AVAILABLE ISOTOPIC MATERIALS AND SERVICES

by

DR. PAUL C. AEBERSOLD, DIRECTOR
OFFICE OF ISOTOPES DEVELOPMENT
U. S. ATOMIC ENERGY COMMISSION

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For over two decades scientists have widely recognized and utilized the uniquely powerful techniques of isotopes and radiation. The tremendous sensitivity and great versatility of these tools has attracted a steadily increasing number of applications. By any measure -- by the wide variety of uses, numbers of users, persons and products benefited and economic returns -- radioisotopes are truly the success story of atomic energy. In fact radioisotopes are acclaimed as the most important peacetime contribution in the whole atomic energy industry.

One extremely important point should be kept in mind however. Everything that isotopes and radiation can do has not been developed. There is a vast realm of unextended and "unborn" uses. Your production or manufacturing problems may not yet have been matched against nuclear techniques -- or present applications may need to be modified to fit new circumstances.

Thus, although isotopes and radiation and many principles of their use are not new, we believe a "new look" is developing -- a growing recognition that present uses are only a small part of the enormous potential. Hundreds of uses await extension or development. Bringing about earlier realization of these undeveloped uses will mean more rapid technical and industrial progress with resultant increases in production and profits for industry, safer and less tedious work for labor, better products for the public and a good return on private as well as government investments for both stockholders and taxpayers.

Let us now discuss the broad field of available isotopic materials and services from both the AEC and commercial suppliers. Additional knowledge about available isotopic materials and services and the Isotopes Development Program may enable you to capitalize on the opportunity for savings possible through the utilization of radioisotopes.

A brief general review of how radioisotopes are made may help you appreciate the broad uses and adaptability of radioisotopes. The technical details of isotope production may be unimportant from the business man's point of view, but, he does need to know that a new industrial tool, inexpensive and easy to operate, is now available for a great variety of applications.

Stable Isotopes and Natural Radioactive Isotopes

(What are isotopes - slide 312A & 45A) Slide #2

An isotope is one of several atoms having the same number of protons in the nucleus; that is, a member of the same chemical species and, therefore exhibiting the same chemical behavior, but having different mass numbers, i.e. weight.

Isotopes are of two kinds, stable and unstable. Most of the elements existing in nature are mixtures of stable isotopes but there are a few known naturally unstable, or radioactive isotopes. Radium is one, uranium is another and radon and polonium, which are disintegrations of radium are two more. The first good source of gamma rays was radium. Over 50 years ago radium came into wide use for medical therapy. It still is and will continue to be a good long-lived useful gamma emitter. It is, however, expensive; has a wide range of gamma rays from low to very high energy, and gives off hazardous radioactive daughters, including radon. These properties restrict its applications.

(Total Number of Isotopes Identified - slide 324A) Slide 3

Today, more than 200 enriched isotopes of over 50 elements are available from ORNL for a wide variety of uses including starting materials for reactor produced radioactive isotopes and in targets for cyclotron-produced radioactive isotopes.

With the nuclear reactor we can make gamma ray sources that are far more intense and compact, less expensive, quite homogeneous in energy, and much safer. It is possible to take stable isotopes, place them in an accelerator or an atomic reactor and knock the stable atoms off-balance to render them unstable; i.e., radioactive.

Machine Produced Radioisotopes

Light — here in Berkeley, home of cyclotron many isotopes discovered here

Prior to World War II the most practical means for producing radioisotopes was by use of the cyclotron, a device for accelerating charged nuclear particles invented by Lawrence in late 1930. Radioisotopes of He_2, O_2, N_2 and others of very short half-life are still made in the cyclotron since they may be obtained with a higher useful activity. In fact, certain radioisotopes cannot be produced in a reactor and therefore must be prepared in the cyclotron. Examples of useful radioisotopes produced by the bombardment of stable isotopes with protons and deuterons from an electronic field are: Na^{22}, Fe^{55}, Fe^{59}, Mg^{52}, Mg^{54}, As^{73}, As^{74}, and I^{125}. (Machine made radioisotopes are readily available from several commercial suppliers and therefore the AEC no longer produces these radioisotopes for commercial users.)

Reactor Produced Radioisotopes

Most radioisotopes utilized today are created in reactors by the bombardment of stable elements with neutrons from the fissioning of uranium. Reactors are cheap bulk producers of radioisotopes compared to the cyclotron and have greatly increased the output of man-made radioactive materials. The following slides show some of the valuable radioisotopes produced by reactors.

(Important R.I. Emitting Beta and Gamma Rays - slide 351A) Slides

(Important R.I. Emitting Beta Rays - slide 350A)

Large quantities of Cobalt 60 are produced in reactors by the bombardment of Cobalt 59, a stable element, with neutrons. This is a typical (n,γ) reaction which produces a gamma emitting product isotopic with the target element. The activity produced per gram of element, called the "specific activity", is dependent on the neutron density or "flux" of the production pile and the duration of the irradiation.

(Production of Radioisotopes - slide 136)

In many instances, the bombardment of an element with neutrons results in a transmutation, through emission of beta rays and alpha particles, to an element having entirely different chemical characteristics from the target element. This chemical difference permits chemical separation of the transmutation product from the target material. The final specific activity of products produced by this reaction mechanism is very much higher than that obtained if the radioisotope were produced by the (n,γ) reaction. High specific activity Carbon 14 (N^{14} (n,p) C^{14}), Phosphorus 32 (S^{32} (n,p) P^{32}) and Tritium (Li^{6} (n,α) H^{3}) are examples of reactor produced transmutations.

Processed Radioisotopes

Radioisotopes produced by reactor transmutations go through a refining process to reach the final radioisotope sought. The following slides illustrate these process steps:

(Removing Radioisotopes from Reactor - slide 2126)

(View of Radioisotope Processing Area - slide 2082)

(Multikilocurie Cell in Operation - slide 2110)

(Masterslave Pouring Operation - slide 2385)

For example, the radioisotope Phosphorus 32 starts out in the reactor as powdered sulfur and comes back to the laboratory as irradiated melted sulfur. It then goes through a chemical distillation process from which 99% pure radioactive Phosphorus 32 is recovered.

(Bottling P^{32} for Shipment - slide 1843)

(Radioisotope Packaging Area - slide 2120)

Approximately 90 different processed radioisotopes for research, industry, medicine, biology and agriculture are now routinely available from the Oak Ridge National Laboratory's Isotopes Division. Processed radioisotopes, produced in the reactor and then purified, are usually in solution form and are sold by the millicurie or microcurie.

(Package Finishing Line - slide 2241)

(Shipping Containers, Pile and Bottle Units - slide 2083) Lights

Of course, among the variety of processed radioisotopes available, there are a few which are currently finding far-reaching applications such as Carbon 14, Tritium, Phosphorus 32, and Iodine 131. (Incidentally, the price of Carbon 14 was recently cut 50 per cent and is now $13.00 per curie.) A majority of the applications utilizing these processed isotopes are related to tracer techniques such as applied to studies of chemical reactions, fluid flow, mixing, wear tests and quality control where a little bit, microcurie to millicurie quantities, go a long way. Tritium, however, has certain characteristics which are highly desirable in industrial applications; and therefore the Atomic Energy Commission increased the availability of Tritium to 1,000,000 curies in April of 1959. It is expected that the much larger quantities now made available at a cost of $2.00 per curie will stimulate development of many new industrial and consumer uses.

Tritium, the only radioactive isotope of hydrogen, has a relatively long half-life (12.46 years), decaying to stable Helium 3. The radioisotope emits very low energy beta particles with no associated gamma radiation. This absence of penetrating radiation is an important safety factor.

The beta particles emitted by Tritium are identical with the electrons bombarding the screen of the ordinary home television set. Just as the beam of electrons traces a luminous path on the phosphor-covered screen, the beta radiation from Tritium mixed with phosphors produces continuously glowing luminous materials having a great variety of uses. The adaptability of these products has been demonstrated in such devices as luminous instrument dials, emergency exit signs, airfield ground equipment and runway markers, mine car warning signs, deck and bulkhead markers and dark room lamps.

Other applications of Tritium include its use in radar tubes and other specialized electron tubes to maintain partial ionization, thus assuring more dependable operation; in experimental fluorescent light tubes, indicating the possibility that accessories such as starters and transformers can be eliminated; as tracers in study of oil well stimulation methods and refinery operations; and in small portable accelerators, used in oil well logging, which produce high-energy neutrons by bombarding a tritium target with deuteron ions. The devices are lowered into oil wells to obtain geological information from study of neutron reactions with the various strata.

As part of its program to encourage private enterprise production of radioisotopes, the Commission has urged industrial consideration of commercial tritium production and will continue to distribute the radioisotope only as long as civilial requirements cannot be economically met from commercial production. The Commission has contracted with General Nuclear Engineering Company of Dunedin, Florida, to study the feasibility of reactor systems suitable for private tritium production, and also contracted with Booz-Allen Applied Research, Inc. of Kenilworth, Ill., to study production of tritium and other radioisotopes in power reactors.

Fission Products

(Uranium Fission Process - slide 322A)

When U^{235} fissions it splits into two fragments (fission products) which may range in weight from 65 to 157, i.e., element 30, Zinc to element 64, gadolinium. Several of these fission products have half-lives sufficiently long to permit recovery for economic benefits important to industry. This slide summarizes some of the useful isotopes resulting from fission of U^{235} and are now available from the Oak Ridge National Laboratory.

(Possible Production by ORNL F3P - slide 437A)

The Atomic Energy Commission has substantially increased the availability of fission products during the past year. Last August, the Oak Ridge Multi-Kilocurie Fission Product Pilot Plant was placed in operation. This facility has the capacity for making available 2,000,000 curies of Cerium 144, 500,000 curies of Promethium 147, 200,000 curies of Cesium 137, 200,000 curies of Strontium 90 and gram quantities of Technetium 99 annually.

(Fission Product Pilot Plant - slides 545A, 2390, 2391)

The Fission Product Pilot Plant, costing about $2,225,000 was built primarily for process development studies related to the recovery of the valuable fission products from reactor fuel processing plant effluents. At the same time it is hoped that the products produced will satisfy industrial needs during an interim industrial product application research and development period. The fission products available to industry to kilocurie quantities from the Fission Product Pilot Plant and distributed by ORNL include:

(Cesium 137 Pellets - slide 2107)

1. Cesium 137 is one of the more important long-lived gamma ray emitting isotopes. It has a half-life of about 27 years, a gamma energy of 0.66 Mev, and is available as a cesium chloride pellet having a density of about 3.3 grams/cc and an activity of 27 curies per gram of solid. Cesium 137 is suitable for radiography, teletherapy and large-scale gamma irradiation applications where a compact, long-lived source of gamma radiation is required. The present cost of Cesium 137 ranges from $2.00 per curie to $1.00 per curie in quantities over 100,000 curies, however, in time cesium could be available at costs less than 20 cents per curie in a multi-megacurie market.

2. Promethium 147 is a pure beta emitter with a maximum energy of 0.223 Mev and a half-life of 2.6 years. The beta particles emitted by Promethium 147 can be absorbed by a phosphor to produce light. It can also be applied to the measurement of the thickness of thin sheets of low density material, or the measurement of small variations of specific gravity or water content.

   Promethium 147 also shows promise as a power source for tiny batteries and as a secondary X-ray source. Promethium is available as oxide pellets compressed to a density of 5 grams/cc and having an activity of greater than 400 curies per gram of solid. Its price ranges from $3.25 per curie to $1.75 per curie in quantities more than 50,000 curies.

3. Cerium 144 has a large number of beta and gamma radiations and a half-life of 285 days. It is recovered as cerium oxide and sintered to give a dense pellet of 5.5 grams/cc and an activity of about 300 curies per gram of solid. Cerium is currently being considered as a power source in space applications and is also suitable for radiography, utilizing bremsstrehlung. At present cerium costs range from $2.00 per curie to $1.00 per curie for quantities over 100,000 curies.

4. Strontium 90 is the best high energy beta emitter presently available in large quantities. It has a half-life of 27 years and its 0.6 Mev beta radiation coupled with the 2.2 Mev beta radiation from its Yttrium 90 daughter makes Strontium 90 an extremely useful power source. The hard beta particles from Yttrium 90 can also be used for radiography by bombardment of various targets to produce a broad range of X-ray energies. Strontium 90 can be made available as Strontium fluoride pellets having a density of 3.0 grams/cc and an activity of about 30 curies per gram of solid. The present cost of Strontium 90 ranges from $10.00 per curie to $5.00 per curie for quantities over 5,000 curies.

(Strontium 90 Battery - slides 549A, 550A, ~~551A, 546A, 547A, 548A)~~

There are several applications where Strontium 90 power units are both economically attractive and provide a source of power which makes the application feasible. This is primarily true for applications in remote regions such as the Arctic or at sea. For example, the Coast Guard has about 3000 light buoys in service of which one half are electrical and one half are acetylene. Within 10 years it is expected that all buoys will be electrically powered. At present these light buoys are powered by special lead-acid batteries. Strontium 90 power sources, computing on the basis of power source cost alone, could be used to replace the lead-acid batteries if the strontium costs were 23 cents per curie. Strontium power source would also have advantages in reduced buoy maintenance and depression of barnacle formation.

If strontium power sources were used to replace the lead-acid battery to power 3000 buoys with 0.75 amp lamps, 16 million curies of strontium 90 would be required. If the buoys were equipped with 3.0 amp lamps, 64 million curies of Strontium 90 would be required.

This potential market for strontium power units, combined with the potential interests of the Weather Bureau, Navy and certain commercial applications could make it possible to produce strontium 90 in megacurie quantities at costs less than 20 cents per curie. At this price, strontium power sources are very attractive for applications in remote installations which require a long, dependable power source life.

The Commission has contracted with the Martin Company to develop a prototype Strontium 90 power unit (5 watts electrical). This prototype strontium power source will be loaned to the Weather Bureau for demonstration, under arctic conditions, in a remote weather station.

The prototype Strontium power source will contain approximately 18,500 curies of Strontium 90 in the form of a highly insoluable, ceramic strontium titanate compound. Strontium titanate, encapsulated in Hastelloy C and nickel, greatly enhances the safety and potential applications of strontium power sources.

Krypton 85 In response to industrial requests for larger quantities of Krypton 85, the Atomic Energy Commission has increased the availability of this radioisotope for civilian uses to 100,000 curies per year.

Krypton 85 is also used for activating phosphors in self-luminous light sources. Some of the major applications where its adaptability has been established and units designed and tested are in emergency aircraft markers, mine safety lamps, ship bulkhead and deck markers, darkroom safety markers, aircraft drogue (a device used in inflight refueling), wing tip, and tail light illumination, and road sign markers.

Krypton 85 is also routinely used in thickness gauges on production lines to help produce more uniform paper, plastics, rubber and numerous other materials. This continuous method of gauging which does not involve physical contact between the gauge and the material is especially useful where products are moving rapidly, temperatures are high, and products are soft or easily marred.

Krypton 85 is produced by fission of uranium in a nuclear reactor. This byproduct may then be obtained by extraction from reactor fuel elememt chemical processing plant off-gases. It has a relatively long half-life of 10.27 years, decaying to stable Rubidium 85 by emitting beta particles and gamma radiation.

The increased availability of Krypton 85 is expected to expand present civilian applications and stimulate development of new uses.

The Commission's price for the radioisotope is $50 for each of the first two curies and $15 for each additional curie.

Irradiated Units and Other Services

In addition to making available processed radioisotopes and fission products, ORNL distributes Iridium 192 and other irradiated units. It also performs service irradiations, neutron activation analysis and is prepared to handle the disposition of waste material from radioisotope customers. Reactor service irradiations and special materials and services are also available from the Argonne National Laboratory, Brookhaven National Laboratory and the National Reactor Testing Station. These Commission-owned facilities and equipment together with services of the regular operators are available for private use if the work cannot be conducted in private facilities and if it will not interfere with Government programs. Work is accepted from the public on an equitable priority basis at charges covering full cost. Requests for the use of Commission facilities should be made directly to the operating contractors.

Rights

GROWTH IN INDUSTRIAL PARTICIPATION

Early in the isotope distribution program, the Commission took the lead in developing the availability of isotopes, isotope compounds, radiochemical services, special type of sources, instrumentation and safe handling devices. Today, the business associated with radioisotopes usage is growing in sizable proportions. Commission facilities are becoming producer-wholesalers of radioisotopes. Commercial firms are now purchasing bulk quantities of radioisotopes for redistribution and reprocessing into labeled compounds, certified drugs for direct medical use and custom manufactured radiation devices, etc.

Industrial firms as well as universities and research centers have contributed to developing new isotope labeled compounds and improving existing production techniques. Bulk shipments of unrefined radioisotopes are purchased from AEC laboratories by secondary suppliers, processed as pharmaceuticals, calibrated and reshipped in small quantities to hundreds of users. Prior to 1950 nearly all "tagged" compounds were prepared in Commission laboratories. To improve this situation, the Commission in the fiscal year 1949 to 1950 gave financial assistance to the development necessary for the synthesis of selected isotope-labeled compounds. Once private groups obtained appropriate techniques and experience in preparing these materials the Commission in 1955 withdrew from providing them. Today, hundreds of different tagged compounds are stocked and made routinely available by dozens of companies. It is no longer necessary for AEC laboratories to supply special isotope compounds. One commercial firm, for example, is currently making approximately

50,000 shipments annually. Pharmaceutical companies now supply doctors with specially prepared and refined radioactive drugs for use in treating patients. Many groups sell isotope gauges to industry for use in manufacturing better products at a lower cost. Non-destructive testing companies now routinely use Cobalt 60, Iridium 192, and Cesium 137 radiography units. The use of radioisotopes of high gamma specific activity in cameras for the taking of pictures for various industrial tests has developed into a good-sized industry in itself. Ten companies have notified the Commission they are prepared to encapsulate large sources. Three of these can handle up to a million curies. Such extremely large sources will be used in the near future for food preservation, pharmaceutical sterilization and chemical polymerization. These ten companies have entered this business since the AEC withdrew from providing Cobalt 60 encapsulation service in March of 1958, in keeping with its policy to discontinue materials and services reasonably available commercially.

In March 1958, the AEC also discontinued providing gamma irradiation service to private groups. Now there are about 120 academic and industrial organizations which have their own Cobalt 60 irradiation facilities. Many of these are willing to perform irradiation service for others on a commercial basis.

The Commission has recently been notified that two groups intend actually to produce at least some Cobalt 60 and tritium (Hydrogen 3) in their own reactors. Other groups are beginning to negotiate directly with private reactor facilities for purchase of commercially produced radioisotopes. It is the Commission's desire that more and more radiomaterials and services now supplied by the AEC be taken over by the rapidly expanding number of commercial firms in the field.

Construction of more privately owned testing reactors could be a major stimulant to the supplying of radioisotopes and irradiation services by private industry. The considerable number of privately owned power reactors expected to be built in coming years also may have marked effect. Although no power reactor operating today has special isotope production or irradiation facilities, the problems and possibilities of designing such dual purpose reactors are being studied carefully by reactor designers and some utility officials.

The growth in isotope utilization through 1958 has been accomplished with little advertisement or promotional effort. However, now that more commercial advertising and promotion techniques are being utilized to increase the public awareness of advantages and benefits of radiation applications, the utilization of radioisotopes and associated domestic and foreign markets are expected to be greatly accelerated. In addition, the increase in availability of the fission products cesium, strontium, cerium, promethium, and krypton, and increased availability of tritium will markedly affect the growth of both domestic and foreign markets. With little promotional effort, the total curies of radioisotopes distributed from ORNL in 1958 increased 37 per cent over 1957 and was double that of 1956. Also, the number of curies of radioisotopes distributed to foreign countries almost tripled in 1958 alone. The following slides illustrate the continuing growth of radioisotope utilization. (These data are based upon sales and on curies shipped by Oak Ridge National Laboratory).

The rate at which a private atomic energy industry develops in this country ultimately depends upon industrial managements assessment of opportunities in the atomic field. It is a policy of the government to encourage private initiative and create industrial opportunities by limiting its own activities or by withdrawing from areas where private concerns demonstrate both the capacity and the desire to undertake activities on their own account. In formulating its programs, the Commission seeks to avoid competition with the private industrial and research sector of the nation's economy.

Cyclotron-produced radioisotopes, natural radioisotopes, stable isotopes and reactor-produced isotopes all are now available commercially from about 150 U. S. firms which advertise they supply these products. Some of these groups are actually producers. Today, the thousands of users throughout the world look mainly to commercial firms, rather than the Commission, for radiomaterials and services.

The availability of radioisotopes and related services has become so extensive that two organizations have compiled guides to suppliers of a particular radioisotope or services. They are The Isotope Index, published yearly by the Scientific Equipment Company, Indianapolis, and Nucleonics Buyers' Guide, published annually by McGraw-Hill Publishing Company, New York. In addition, each supplier has his own detailed catalog.

TECHNICAL INFORMATION SERVICES AND TRAINING PROGRAMS

A major objective of the Atomic Energy Commission is to provide private industry with technical information developed within the National Atomic Energy Program. From the very beginning the Commission has encouraged scientists and engineers engaged in Government-sponsored work to report their unclassified findings in scientific, engineering and trade journals. The Commission has also sold its unclassified technical reports and its abstract journals since 1948.

Certainly there is a wealth of information available to industry that can provide a key to possible utilization of isotopes in business. However, it should be recognized that a shortage of scientists trained in the use of radioisotopes will be a more limiting factor in expanding radioisotope benefits that would problems of supply or distribution. The Commission is meeting this challenge through a vigorous program of training and information activities that has grown in scope to meet increasing needs.

The principal agent of the Commission in providing isotope training has been the Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tennessee. A basic isotope technology course that would be suitable to prepare a mature scientist adequately trained in his own field to begin applying radioisotopes to his research problems was initiated in early 1948.

So many industrial personnel have applied for these courses that a course has been specifically designed for personnel from industrial organizations interested in the application or potential use of radioisotopes in industrial research and development. This industrial radioisotope course will assist senior technical personnel in obtaining sufficient experience in the use of radioisotopes to utilize them safely and efficiently. Selection of the participants for the courses is based on the applicants research experience and the applicability of the training in his current work. The minimum scholastic requirement for participation in the industrial radioisotopes course is a Bachelors Degree in a technical field or its equivalent. It is, of course, desirable and important that industrial applicants be familiar with the technical problems in their organizations and be in a position to make recommendations to management.

To familiarize management in applications of radioisotopes and increase awareness of the industrial opportunities they provide, the Commission is sponsoring in cooperation with local business, industrial and other organizations two day symposiums on industrial uses of radioisotopes. Coordination between the Commission and State and local governments in regulation of radioisotopes and radiation is becoming increasingly important. A new program called "Special Assistance for Training in Radiation Control" was inaugurated during the current year which offers training similar to that under the radiological physics program. The Commission has also arranged conferences and symposiums to meet the needs of Union representatives concerned with regulatory, safety, and administrative responsibilities in the atomic energy field.

RADIOISOTOPE PROGRAM AND DEVELOPMENT OF NEW APPLICATIONS

Developments to date in applying radioisotopes for increasing human well-being and industrial progress represent only the early beginning of what can be accomplished. To accelerate achievement of their potential benefits, the Atomic Energy Commission laid the groundwork for an Isotope Development Program in May 1957. In February 1958, the Commission approved a $5 million budget for isotope development activities, and in October established the Office of Isotopes Development to carry out the program.

Plans for the development program include:

1. Research and Development of Isotope Applications.

Applications will increase only as engineers and technicians well aware of industrial problems conceive new ways to apply radioisotopes to extend present applications to meet particular problems. Although the technical soundness of radioisotope application frequently can be demonstrated with mock-up equipment on a laboratory bench, much development and engineering usually must be done before the application can be used in a factory. This is often quite expensive and beyond the means of the private organization which conceived the idea. (53 contract projects for $2,341,000)

2. Training

Industrial isotope technology is required to provide industrial personnel with increased opportunities to master the technology of practical applications of isotopes. (9 contract projects for $555,000; 33 equipment training grants to schools for $604,000)

3. Isotope Production and Process Development

Activities are being directed toward making available commercial quantities at economic prices, at the same time making it attractive for private enterprise to produce special radioisotopes. To meet these objectives, isotope production pricing and marketing policies are being designed specifically to encourage development of markets attractive to private production; 3 contracts, including support of National Laboratory, for $500,000.

4. Industrial Process Radiation

Activities are being directed toward developing the field of applied radiation in the United States. The growth of the nuclear power industry is providing an accumulation of fission by-products that will present an increasing wealth of natural resources. Development of industrial process radiation uses is expected to draw upon this modern source of radioactivity and convert it into an industrial asset. Useful applications of process radiation in industry are expected to have national economic significance. To capitalize on the huge reservoir of radiation available form fission by-products, work is being done toward development of fission by-product source technology and methods for their efficient utilization. (20 contract projects for $1,200,000)

Contract Activities to Date

Since the beginning of the Isotopes Development Program in 1958, a total of 85 contract projects have been authorized at a cost of $5,300,000. Individual categories are: Isotope Applications -- 53 contract projects for $2,341,000; High Intensity Radiation -- 20 contract projects for $1,300,000; Education and Training -- 9 contract projects for $555,000; Equipment Training Grants -- 33 schools for $604,000; and Production and Process Development -- 3 contracts for $500,000.

CONCLUSION

Here then are challenges and real opportunities for government and industry in the Isotopes Development Program: (1) To condense the time from an isotope and radiation principle in the laboratory to useful practice in industry; (2) to accelerate the development and utilization of new ideas and concepts for industrial application; (3) To see that practicability and benefits are more rapidly demonstrated and continuous improvement is encouraged.