 30th June, 1957.
(b) Report of Director, Dominion X-Ray & Radium Laboratory, Christchurch, New Zealand for year ended 31st March, 1957.
(c) Second Annual Report of the United Kingdom Atomic Energy Authority, 1955-1956.
(d) Major Activities in the Atomic Energy Programs. U.S.A.E.C. January to June, 1957.

Because a large proportion of the shipments to Australia and New Zealand are from the United Kingdom, the figures for these three countries can be accurately compared. New Zealand exceeds Australia in isotope application on a population unit basis, but it is clear that this is due to a greater use in medicine, and the industrial and research uses are few. The table shows very well the relatively small use of radio-isotopes in Australia at present, in comparison with the British usage.

Extensive exploitation of radio-isotopes, particularly in industry, has progressed more rapidly in countries which have had their own atomic energy projects for a number of years. These countries, particularly the United Kingdom and the U.S.A., have had Government-sponsored advisory services attached to their atomic energy projects. These services assist industry in methods of application, correct handling, and health procedures etc. The U.S.A. also has a large number of private consultants actively engaged in radio-isotope techniques in industry. These services are supported by local isotope production, and a thriving and competitive group of equipment suppliers. Until recently, Australia has had no atomic energy project, has not yet a local supply of radio-isotopes, and depends almost entirely on overseas supplies for industrial isotope equipment. These factors probably explain, with the relatively smaller potential industrial demand, why Australian industry has been hesitant to use radio-isotope techniques. Also, a lack of competition in the last few years in many Australian industries is almost certainly a factor. Nevertheless, the use of radio-isotopes in Australian industry and research has been increasing and has shown a rapid rise during the past year.

*Australian Atomic Energy Commission, Research Establishment, Lucas Heights. Manuscript received March 20, 1958.

TABLE 2. — SURVEY OF AUSTRALIAN RADIO-ISOTOPE IMPORTS FOR INDUSTRIAL PURPOSES (OCTOBER, 1951, TO JUNE, 1957) (a).

Year 1st July to 30th June	1951-53(b)	1953-54	1954-55	1955-56	1956-57	INDUSTRIAL USE
Iridium 192	3	11	12	14	23	γ-radiography
Cobalt 60	10	5	3	6	2	γ-radiography
Caesium 137	—	—	3	2	—	γ-radiography
Strontium 90	1	1	2	3	5	Thickness gauging and weight control.
Thallium 204	—	—	5	2	9	Thickness gauging
Krypton 85	—	—	—	—	1	Thickness gauging
Rubidium 86	—	1	1	—	—	Industrial investigation
Mercury 203	—	—	—	—	1	Industrial investigation
Total	14	18	26	27	41	

* The radiography source imports for 1957-58 are already in excess of 1956-57 figures (28 shipments to March, 1958).

(a) Data in Tables 2, 4 and 5 obtained from Commonwealth X-Ray and Radium Laboratory Annual Reports for 1951-1957 and further information kindly supplied by the above laboratory.

(b) October, 1951, to June, 1953.

THE DEVELOPMENT OF RADIO-ISOTOPE USAGE IN AUSTRALIA — 1951 TO 1957

Table 2 shows the industrial imports analysed in detail. This shows clearly an increasing and broader use of radio-isotopes in the past two years.

Gamma radiography, in which the gamma-radiation from iridium 192, cobalt 60, caesium 137 or thulium 170 is used for industrial radiography, was established fairly early. This is probably due to the simplicity of the process and the equipment required. However, there has been a marked increase lately in iridium 192 radiography, which is rapidly becoming the most popular here and abroad, because of its favourable radiation spectrum which helps to overcome the disadvantage of its short effective life. A thulium 170 radiographic source was recently imported by the A.A.E.C.

Another feature of Table 2 is the recent increase in beta-ray thickness gauges, using strontium 90, thallium 204, and krypton 85, which are only now becoming established, even in the traditional overseas fields such as paper making, sheet rolling, and cigarette density gauges.

It is interesting to note here, for comparative purposes, the total number of users of industrial isotope equipment in the U.S.A. at November 30, 1956.

TABLE 3.—INDUSTRIAL ISOTOPES IN U.S.A., NOVEMBER 30, 1956.*

Application	Approximate number of licensed users
Beta-ray thickness gauges	840
Beta-ray cigarette density gauges	2,200
Miscellaneous density gauges	300
Gamma-radiography	500

The annual saving to industry in the U.S.A.* from isotope applications was estimated to be about $391 million in 1956. Nearly one-third of this results from the first three items in Table 3, but tracer application in oil well stimulation alone amounts for more than one-third.

On the research side, the use of isotopes in Australia shows the same trends as the industrial uses (Table 4). The steady rise of about 45 per cent. per annum to 1956 was almost doubled last year. There is also a steady increase in the number of different isotopes and the total activity imported. Only eight of the 207 imports in 1956-57 were used in industrial laboratories—the balance went to universities and government research organisations.

The principal isotope used in biochemical and organic research is carbon 14 and C14 labelled compounds. Table 5 shows the use of such compounds, indicating a recent rapid rise. The quantities of carbon 14 imported head the list for all research isotopes. This is in agreement with experience in other countries in the use of this tremendously valuable tracer.

During the past 18 months the Isotopes Section of the A.A.E.C. has operated an advisory service to industry and research, and the records of this service also indicate an increasing interest.

The range of interest in these inquiries is shown by the analysis in Table 7.

DETAILS OF INDUSTRIAL INSTALLATIONS

Beta-ray thickness gauges

As mentioned earlier, one of the most valuable and widely used applications of beta-emitting radio-isotopes is in the measurement and control of the thickness or weight per unit area of continuously produced sheet materials. The gauge depends on the appreciable quantitative attenuation of beta-radiation by relatively small amounts of solid matter.

* Major activities in the Atomic Energy Programs. U.S.A.E.C., January to June, 1957.

TABLE 4. DETAILS OF RADIO-ISOTOPES IMPORTED FOR RESEARCH PURPOSES. (OCTOBER 1951 to JUNE 1957.)

Year 1st July to 30th June	1951-53 (e)	1953-54	1954-55	1955-56	1956-57
Total Imports	39	52	84	116	207
Number of Different Isotopes	17	21	22	32	35
Total Activity (mc)	287	234	1100 (a)	1232 (b)	9252 (c) (d)

(a) Includes 400 mc Cr51, 235 mc Tm170 each in one source

(b) Includes 1,000 mc Sb/Be neutron source

(c) Includes 5,238 mc Co60 & 2,000 mc H3 in single sources and a 1,000 mc Sb/Be neutron source.

(d) A 500c Co60 source was also imported by N.S.W. University of Technology in 1956-57.

(e) October 1951 to June, 1953.

TABLE 5.—DETAILS OF CARBON 14 COMPOUNDS IMPORTED INTO AUSTRALIA FOR RESEARCH PURPOSES (OCTOBER, 1951, TO JUNE, 1957).

Year (1st July to 30th June)	1951-53(a)	1953-54	1954-55	1955-56	1956-57
Total imports	13	15	41	47	76
Number of different compounds	8	12	22	31	44
Total C14 activity (mc)	11	27	34	29	46

(a) October, 1951, to June, 1953.

Probably the first application of such a gauge in Australia was in the measurement of weight per unit area of rubber-coated fabric by a Sydney rubber company. This gauge has two strontium 90 measuring heads, which can be compared with a standard head containing a correct weight sample. The unit is still in operation after five years.

In line with overseas experience, the paper and allied products industry is now one of the major users of beta-gauges. They are fitted to paper machines owned by manufacturers in Victoria, Tasmania, and New South Wales. At least seven units are in use, and six further units are to be installed soon for paper measurement in South Australia. All the gauges operating on paper machines have been installed during the past 18 months.

TABLE 6.—ISOTOPES ADVISORY SERVICE. NEW ENQUIRIES.

Period	Total of new enquiries
July-December, 1956	80
January-June, 1957	124
July-December, 1957	171

TABLE 7.—ANALYSIS OF ENQUIRIES, JULY TO DECEMBER, 1957.

Subject	Enquiries
Industrial and field applications	73
Laboratory applications	32
Food preservation by radiation	4
Technological uses of radiation	6
Information to equipment suppliers	27
Handling and health problems	9
Agricultural applications	4
Information to educational establishments	2
Radio-isotope supply	10
Information to trade, technical journals and press	4
TOTAL	171

The thickness of plastic on plastic-coated fabric is measured on one installation in Victoria with two thallium 204 gauges on either side of the web. Other uses, also in Victoria, include plastic sheet measurement and the monitoring of waxed cellophane and waxed paper. The latter is of interest because the gauge for this lightweight material uses the soft beta-radiation from cobalt 60, which is traditionally regarded as a gamma-source. Only one application in metal foil rolling is known. This is no longer in use because of difficulties arising from adherent lubricant films.

Gauges using thallium 204 are shortly to be installed in Sydney for measurement of laminated paper sheet and adhesive tapes. These will be the latest type of unit.

Only three installations of cigarette rod density machines, using strontium 90, are known of in Australia, in comparison with the U.S. total of 2,200.

Gamma-radiography

As described earlier, this was one of the first established applications in Australia of radio-isotopes in the industrial field, and it is now firmly entrenched. Leadership in this field has come from the Defence Standard Laboratories, who have trained many of the operators and developed techniques. There are also at least three private consultants operating in Australia.

The principal users of gamma-radiography in Australia also include hydroelectric authorities such as the Snowy Mountains Authority and Tasmanian Hydroelectric Commission, oil companies, and gas and water authorities. The principal uses are in weld examination of overland pipelines, and on refinery pipes and vessels in construction. There is also a considerable application in foundries for radiography of castings, and in examination of welds in pressure vessels, gas cylinders, etc.

Miscellaneous industrial installations

An underground 8in. diameter pipeline operated by the Shell Oil Co. between Melbourne and Geelong over a distance of 39 miles is regularly cleaned out by a pipe-cleaning "go-devil." This go-devil carries a small source of cobalt 60 and, on the occasions when it becomes jammed in the lines, it can be very easily found with a portable Geiger counter.

A Victorian town's gas producer uses a portable gamma-thickness gauge for measurement of the thickness and determination of corrosion and wear in pipelines up to 1in. wall thickness. This instrument uses radium, and depends on the attenuation of a tangential gamma-ray beam.

Radiation beams are frequently used overseas for detecting the completeness of filling of products, but none are at present used in Australia. However, three of these package monitors are to be installed soon in Melbourne. One is to check the filling of soap powder packages, another the completeness of filling of cartons of beer bottles, and a third is designed to detect the absence of single phials of insulin or antibiotics in a packed carton.

Gamma-radiation can be used for level detection and density measurement in liquids, slurries, etc. A number of gamma level gauges are to be installed in the near future by a mining company to detect blockages of ore in underground crushing plant, and a similar principle will probably be used in a coal hopper. A gamma density gauge for checking concentrated caustic soda density is also scheduled for installation in a chemical plant.

The Defence Standards Laboratories have developed a unique technique for examining the assembly of a small rocket by gamma-radiation. Three collimated beams from the same radium source are made to pass through critical sections of the rocket assembly. The rocket is then slowly rotated on its axis, and the variations in intensity of the transmitted beams measured with three recording Geiger counters. The pattern of variations indicates correctness or otherwise of assembly.

INDUSTRIAL AND FIELD INVESTIGATIONS

Leaks in underground telephone cables

One of the first field applications in Australia is described in a Postmaster-General's Department Research Laboratory Report (Brett., 1953). In this work, radon gas was used to detect leaks in pressurized telephone cables, 1ft. 6in. to 2ft. 6in. underground. This technique has been very useful in pin-pointing a leak when pressure drop measurements have located it to within 100-200 yards. About 20 mc. of radon gas is injected as a "slug" into the leaking cable, and its progress followed by portable Geiger gamma detectors on the surface. The point of leakage can be detected by a discontinuity in the flow of the radon and the residue of activity in the soil. Care must be taken to balance the airflow conditions in the cable towards the leak from either end. To the date of the report, this test had been used on 10 leaks in trunk cables with considerable success in locating faults. The work was done in co-operation with the Commonwealth X-Ray and Radium Laboratory, Melbourne.

Underground water movement

Barker and Green (1957), of the N.S.W. University of Technology, have described recently some experiments on the movement of underground water at Botany, N.S.W. A factory building had experienced some undesirable movement of foundations, and it was suspected that movement of underground water was the primary cause. Before further building could be planned on the site, it was necessary to know the rate of flow and the preferred direction of movement of the water, apart from the tidal oscillation. The soil in the area was mainly sand, and the water table was only a few feet underground.

Bromine 82 as potassium bromide was chosen as a tracer to follow the water movement, for two main reasons.

(i) Higher atomic weight anions are less readily adsorbed on soil, and therefore remain with the water, particularly with excess carrier bromide present.

(ii) Bromine 82 has a short half-life (35.9 hr.) which reduces the health hazard, being "self-disposing." This half-life allows sufficient time for investigations of this type, but ensures that complete decay will occur before migration away from the area under control.

To conduct the experiment, a central bore hole was made with a radial pattern of sampling bore holes around it. Each hole extended at least 6in. below the water level, and they were arranged in two circles of 6ft. and 12ft. radius. The radio-active bromide, plus inactive carrier, was added to the central hole and thoroughly stirred. Regular samples of water were then taken from the test holes, and the radio-activity content measured in the laboratory.

From the radial pattern of the radioactivity building up in the various sample holes, the preferred direction of water flow was readily determined and found to be constant over the five days of the experiment. By examination of the rate of build-up of bromine 82 in the sampling holes, it was possible to estimate that the velocity flow ranged from about 4 to 14ft. per hour during the test.

The bromine 82 used for this test was supplied with the co-operation of the Australian National University. It was prepared by irradiation of potassium bromide in the Australian National University cyclotron.

Bromine 82 from the same source (Mills, 1957), has also been used to trace the path of water loss from a freshwater swimming pool. The pool was losing some 100,000 gallons per day, and this water was not passing through the normal leakage sump. The position of the leak was found by soluble dye techniques, and potassium bromide labelled with about 2-3 mc. of bromine 82 was added at this point.

Using very sensitive gamma-scintillometers, the water was found to be escaping along the side of a sewage pipe, through the loose earth around it. The movement of the radio-active water was then traced some distance right to the sewer outlet. This simple experiment gave vital information for the re-design of the pool drainage system.

Isotope dilution techniques

Campbell (1958), of Australian Paper Manufacturers Ltd., has recently described a valuable isotope dilution technique which is used regularly to measure the amount of mercury in de Nora electrolytic cells for chlorine manufacture at Maryvale, Victoria. About three-quarters of a ton of circulating mercury acts as the cathode in these cells. In circulation, it passes through a graphite-lined extraction column, where the sodium is removed by water, and is then pumped back to the cell.

A carefully measured quantity (about 20mc) of radio-active mercury 203 in about 20 cc. ordinary mercury is added to the mercury in each cell, and left until mixing is complete. This takes about two weeks. A sample of mercury is then taken, and its specific activity examined. This gives the degree of dilution of the original mercury 203, which is directly dependent on the quantity of mercury in the cell.

It is estimated that the quantity of mercury in the cells can be assessed to about ± 1 per cent. without interruption of production. It takes one man about two weeks to complete the stocktaking of 20 cells, and the total consignment of mercury 203 costs less than £100. A mercury stocktaking by conventional methods would cost £2,500.

The valuable assistance of the Commonwealth X-Ray and Radium Laboratory, Melbourne, is acknowledged by Dr. Campbell in the conduct of this work.

Radio-isotopes are becoming a significant part of the operations of Australian Paper Manufacturers Ltd. (1958), and they are building a specially-equipped radio-chemical laboratory, with appropriate staff under a Senior Radiation Officer.

Other isotope dilution techniques have been used in industry in Australia, but little information is available apart from the materials used, viz., carbon 14-labelled methoxone and benezene and chlorine 36 as hydrochloric acid.

Power station cooling pond investigations

The Electricity Commission of N.S.W. is investigating the characteristics of power station cooling ponds with a view to their possible use in cooling condenser water in some of their new large power stations. The 20 megawatt power station at Maitland uses a small disused reservoir, of 200 million gallons capacity and area of 40 acres, as a cooling pond. This pond is being utilised for investigations on pond characteristics. Included in the information required is data on the mixing and flow of the warm water after it enters the pond. The warm water is taken by a channel to the far end of the pond, and cool water pumped out at the near end.

Fluorescein has been used to date to follow the movement of the water, but it has the limitations of being visible only for a few hours and giving very little information about vertical mixing. It also gives only qualitative information.

Recently, the flow and mixing problem was investigated by the Australian Atomic Energy Commission, in co-operation with the Electricity Commission of N.S.W., using radioactive iodine 131 as iodide. About 500 mc. of iodine 131 in solution with 20lb. of potassium iodide carrier was added at the inlet to the pond. The movement of the water carrying the iodine 131 was then followed by boats fitted with portable Geiger counter units and very sensitive gamma-scintillators, capable of underwater operation to the maximum depth of the pond (30ft.). At the power station intake a fixed scintillator with recorder, monitored the water as it left the pond.

The experiment commenced on the morning of March 13, 1958, and is still proceeding (March 17, 1958) with the results not yet fully analysed. However, it is obvious that this single experiment will yield a large amount of very valuable information.

The first of the water carrying the activity arrived back at the power station about three hours after the injection, and the activity recorded at the power station intake rose to a peak with a total duration of about five hours. Integration over the peak indicated that about 90mc. had passed through during this period. This showed that about one-fifth of the warm water is channelled back to the station very rapidly. Observations taken on the pond showed that it flowed in a thin surface layer with a certain amount of lateral spreading, but not much movement in depth during this period.

There is also evidence of a somewhat smaller "second time round" pulse of activity several hours later. Subsequently, the activity passing through the power station gradually decreased.

The pond observations then showed almost complete lateral spreading and a more or less linear vertical penetration with time. On March 16, the water carrying the activity had penetrated to a depth of about 14-16ft. At all times the active layer showed a sharply defined boundary, with a roughly uniform concentration from the boundary to the surface. The magnitude of the concentration on March 16 appears to be consistent with 500 mc. being diluted to the known pond volume above the 14-16ft. level.

Further analysis of the results will be necessary for complete quantitative information, and this will be published in detail later.

It is interesting to note that with the use of extremely sensitive scintillometer units, practically the whole of this experiment was conducted at an iodine 131 concentration below the drinking water tolerance recommended by the International Commission on Radiological Protection (6 x 10-5 microcuries/c.c.). The maximum concentration of the isotope entering the power station was about one quarter of the permitted water tolerance and, after four days, the uniform level was about one-fortieth of tolerance, but still quantitatively measurable.

Miscellaneous industrial and field investigations

At present, the Isotopes Section of the A.A.E.C. is assisting in the development of several industrial and field tests. These include a technique for measurement of density and moisture content of brown coal, the use of radioactive cutting tools for machinability measurement, and the tracing of silt in the Hunter River.

RADIO-ISOTOPES IN THE RESEARCH LABORATORY

University research

Very active schools of radio-chemistry exist in the chemistry departments of Melbourne University, the N.S.W. University of Technology, and in the School of Physical Sciences at the Australian National University. These, and most of the other Australian universities, are also using radio-isotope tracers in a variety of applications in biochemical, biological, and chemical research.

The Institute for Nuclear Engineering in the N.S.W. University of Technology has been very active recently in holding special courses in radio-isotope applications and techniques, and is planning further courses this year. Instruction and experience in radio-chemical techniques is also available at Melbourne University on a less formal basis. Several years ago, the first radio-isotope course in Australia was conducted very successfully by the Nuclear Research Foundation at the University of Sydney.

The Chemical Engineering School of the N.S.W. University of Technology has recently imported a 500 curie cobalt 60 source for radiation studies. This source is normally stored in a water-filled well, and is brought up by a winch into a specially shielded concrete cell for use. It has already been used for various food irradiation studies, plant mutations, the investigation of heavy concrete for radiation shielding and other radiation technology studies.

Use by C.S.I.R.O.

Tracer techniques are established practice in many C.S.I.R.O. laboratories, particularly those working in the biological sciences. C.S.I.R.O. had a Tracer Elements Section for some years. The principal responsibilities of this section were preparation of labelled compounds for use within the organisation and other research groups, and the study of radiation assay methods. The section was disbanded several years ago.

Industrial laboratories

As indicated earlier, only eight of the 207 research imports went to industrial laboratories in 1956-57. There is little information available on their use, but I.C.I. Central Research Laboratories are using carbon 14 compounds for isotope dilution analysis and the study of plant metabolism. C.S.R. Chemicals Pty. Ltd., are also preparing to use carbon 14—labelled mannitol for dilution analysis, and to follow its separation from sorbitol.

THE COMMONWEALTH X-RAY AND RADIUM LABORATORY

For a number of years, the Commonwealth X-ray and Radium Laboratory have taken an appreciable part in the development of radio-isotope use in Australia. They are the importing authority for the Commonwealth, and provide a purchasing service and advice on the supply of radio-isotopes for all purposes. The Laboratory also has operated an advisory service to medical users, and until 1956, to industry and research. In 1956, the advisory responsibilities in the industry and research were handed over, by agreement, to the Australian Atomic Energy Commission.

Commonwealth X-Ray and Radium Laboratory also gives advice and assistance on health aspects and disposal of radioactive waste, and controls the film badge service for exposure measurements.

THE ISOTOPES SECTION OF THE A.A.E.C.

This Section was formed in July, 1956, with the principal objective of assisting industry and research to obtain the maximum benefits from the use of radio-isotope techniques. The Section operates an advisory service to industry and research, gives assistance in field tests using radio-isotopes, and conducts research into radio-isotope techniques.

In the near future, it will be responsible for the production of radio-isotopes in the A.A.E.C. reactor HIFAR, at Lucas Heights. The work of the Section is more fully described in a recent publication (Gregory, 1958).

THE SUPPLY OF RADIO-ISOTOPE EQUIPMENT IN AUSTRALIA

At present, all industrial isotope equipment and many of the laboratory instruments used in Australia are imported. The three major U.K. producers of electronic industrial isotope equipment and one German manufacturer are now well represented in Australia. Many of the United States suppliers are represented, but there is practically no United States equipment on the industrial side here.

Much of the work of the A.A.E.C. advisory service has been concerned with advice to equipment suppliers (See Table 7). Many of these suppliers still need to increase their technical and scientific strength to render effective service to the user.

CONCLUSIONS

Radio-isotope techniques are relatively new to Australia, and have not yet reached any appreciable significance in the Australian industrial and scientific scenes. However, this paper shows that there is an increasing interest in the subject. More laboratories are starting radio-isotope units, and more industries are trying out their value in production and investigation. But, much has yet to be achieved to equal the uses in other industrialised countries.

It is hoped that the influence of the Atomic Energy Commission, in conjunction with other authorities already in the field, the production of radio-isotopes in the near future at Lucas Heights, and an improving equipment supply position will further stimulate the development of this subject in Australia. There is plenty of overseas evidence to prove it a worthwhile development.

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