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ORNL-TM-2876

RADIOISOTOPE PROGRAM (8000) PROGRESS REPORT

FOR JANUARY 1970

A. F. Rupp

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ORNL-TM-2876

Contract No. W-7405-eng-26

Isotopes Development Center

RADIOISOTOPE PROGRAM (8000) PROGRESS REPORT FOR JANUARY 1970

A. F. Rupp

FEBRUARY 1970

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RADIOISOTOPE PROGRAM (8000) PROGRESS REPORT FOR JANUARY 1970

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RADIOISOTOPE PRODUCTION AND MATERIALS DEVELOPMENT

NEUTRON PRODUCTS - 08-01-01

A. Biomedical Radioisotopes

1. Thulium-171

Nothing to report.

2. Phosphorus-33

Nothing to report.

3. Potassium-43

The objectives of this project are: to prepare potassium-43 by the $^{43}Ca(n,p)^{43}K$ reaction, using isotopically enriched ^{43}CaO targets, in quantities sufficient for medical and biological experiments; to define a method for separating potassium-43 from the target in a purity suitable for medical use; and to establish cooperative programs with medical institutions interested in evaluating its usefulness.

Potassium-42 has been used, primarily in animals, to locate tumors, to tag red blood cells, and to study blood flow, but it has very limited use in humans because of its high beta energy (3.53 MeV), its high-energy (1.52 MeV) gamma ray, and its relatively short half-life (12.4 hr). Potassium-43, with a half-life of 22.4 hr and gamma-ray emissions of 0.373 and 0.617 MeV, is more suitable for metabolic and clinical studies, because the lower dose rate would permit multiple doses. It has been suggested as a possible tool for studying blood flow through the heart and for diagnosing myocardial infarctions or immune rejection of transplanted organs. It has also proved capable of diffusing through a kidney with greatly reduced renal function, providing a good image of this organ.

The yield of potassium-43 from a 90-mg target of ^{43}CaO (61.6% enrichment) irradiated 65 hr in a fast flux of approximately 10^{15} n/cm^2.sec was 9 mCi. The ion-exchange separation was made with Bio-Rad AG 50W-X8 as described last month. The product was dried, taken up in sterile saline for injection, and shipped to Johns Hopkins for cardiac studies. A delay in the shipment prevented the administration of the product to a scheduled human patient, but studies made on a dog gave inconclusive results. The expected myocardial infarct was not observed in the scans, and an autopsy will be performed on the dog to determine if the infarct actually existed.

The shipping problem is one of the serious obstacles to clinical use of the short-lived isotopes.

Four calcium-43 targets were recovered by oxalate precipitation. Based on the weights of the four targets processed, the overall calcium-43 recovery was 95%. The tentative conclusion concerning the trace of iridium in the target material is that it does come from the platinum crucible used to calcine the target, but since the amount will decline with use of the crucible, it was again used in calcining. The problem would be eliminated if the calcium-43 were recovered as the carbonate, and studies will be conducted to demonstrate the safety of this compound under irradiation.

The relative efficiency of the Ge(Li) detector used in our studies has been determined using cobalt-56, antimony-125, barium-133, and europium-152 as relative intensity standards. A calcium-43 level scheme (Fig. 1) shows the energies and relative intensities (in parentheses) of the gamma emissions observed in the decay of potassium-43.

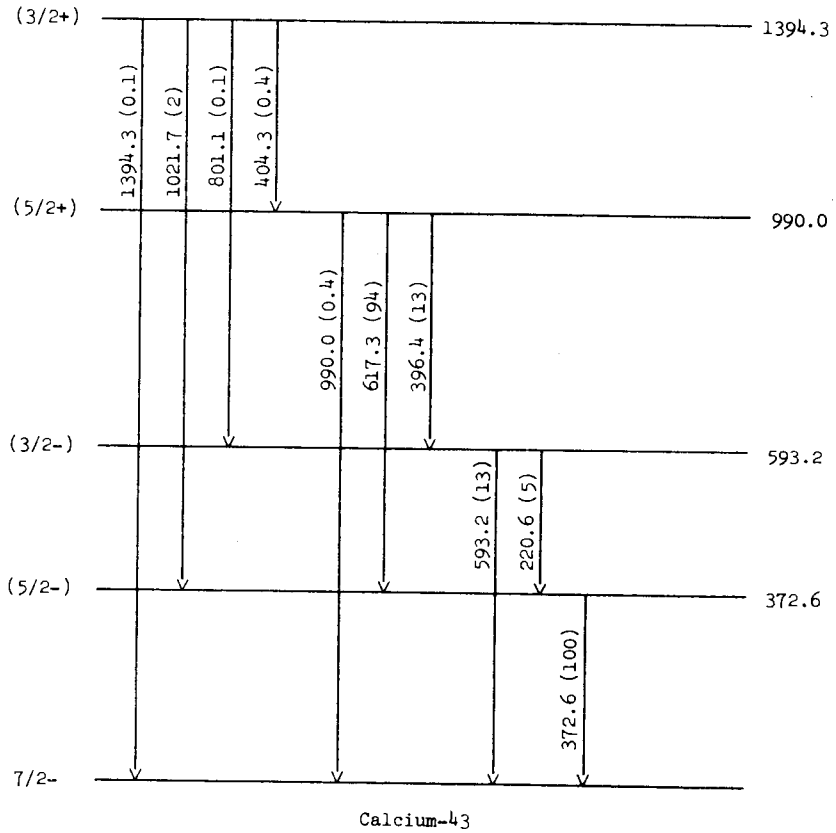

Fig. 2. Levels of Calcium-43 and Gamma Rays Observed in the Decay of Potassium-43.

4. Rubidium-84

The 0.51-MeV annihilation radiations of rubidium-84 (33 days) are used in studies of damaged heart muscles. Rubidium-83 (83 days), with gamma energies near 0.51 MeV, is an undesirable radionuclide impurity in rubidium-84 products made by proton bombardment of normal krypton and also by fast-neutron irradiation of enriched strontium-84.

The objectives of this work are to develop the production technology of rubidium-84 prepared by neutron irradiation and to characterize the product in detail with respect to the rubidium-83 and rubidium-86 impurity levels.

Cooperatives with medical investigators will be established if an acceptable product can be prepared.

Previous work showed the yield of 33-day rubidium-84 from enriched strontium-84 irradiated 46 days in a fast neutron flux of 2.5×10^{14} n/cm^2.sec was lower than expected, and the rubidium-83 and rubidium-86 levels were too high for the rubidium-84 to be useful for heart studies. Targets of enriched strontium-84 have been prepared and are presently being irradiated in selected facilities of the Oak Ridge Research Reactor (ORR) and the HFIR. These targets will be processed for the rubidium activities to determine yield and purity of the rubidium-84. Each target had flux monitors to determine the thermal and fast-neutron flux in each irradiation. These data will be used to estimate the yield and purity of rubidium-84 that can be made under various conditions in the neutron fluxes available.

A rubidium-84 counting standard was prepared for use in the assay of the reactor targets. The rubidium-84 was prepared by cyclotron bombardment of rubidium by the $^{85}Rb(p,pn)^{84}Rb$ reaction. The counting standard was calibrated by calculations from the decay scheme of rubidium-84 and counting on a Ge(Li) detector on which the absolute efficiency curve was known from counting other radiation standards. Yield and specific activity of the rubidium-84 prepared by this reaction (0.15 mCi per g of natural rubidium) were too low for this reaction to be of value as a method of preparing rubidium-84 for medical use.

B. Research Radioisotopes

1. Lanthanum-137

Nothing to report.

C. Isotopic Power

1. Thulium-170

The objectives of this research are to provide sufficient data on thulium-170, which has been proposed as an isotopic-power source for short-duration missions, to permit reasonable assessment of its potential application, and to permit preliminary engineering design of power sources. The economics for reactor production of thulium-170 (128.5 day; $E_{\beta-av}$ = 0.32 MeV)

from natural thulium-169 are favorable and the sesquioxide offers a promising fuel compound, having a practical specific power of approximately 2 W/g and a power density of approximately 16 W/cm^3. The study will include measurements of thermal conductivity and thermal diffusivity, leach rates for safety analysis, high-temperature compatibility with suitable containment metals, vapor pressure, and fuel form densification.

Preliminary measurements of thermal conductivity were reported last month. Work this month consisted of making measurements on an instrumented specimen to determine the systematic errors of the measurements. The analysis will be completed during February.

Thulia wafer specimens for future compatibility studies are under irradiation in a flux greater than 10^{15} n/cm^2.sec. It is expected that the high temperature material compatibility exposures will commence at the beginning of the next fiscal year. The longest exposures will run for a period of 5000 hr. These specimens will be examined before the specimens of shorter exposures are examined.

D. Miscellaneous

1. HFIR Target Testing

Seven rabbits and three removable beryllium stringers were leak and pressure tested; one rabbit and one removable beryllium assembly were found defective. Five of these rabbits contained radioactive ZnO reading up to 2 R/hr on contact.

Since our stock of rabbits and removable beryllium stringers is getting low, 100 rabbits and 12 removable beryllium stringer assemblies were ordered. The stock of raw finned tubing is also low; an order for 200 ft of new finned tubing was placed with the fabricator.

E. Supporting Technology

1. Radioisotope Characterization

It is well known that the half-lives of nuclides which decay by electron capture and by converted isomeric transition can be altered slightly by the environment in which the radioatoms find themselves. A European author has recently published several papers showing substantial effects on half-lives of beta emitters, for which there is neither prior experimental nor theoretical support. After an exchange of letters, it was decided to attempt to confirm his experimental work on iodine-131 and copper-64. G. I. Gleason* irradiated copper foil, verified the purity of copper-64 by Ge(Li) spectrometry, and followed decay of copper metal and $Cu(NO_3)_2$ solution by means of a NaI(Tl) spectrometer. His results were: metal 12.723 ± 0.015 and 12.730 ± 0.022 hr and $Cu(NO_3)_2$ 12.700 ± 0.022 hr. There are no significant differences among these values, and they are in agreement with that of Emery, 12.71 ± 0.01 hr (solution and solid samples), reported previously.

*Oak Ridge Associated Universities.

The iodine-131 half-life values are shown below. Emery used a well type scintillation counter and Gleason a NaI(Tl) spectrometer.

Chemical Form	Emery's Value, days	Gleason's Value, days
Solution	8.043 ± 0.002	8.028 ± 0.007
I_2 in CCl_4	8.041 ± 0.002	
LiI solid	8.042 ± 0.002	
KI solid	8.043 ± 0.002	8.030 ± 0.007
AgI solid	8.036 ± 0.002	8.019 ± 0.006

Again it appears that there are no significant differences. These findings were reported to the European investigator, and he was told that they will be included in our next paper on half-lives. Hopefully this study will eliminate the temporary confusion about chemical effects on half-lives.

2. Radioisotope Special Analysis and Quality Control

A dilute alloy of cobalt in aluminum has long been used for monitoring thermal-neutron flux in reactors. The National Bureau of Standards has recently issued SRM 953, Neutron Flux Monitor Wire, with the cobalt content certified as 0.116% with an uncertainty of 0.002%. This value was confirmed within the stated uncertainty by using activation analysis with ORNL standards. It was necessary to allow 2.7-day gold-198 to decay before measurement; this nuclide is formed from a trace impurity of gold in the alloy.

The program on evaluation of status and needs for radioactivity standards, being carried on for the National Research Council, is progressing satisfactorily. The advisory panel has been appointed; the chairman is Prof. L. R. Zumwalt, and members are G. Friedlander, B. Fries, J. H. Harley, E. Saenger, and R. Schmitt. The panel will meet February 5-6 in Washington, at which time members will consider our presentation of tabular material on availability of standards from national, international, and commercial suppliers, examples of satisfactory and unsatisfactory standards, and some recommendations for needed action. Further, the panel will hear from selected producers and users, and will draw tentative conclusions, subject to additional information which will be obtained from our interviews and correspondence with selected people in the standards field.

CYCLOTRON PRODUCTS - 08-01-02

A. Biomedical Radioisotopes

1. Rubidium-83

The chief objectives of this work are to supply rubidium-83 for medical and research applications under cooperative programs and to develop the technology for preparing a high-purity product acceptable for human use. Rubidium-83 is prepared by cyclotron bombardment of strontium-84 by the following reactions:

$$^{84}Sr(p,2n)^{83}Y \xrightarrow{EC,\ \beta^+} {}^{83}Sr \xrightarrow{EC,\ \beta^+} {}^{83}Rb\ ,$$

$$^{84}Sr(p,pn)^{83}Sr \xrightarrow{EC,\ \beta^+} {}^{83}Rb\ ,$$

$$^{84}Sr(p,2p)^{83}Rb\ .$$

Rubidium-83 has a half-life of 83 days and principal gamma emissions of 0.521 (100%), 0.530 (66%), and 0.553 (36%) MeV.

A request was received from our cooperative participant at the University of Utah requesting rubidium-83 to be used in muscular dystrophy studies. A 133-mg sample of reprocessed ^{84}SrO (75.6% isotopically enriched) was fabricated into a window-type target[1] and irradiated for 2 hr at an average beam current of 85.5 μA. The irradiated sample was set aside for 14 days to allow decay of strontium-83 (33 hr) to rubidium-83 before processing.

A preliminary separation of strontium-84 target material from the carrier-free rubidium-83 product was performed by precipitation of $^{84}Sr(NO_3)_2$ from fuming HNO_3 solution. The partially separated sample was then converted to chloride salts and loaded onto a Bio-Rad AG 50W-X8 (100-200 mesh) cation column in 0.1 M HCl and eluted with 0.5 M HCl. The rubidium-83 product was collected between approximately 30 and 70 column volumes with the maximum activity being eluted during the 50th column volume. An unexpected activity was eluted within the first 20 column volumes which was later identified as a mixture of bismuth-205 and bismuth-206. The presence of these radionuclides is attributed to lead-206 contamination of the target during fabrication. Preliminary tracer experiments and distribution coefficients applicable to this cation exchange system[2] indicated that neither Sr(II) nor Y(III) is eluted within the first 100 column volumes by 0.5 M HCl.

The major radionuclidic impurities in the initial unprocessed sample were yttrium-87 and yttrium-88 produced by (p,n) reactions on isotopic strontium impurities (the target contained 2.24 at. % strontium-87 and 17.11 at. % strontium-88) and strontium-85, present in the initial reprocessed target which had been previously used for reactor irradiations. The radionuclidic purity of the final product was determined by gamma-ray spectrometric analysis using a Ge(Li) detector and a 4096 channel pulse height analyzer. No gamma rays were detected corresponding to any of the radionuclidic impurities mentioned above, i.e., bismuth-205, bismuth-206, strontium-85, strontium-87m (daughter of yttrium-87), yttrium-87, and yttrium-88. The radionuclidic purity is estimated to be ≥99.8% at time of shipment.

The chemical processing yield and cyclotron production rates and yields for rubidium-83 could not be determined from an aliquot of the unprocessed sample due to appreciable, unresolvable contributions from radioactive

[1] J. J. Pinajian and T. A. Butler, ORNL 86-Inch Cyclotron Facility for Isotope Production, Isotopes Radiation Tech. 1(2): 137 (1963).
[2] F. W. E. Strelow, An Ion Exchange Selectivity Scale of Cations Based on Equilibrium Distribution Coefficients, Anal Chem. 32: 1185 (1960).

impurities to the rubidium-83 photopeak. In order to circumvent this difficulty, all waste fractions from the original rubidium-83 purification were combined, including the $^{84}Sr(NO_3)_2$ precipitate, and reprocessed by cation exchange only. A chemical process yield of 94.2% and cyclotron production rate and yield values of 1.8 mCi/mA-hr and 310 μCi, respectively, were determined from the reprocessing of rubidium-83 recovery. This reprocessing procedure also offered a convenient and efficient method for purifying and recovering the costly strontium-84 target material ($15/mg), free of yttrium and rubidium impurities. An overall process recovery of 93.1% was achieved. Sufficient high-purity, carrier-free yttrium-88 (108 days) was also recovered as a by-product for use by members of the ORNL Chemistry Division as an electron standard for their β^--ray spectrometer.

No further work is planned on this project until our cooperative participant requires additional material.

2. Gallium-67

The objectives of this program are to determine the optimal target configuration for gallium-67 (78 hr) production in acceptable purity and quantity and to provide gallium-67 for clinical applications research and development. Interest in this isotope has been spurred by evidence, obtained by the Medical Division of Oak Ridge Associated Universities (ORAU), of a high uptake of carrier-free gallium-67 by lymphoid tumors in both animals and humans. This interesting discovery was made during the evaluation of gallium-67, produced in the ORNL 86-Inch Cyclotron by the $^{68}Zn(p,2n)^{67}Ga$ reaction, as a bone-scanning agent for a patient with Hodgkin's disease.

Due to inclement weather only one gallium-67 experimental target was processed and shipped. No new target development work was done. A new target of natural zinc electrodeposited on copper will be fabricated, but testing of this target is as yet unscheduled.

3. Indium-111

The objectives of this program are twofold: to elucidate, define, and optimize pertinent production parameters (e.g., cyclotron target material, cyclotron beam energy and current conditions, adverse side reactions leading to undesirable isotopic impurities, target processing and product purification procedures, and target recovery, if necessary) and to make sufficient material available to cooperative participants for their evaluation of indium-111 as a diagnostic radionuclide in medicine. Such applications would include spinal-cerebral cisternography, aerosol lung studies, delayed brain scanning, visualization of the lymphatic system, metabolic studies of indium-labeled macroaggregates and colloids, and possible applications for tumor localizations. Indium-111 has both a favorable decay scheme [gamma emissions of 173 keV (89%) and 247 keV (94%)] ideally suited for external detection and an optimal half-life (2.81 days) for labeling and distribution studies which must be carried out over 24 hr or longer. The use of indium in such lengthy studies is impossible with the indium-113m (1.73 hr) isotope now in general use.

The use of this product in humans makes product characterization and quality control very important and necessary items. In an attempt to completely characterize the chemical composition of the initial indium-111 products being produced by the HBr-isopropyl ether extraction procedure currently being investigated, an aliquot of the purified product was analyzed by spark-source mass spectrometry. The analysis indicated the following levels of chemical impurities in the final product greater than 0.5 ppm: aluminum at 3 ppm, zinc at 16 ppm, iron at 29 ppm, cadmium at 35 ppm, silicon at approximately 40 ppm, and bromine at ≥100 ppm. The sources of these impurities can be easily rationalized, and the purification chemistry will be altered accordingly to improve the decontamination factors for these elements. It is hoped that the iron value can be reduced by altering the extraction conditions without reverting to a chemical reducing agent (e.g., titanous chloride) which would introduce additional impurities and complicate the target recovery procedure. The only unexpected and unexplained result is the cadmium value which is at least a factor of two larger than the contamination limit set by a chemical spot test used for cadmium. It is hoped this discrepancy will be resolved in future samples.

Work was continued to determine thick-target production rates for the $^{111}Cd(p,n)^{111}In$ reaction. In an attempt to better utilize the ORNL 86-Inch Cyclotron beam, an improved internal beam capsule target[1,2] was designed, fabricated, and tested. The new design utilized a 0.060- by 1.25-in. capsule void compared to the 0.100- by 0.625-in. void capsule used in earlier experiments. This change resulted in a 15% increase in thick-target production rate with a 16% decrease in target size.

Additional operating experience for the HBr-isopropyl ether extraction purification process for indium-111 was obtained. Chemical process yields of approximately 98% and target recovery yields of approximately 94% were reproduced and would seem routinely practicable at this time. Preliminary chemical spot tests of this last product indicated less than 20 μg of cadmium per milliliter, but greater than 5 μg of iron per milliliter in the final product. This level of iron contamination is considered unacceptable for products destined for biomedical applications. If a product containing macro amounts of iron is used for distribution studies without the addition of a complexing agent to complex the iron, when the product is adjusted to pH = 7 for injection, appreciable amounts of indium-111 would be expected to be carried on the $Fe(OH)_3$ precipitate leading to erroneous results. An iron content of ≤5 μg/ml (5 ppm) would seem to be a practical limit that would be considered acceptable by our cooperative participants.

Another development run for indium-111 has been scheduled for February to gain additional operating experience on the HBr-isopropyl ether extraction process, to check the reproducibility of the pertinent production

[1] J. J. Pinajian and T. A. Butler, ORNL 86-Inch Cyclotron Facility for Isotope Production, Isotopes Radiation Tech. 1(2): 137 (1963).
[2] J. A. Martin and F. L. Green, Cyclotron Target for the Irradiation of Chemical Compounds, Nucl. Sci. Eng. 1: 185 (1956).

parameters (e.g., chemical yield, production rate and yield, chemical and radionuclidic purity of the product, target recovery, and iron decontamination), and to provide sufficient material to cooperative participants for their evaluation. Preliminary consideration will also be given different types of cyclotron targets for indium-111 production by the $^{112}Cd(p,2n)^{111}In$ reaction. The cross sections for the (p,2n) reaction on cadmium-112 are approximately twice that for the (p,n) reaction on cadmium-111, which makes this alternative look promising for higher production rates if the target fabrication problems can be overcome.

4. Neodymium-140

Nothing to report.

FISSION PRODUCTS - 08-01-03

A. Krypton-85 Enrichment

No gas transfers were made in any of the enrichment units. The total activity contained in each unit, the elapsed operating time on the current runs, and the average count rate at each end of the center product section are shown below:

Unit	Activity in Unit, Ci	Time Since Last Product Removal, days	Count Rate in Product Section, counts/min	
			December 1969	January 1970
A	515	67	3,300	5,200
AB	1071	37	5,350	7,350
B	843	37	3,900	6,400
C	1044	37	4,800	4,200
CD	1906	91	8,550	11,250
D	1150	67	6,350	9,200

The count rate data for the month of December 1969 is shown for comparison with the current data for January 1970. It may be noted that there was a little change in the count rate for unit C over the period. This failure to change was noted early during the operating period, and after checking the system, it was discovered that the electric motor driving the bellows pump which provides gas transport through the system had stripped a gear and was not functioning. This has been repaired and the unit is now operating properly.

The metering pump which supplies sodium dichromate solution to the cooling tower water ceased to function. Some adjustments were made and operation was restored. Since this pump is an inexpensive item, and total loss of a pump would be a serious matter, a spare pump was ordered from Water Services Inc., the original supplier.

The dissolved solids content of the tower water is controlled by a conductivity measuring system which operates a solenoid valve to dump water out

of the cooling system from time to time. This solenoid valve and its piping froze due to the extreme cold weather during the month, and control was achieved by manually operating another indoor valve. The outdoor dump line and valve will be steam-traced as soon as possible to prevent further freezing problems.

B. Cesium-137 Process and Product Technology

1. Fission-Product Process Study

The purpose of this project is the study and development of economical processes for recovery, purification, and conversion of fission products (cesium-137 in particular) obtained from reactor fuel processing operations.

The current objectives are to become familiar with the operation of the differential thermal analysis (DTA) unit to be used in the study of the KCl-CsCl system and to continue the work to develop a generalized method for economic evaluation.

The DTA thermograms have been obtained for benzoic acid (calibration standard) and CsCl (three runs each) under a constant flow of helium gas. The thermograms for benzoic acid were reproducible with a negligible difference for the second and third runs, but their agreement with the standard thermogram was only fair. The temperatures for the onset of melting and freezing (approximately 110°C and 100°C, respectively) were somewhat lower than the standard values (117°C and 102°C, respectively). The base lines (sections of the thermogram outside the melting endotherm and the freezing exotherm) exhibit rather steep negative slopes as contrasted to the almost straight and flat base line of the standard thermogram. This situation has made estimation of phase transition temperatures difficult. The base line slope adjustment has not corrected this deviation to any significant extent.

Behavior similar to that of benzoic acid was observed in thermograms for cesium chloride. The onset of the solid-solid and the solid-liquid transitions are estimated at 452-453°C and 616-617°C, respectively, as compared to literature values of 469°C and 646°C. Again the thermogram base line was sloped considerably. The slope of the base line is related to the ratio of specific heat to thermal conductivity (C_p/k) of the sample under the condition of a constant heating rate. Based on calculations using the available literature data, it is estimated that the thermal conductivity, k, (by extrapolation) of CsCl may be reduced to less than one-half the value at room temperature when CsCl is heated to the solid-solid transition point (469°C). In contrast, the specific heat, C_p, increases slowly in the same temperature range (room temperature to 469°C) with a net total change of less than 10% of the room-temperature value. Thus, the negative slope of the base line for CsCl may be partially explained by the increasing value of the ratio (C_p/k) with the temperature. However, the significant deviation of the thermogram for benzoic acid from the standard indicates that further adjustment of the DTA unit is needed.

Since the amount of sample to be used in the DTA unit is very small, an efficient technique for mixing CsCl with KCl is required to obtain accurate

DTA thermograms. A miniature laboratory shaker was found to be suitable for mixing small amounts of solid material. Preliminary test runs using a mixture of sands and dark-colored abrasive powders have produced satisfactory results.

The process alloy factor (f_a) to be used in the equation presented in IDC Newsletter for July 1969 (ORNL CF-69-8-13) has been estimated as follows:

Process 1 (HCl as eluant): 0.4
Process 2 (HNO_3 as eluant): 0.3
Process 3 [$(NH_4)_2CO_3$-NH_4OH as eluant]: 0.2

In February studies on the equilibrium phase behavior of the CsCl-KCl system will continue. Further adjustment of the DTA unit will be made to see whether the accuracy can be improved. An additional study on the solid mixing technique is to be carried out using the CsCl-KCl mixtures. The degree of uniformity of the mixture will be checked by the chemical analysis. The process economics study will be continued as time permits.

2. Cesium Chloride Slab Sources

Nothing to report.

RADIATION SOURCE DEVELOPMENT - 08-01-04

A. Strontium-90 Silicate Sources

1. Matrix Studies

Nothing to report.

2. Encapsulation

Nothing to report.

3. Characterization

Studies to determine the solubility of strontium silicate in aqueous solutions, acid, and basic solutions, as well as distilled water, are in progress. Inactive strontium silicate is used to develop procedures that will be followed with the active strontium silicate.

Hot-pressed strontium silicate cylinders are being prepared for measurement of thermal conductivity. In addition to the pure strontium silicate, the thermal conductivity of composites made with strontium silicate beads in aluminum matrix will be measured.

B. Fabrication of Carbon-14 and Technetium-99 Radiographic Sources

Nothing to report.

C. Alpha Source Fabrication Development

Nothing to report.

RADIOISOTOPE SOURCE SAFETY TESTING - 08-01-04

A. Special Form Prototype Testing

Nothing to report.

B. Testing Sources with Manufactured Leaks

Nothing to report.

C. Surveillance of Regulations and Cask Evaluations

Large quantity radioactive material packages are evaluated prior to application for AEC certification and petitions for USA DOT approval. A certification that the SNAP-7D Thermoelectric Generator meets the requirements of AECM-0529 was received from AEC-ORO. A petition for a special permit was prepared in the format of and including the information required by 49 CFR 170. This petition has been sent to the Hazardous Materials Regulations Board of the Department of Transportation.

The structural and thermal analysis of the lightweight drum package for transuranium radionuclides was completed. An evaluation in the format of and including the information required by AECM-0529 is being prepared for submission to AEC-ORO.

New designs of shipping containers are tested to determine their effectiveness during transport. A 6000-lb shipment of lithium hydroxide monohydrate was received which will be used as shielding in the two casks and three fire shields that are presently being fabricated. Testing of shield effectiveness and thermal dissipation will begin upon receipt of the casks.

Up-to-date information on radioisotope regulations is maintained by review of the Federal Register and other sources of regulatory information. Comments were forwarded to AEC-ORO regarding the agenda of the IAEA meeting in Vienna, Austria, February 2-13, 1970, Review of the Regulations for the Safe Transport of Radioactive Materials. It was pointed out that while many of the member countries' proposed changes will be beneficial in clarifying and simplifying the IAEA regulations, the British and Australian proposals to change the interpretation of the half-hour fire test to "allow any combustion of the packaging itself to proceed for another 3 hours" is not practical.

D. Source Leak Test Guide

A guide for leak testing encapsulated radioactive sources is being edited for publication. This guide discusses each of the common leak test methods from the viewpoint of reliability and sensitivity.

E. Sealed Source Testing

Nothing to report.

F. Unsealed Source Testing

Testing of commercial tritium foils was continued. Due to an interest in tritium losses in an argon atmosphere, the elevated temperature tests (gas chromatographs containing tritium foil sources) are being repeated with argon rather than dry air as the carrier. The foils are purged with dry air at 25°C for 16 hr prior to testing to minimize differences due to humidity. In each test a section of foil is placed in a quartz tube which has been preheated to the desired temperature and an argon purge is provided to sweep the released tritium into the recovery train to obtain a 2-hr sample. The tritium losses from the 15-Ci/in.^{2} foils at 150, 200, 300, and 400°C were 0.00023, 0.0038, 0.078, and 0.62% of the initial activity, respectively. At 300°C the tritium loss in an argon atmosphere was approximately 65% of that which occurred during a previous test in an atmosphere of dry air.

Another group of the foils was subjected to a 24-day water leach test. Each foil was tested separately by placing it in a glass tube, adding distilled water, and sealing the tube to prevent tritium losses. The water was sampled and replaced with clean water after 1, 2, 3, 10, 17, and 24 days. The results (Table 1) are given as the accumulated tritium losses during the accumulated leach times.

Table 1. Tritium Loss During Water Leach Tests at 25°C

Accumulated Leach Time, days	Accumulated Tritium Loss, % of initial activity			
	1 Ci/in.^{2}a	4 Ci/in.^{2}a	8 Ci/in.^{2}a	15 Ci/in.^{2}a
1	0.010	0.0023	0.00063	0.00021
2	0.024	0.0037	0.0012	0.00028
3	0.035	0.0044	0.0018	0.00035
10	0.047	0.0066	0.0031	0.00049
17	0.054	0.0074	0.0035	0.00056
24	0.057	0.0084	0.0038	0.00064

[a]Nominal activity of foil.

TECHNOLOGY UTILIZATION - 08-01-05

A. Information Center

The Isotopes Information Center now has 16,500 accessioned items with no indexing backlog.

During January, 291 IIC reports and reprints were sent out in answer to requests, and 53 requests that required specific answers were filled. A list of reviews in progress is given below:

Title	Author(s)	Status, % complete
Cement-Polymer Combinations	Martha Gerrard, P. S. Baker, R. E. Greene	95
DID Research and Developments - 1969	Isotopes Information Center Staff	85
Flow Measurement	R. H. Lafferty, Jr.	5
Indium-113m: Preparation and Uses	Martha Gerrard	10
Iodine-125	P. S. Baker, Martha Gerrard	25
Isotopic Methods of Examination and Authentication in Art and Archaeology	F. J. Miller, E. V. Sayre, B. Keisch	95
Oceanography[a]	Isotopes Information Center Staff	90
Patent Review - Process Radiation Development	R. E. Greene, P. S. Baker, Helen Warren	80
Potato Sprout Inhibition by Radiation	F. E. McKinney	20
Radiation vs Glass[b]	D. N. Hess	20
Radioisotopes in Automatic Control Systems	R. H. Lafferty, Jr.	-
Radioisotopes in the Pharmaceutical Industry	P. S. Baker, Martha Gerrard	5
Radioisotopes in the Steel Industry[c]	Republic Steel Corporation	10
Radioisotopes in the Textile Industry	F. J. Miller	90
Radioisotopes in X-Ray Fluorescence Analysis	R. H. Lafferty, Jr.	5
Selected Abstracts of World Literature on Production and Industrial Uses of Radioisotopes, 4th Quarter 1969	Martha Gerrard, P. S. Baker	In Reproduction
Self-Diffusion in Liquids	F. J. Miller	75
Snow Gaging and Water Management	James L. Smith	-
Strontium-90	Roberta Shor, R. H. Lafferty, Jr., P. S. Baker	85
Technetium-99m: Preparation and Uses	Martha Gerrard, P. S. Baker	30
Use of Radioisotopes in Sedimentology	V. Romanovsky (translated and edited by Martha Gerrard)	10
Wheat Disinfestation - A Worldwide Review	F. E. McKinney	5
Wood Plastics	R. E. Greene	75
Yttrium-90	Martha Gerrard	10

[a]Draft completed; being held at DID.
[b]Indefinite.
[c]Will be in sections; first section now in hand.

B. Isotopes and Radiation Technology

Final page proofing was done on Isotopes and Radiation Technology 7(3), and manuscript for 8(1) was started.

C. Publications

Ruth Curl (compiler), List of AEC Radioisotope Customers with Summary of Radioisotope Shipments, FY 1969, ORNL-IIC-27 (January 1970).

Charles Engelman, Activation Analysis with Charged Particles and Gamma Protons, Bull. Inform. Sci. Tech. 140: 65-70 (September 1969); French translation ORNL-tr-2265, Martha Gerrard.

RADIOISOTOPE APPLICATIONS DEVELOPMENT

BASIC TECHNOLOGY DEVELOPMENT - 08-03-01

A. Liquid Scintillation Development

1. Alpha Radiation Damage in Phosphors

Nothing to report.

2. Cerenkov Counting

Wave-shifting compounds are often used in Cerenkov counting to enhance the detection efficiency of low energy nuclides. A study of the effect of pH on the conversion efficiency of 13 typical wave-shifters was completed as part of our general Cerenkov investigation. Although most of the conversion materials show a marked sensitivity to sample pH, three materials (4-methylumbelliferone; 2-naphthol-3,6-disulfonic acid disodium salt; 7-amino-1,3-naphthalene-disulfonic acid) are remarkably stable over the pH range of 2 to 12. All our results on wave-shifting materials for aqueous Cerenkov counting systems are being prepared for an invited paper at the 1970 International Conference on Organic Scintillators and Liquid Scintillation Counting.

SYSTEMS ENGINEERING APPLICATIONS - 08-03-02

A. Oceanographic Systems Study

Preparations for the sand transport survey at Oceanside, California, are complete and field operations will begin February 1, 1970. One of the detector assemblies has been equipped with an electromechanical cable which will be tested during this experiment. The detector assembly has been calibrated by making measurements with gold-198 tagged sand buried at various depths up to 8 in. Data were collected from two burial conditions: (1) tagged sand mixed with sand to form a layer and (2) a layer of sand containing radioactive material covered with a layer of nontagged sand. By incorporating photo peak ratios from the gold-198-199, this calibration will make it possible to relate radiation counts to the actual quantity of radioactive material present. This information is necessary for determining the quantity of sand in transport. A stationary detector, calibrated as a function of radiation count versus core depth, will be used to monitor a core injection and to provide information concerning the quantity of tagged sand that has been removed from the injection core. It will also provide information concerning the depth of movement.

B. National Security

Nothing to report.

RADIATION PROCESSING APPLICATIONS DEVELOPMENT

ORGANIC SYNTHESIS WITH ISOTOPIC SOURCES - 08-04-01

A. Allyl Alcohol

Allyl alcohol can be converted to glycerin (glycerol) via aqueous chlorination to glycerol α-chlorohydrin, which is then hydrolyzed by a base (NaOH) to glycerin.

The radiolytic hydrolysis of allyl alcohol was studied to determine whether the double bond was amenable to addition of two hydroxyl groups under the influence of gamma irradiation. Samples were made by mixing 5 ml of allyl alcohol with 10 ml of water, 10 ml of 30% hydrogen peroxide, and 10 ml of 50% acetic acid-50% water; 5 ml of acetic acid and 5 ml of 30% hydrogen peroxide; and 10 ml of 1 N sodium hydroxide, respectively. Each mixture was irradiated with 1.12×10^7 R (total dose). No signicant changes were observed. Similar mixtures were irradiated as above at 1500-psig oxygen pressure and exposed to the same total dose. The results were not different.

B. Sucrose

Commerical oxidation of sucrose with nitric acid leads to important difunctional acids - oxalic and tartaric.

Our preliminary investigation of gamma radiolytic oxidation of sucrose was done with a saturated 5-ml aqueous solution under 1500-psig oxygen pressure. This solution was irradiated with a total dose of 2×10^7 R. Since analysis of the sample required the absence of water, the solution was distilled *in vacuo* to remove the water; however, a volatile fraction was recovered from the liquid nitrogen trap. Infrared spectroscopy showed the presence of carbonyl functions at 1720-1730 cm^{-1} for ketones and/or aldehydes. The residue from the distillation was essentially unchanged sucrose. The carbonyl functions show that we are obtaining intermediates that lead to organic acids.

C. Straight Chain Fatty Acids

The radiolytic oxidation of long chain hydrocarbons is fairly complex; therefore, shorter chain hydrocarbons were used to study the mode of oxidation. Hexane was placed under 1500-psig oxygen and irradiated with 2×10^7 R total dose. There was fragmentation of the chain. Retention time on gas-liquid chromatography indicated the presence of formaldehyde, formic acid, and acetic acid. Infrared spectroscopy showed the presence of acid(s). There was oxidative fragmentation when 2-hexene was irradiated under similar conditions. However, the presence of the double bond could lead to maleic and fumaric acids since attack under radiation would be alpha to the double bond. At present we are analyzing for these acids.

Work in February will be concentrated on the oxidation of sucrose and straight chain acids. The behavior of allyl alcohol will be investigated under aqueous radiolytic conditions.

RADIOISOTOPE SALES

Requests for quotations were received from Cleveland Clinic for up to 52 tritium-titanium targets and from Los Alamos Scientific Laboratory for 10-g quantities each of freshly purified promethium-147 metal and $^{147}Pm_2O_3$.

Orders were received from Radiochemical Centre for 30,000 Ci of tritium; McDonnell Douglas Astronautics Company for 50,001 Ci of promethium-147 as Pm_2O_3 (20,000 Ci of promethium-147 with low promethium-146 content and 30,001 Ci of promethium-147 with a specific activity of 750 Ci/g); and from U. S. Navy for 556,982 Ci of strontium-90 as encapsulated sources.

Shipments made during January included 10,000 Ci of tritium to U. S. Radium Corporation and 15,000 Ci of tritium to Britain's Radiochemical Centre.

A list of outstanding large orders is shown below:

Isotope	Amount, Ci	Customer
Cesium-137	360,000	Brookhaven National Laboratory[a]
Cesium-137	~180,000	American Nuclear Corporation[a]
Cesium-137	~207,000	U. S. Army, Natick Laboratories[a]
Cesium-137	205,000	Industrial Reactor Laboratories, Inc.
Cesium-137	1,180,000	Radiation Machinery Corporation
Cesium-137	~194,000	Atomic Energy of Canada Limited
Cesium-137	200,001	General Nuclear, Inc.
Cesium-137	40,000	Radiation Resources, Inc.
Cesium-137	20,000	Radiochemical Centre
Cesium-137	200,001	CEA, France
Cesium-137	200,001	Radiation Resources, Inc.
Cesium-137	~5,000	Miscellaneous orders
Strontium-90	300,000	CEA, France
Strontium-90	~532,000	Isotopes, Inc.
Strontium-90	~105,000	Isotopes, Inc.[a]
Strontium-90	~41,000	Brookhaven National Laboratory
Strontium-90	4,951	Radiation Machinery Corporation
Strontium-90	556,982	U. S. Navy
Strontium-90	~2,000	Miscellaneous orders
Promethium-147	5,100	Reactor Centrum Nederland
Promethium-147	5,000	Mitsubishi Corporation (Japan)
Promethium-147	50,001	McDonnell Douglas Astronautics Co.[b]
Carbon-14	1,445 mCi	Catholic University
Tritium	10,001	Radium-Chemie A. Zeller Co.
Tritium	90,000	Radiochemical Centre

[a]Activity has been billed in previous fiscal years. Material is now being fabricated into sources or has already been fabricated into sources and is stored for future requests for shipments.

[b]Material to be shipped from Richland, Washington.

Tables 2 and 3 give the ORNL and non-ORNL cyclotron customers and runs for January 1970.

Table 2. ORNL Cyclotron Customers and Runs for January 1970

Customer	Product	Target	Time, hr:min			Total Charges
			Beam	Misc	Total	
Isotopes	Rubidium-83	Rubidium	2:00	1:05	3:05	$ 292.92
	Indium-111	Cadmium-111	2:00	1:15	3:15	318.75
ORAU	Gallium-67	Zinc	1:00	1:15	2:15	248.85
Physics	Cobalt-61	Nickel-64	1:45	1:15	3:00	295.00
Stock	Gallium-67	Zinc	:20		:20	
Total			7:05	4:50	11:55	$1155.52

Table 3. Non-ORNL Cyclotron Customers and Runs for January 1970

Customer	Product	Target	Time, hr:min			Total Charges
			Beam	Misc	Total	
New England Nuclear Corporation	Yttrium-87	Strontium-87	2:30	1:15	3:45	$ 610.10
	Yttrium-87	Strontium-87	3:00	1:15	4:15	680.10
	Rubidium-84	Krypton	1:30	:25	1:55	341.67
Huntington Hospital	Rubidium-84	Krypton	8:00	:50	8:50	1383.32
International Chemical & Nuclear Corporation	Yttrium-88	Strontium	8:00	1:15	9:15	1340.25
Stock	Rubidium-84	Krypton	1:00		1:00	
Total			24:00	5:00	29:00	$4355.44

The radioisotope sales proceeds and shipments for the first six months of fiscal years 1969 and 1970 are given in Table 4.

Table 4. Radioisotope Sales and Shipments

Item	7-1-68 thru 12-31-68	7-1-69 thru 12-31-69
Inventory items	$258,735	$304,346
Major products	48,711	57,277
Radioisotope services	94,972	125,492
Cyclotron irradiations	88,951	72,637
Miscellaneous processed materials	30,098	41,801
Packing and shipping	40,997	37,615
Total Radioisotope Sales	$562,464	$639,168
Total Radioisotope Shipments	1,393	1,260

RADIOISOTOPE PRODUCTION

CESIUM-137 PROCESSING

No cesium-137 processing was done this month.

STRONTIUM-90 PROCESSING

Analysis of the $^{90}SrTiO_3$ products produced by the potassium carbonate procedure indicates contamination of up to 1.3% of potassium and carbonate. It has been decided to withhold the use of $^{90}SrTiO_3$ products made by the potassium carbonate procedure until investigations can be made to determine the effect of the potassium on the integrity and quality of the sources.

The high carbonate content has been traced to a failing calcination furnace in the strontium-90 powder preparation cell. This furnace has been taken out of service and all future batches of $^{90}SrTiO_3$ will be calcined in the hot-press furnace. A resistance-heated hot press with remote maintenance capabilities will be installed in the near future. This new unit will serve a dual purpose and can be accurately controlled for calcination of powder or hot-pressing pellets.

Two $^{90}SrTiO_3$ products were made using the NH_4OH-$(NH_4)_2CO_3$ precipitation procedure, with a yield of approximately 100,000 Ci. Analytical data results and material balance calculations for these runs are currently in progress. It is planned to process approximately 150,000 Ci of $^{90}SrTiO_3$ by this procedure to complete the bulk powder order for France (CEA).

A press-fit end cap was expelled from a powder can containing approximately 13,000 Ci of $^{90}SrTiO_3$. Two powder cans were selected for gas measurements and sampling to check for unsuspected gas buildup. One can contained material processed by the NH_4OH-$(NH_4)_2CO_3$ procedure and the other contained material processed by the new KOH-$KHCO_3$-K_2CO_3 procedure.

The contained gases were sampled into evacuated flasks and submitted for mass spectrographic analysis. The results are given in Table 5.

Table 5. Mass Spectrographic Analysis of Gases in $^{90}SrTiO_3$ Powder Cans

	Can No. 69-S-20	Can No. 69-S-7
Type process	KOH-$KHCO_3$-K_2CO_3	NH_4OH-$(NH_4)_2CO_3$
Powder batch number	SR 69-8	Blend 5-6-7
Specific activity level, Ci/g	27.8	29.2
Powder weight, g	500	458
Total activity, Ci	13,900	13,373
Measured gas pressure, psia	17.0	11.7
Mass spectrographic number	A-9	A-2
Analysis results		
H_2	<0.1	<0.1
H_2O	0.1	<0.1
N_2 or CO[a]	98.1	98.2
O_2	0.1	0.1
A	1.7	1.7
CO_2	<0.1	<0.1

[a]Reported to be over 90% N_2.

MAINTENANCE

Decontamination of the manipulator cells used for cesium-137 processing continued on an intermittent basis. It is expected that personnel entry for decontamination purposes will be effected in February.

An existing nitrogen storage system has been revamped for the use of argon throughout the Fission Product Development Laboratory. The new argon storage station services all window purge systems, in-cell welding, and hot presses, as well as the maintenance shop. This system eliminates the costly handling problems encountered with standard gas cylinders.

The fabrication of the off-gas dehumidifier system is approximately 90% complete. This equipment, after installation in the plant off-gas system, should reduce the plugging problems associated with the off-gas system HEPA filters. These problems are primarily the radiation background at the filtration cell and the absorption of water on the HEPA filters.

SOURCE FABRICATION

A. Cesium-137

Preparation of the RAMCO order for 210 cylindrical $^{137}CsCl$ sources, 400 Ci each, was completed. During this cycle, there were 19 rejected liners due to weld overhang. This particular design is susceptible to this problem since the liner outside diameter is only 0.4 in., the wall thickness is 0.02 in., and the clearance between the liner and the capsule is 0.015-0.020 in. One rectangular BNL source of a group of 30 was slightly contaminated after the one-week shelf test. It was defueled and a replacement was fabricated. Completed cesium-137 sources currently on hand, either ready for shipment or on shelf test, are as follows:

Customer	Sources	Amount of ^{137}Cs, Ci
U. S. Army (Natick)	46 Type 1 rectangular	213,600
Brookhaven National Laboratory	15 Type 1 rectangular	68,300
Brookhaven National Laboratory	15 patterned rectangular	47,900
Radiation Machinery	12 short-form rectangular	36,000
Radiation Machinery	210 cylindrical	84,000
Miscellaneous	8 assorted cylindrical	6,500
		456,300

A miscellaneous cesium-137 source run is scheduled to start. This run involves sources of several different designs, ranging in content from 5 to 2,000 Ci.

B. Strontium-90

Liners for ten Sentinel-25 strontium-90 sources were received from Isotopes, Inc. Fabrication of the first five of these units, containing 110,000 Ci (750 W) each, will probably start late in February. Dies for the preparation of some strontium-90 pellets of various fuel compositions

for compatibility tests have been received. These pellets will be prepared before starting fabrication of the Sentinel-25 sources.

SPECIAL FORM MATERIALS

A shipment of 180,000 Ci of bulk $^{90}SrTiO_3$ powder in 13 welded shipping cans was loaded for delivery to the CEA, France, and one shipment of 500 Ci of bulk $^{137}CsCl$ powder was made. During the miscellaneous $^{137}CsCl$ source run in February, the stockpile of assorted $^{137}CsCl$ powder shipping cans will be replenished.

OPERATIONAL SUMMARY

	January 1970		FY 1970	
	Number	Amount, Ci	Number	Amount, Ci
Cesium-137				
HAPO shipments received	0	0	0	0
Product batches prepared	0	0	0	0
Sources fabricated	126	50,400	185	305,400
Special form containers	0	0	0	0
Strontium-90				
HAPO shipments received	0	0	0	0
Product batches prepared	2	100,000	13	509,500
Sources fabricated	0	0	0	0
Special form containers	13	180,000	32	212,900

PROCESS STATUS

Item	Physical Inventory: Cesium-137, Ci	Physical Inventory: Strontium-90, Ci
In-process materials	243,500	1,092,600
Product powder	440,800	930,000
Sources in fabrication	2,600	0
Completed sources[a]	454,300	704,000

[a]Includes stored sources and completed bulk shipping cans.

MISCELLANEOUS RADIOISOTOPE PROCESSING

Short-Lived Fission Products			Processed Units			Service Irradiations	
Radioisotope	No. of Batches	Amount, Ci	Radioisotope	No. of Batches	Amount, mCi	Type	No. of Irradiations
Xenon-133	1	600	Tungsten-187	1	1,500	Y_2O_3	2
Iodine-131	1	100	Calcium-37	2	18	Vanadium	1
			Iodine-131 (elemental)	1	300	Platinum-190	1
	2	700				Platinum-196	1
			Copper-67	1	16	Antimony	1
						Gold	1
				5	1,834	Fe Ni	1
						Uranium-236	1

The cerium-144 run started last month was continued during January; this separation has not resulted in a finished product. Work was suspended in order to make a yttrium-91 separation for Lovelace Foundation. The yttrium-91 separation is approximately 80% complete and should be completed by February 1.

ADMINISTRATIVE SECTION

Travel by IDC personnel and visitors to the IDC are given in Tables 6 and 7, respectively.

Table 6. Travel of IDC Personnel

Site Visited	Purpose of Visit
Vanderbilt University Nashville, Tennessee	Discuss radiographic sources for medical research
Coastal Engineering Research Center, Washington, D. C.	Discuss RIST program and data treatment
Greensboro, North Carolina	Discuss radiation processing of textile waste

Table 7. Visitors to IDC

Visitors (affiliation)	Purpose of Visit
Korean Atomic Energy Commission	Discuss radioisotope production technology - ^{99}Mo-^{99m}Tc
Energy Systems, Inc. Melbourne, Florida	Obtain information on radiation effects on viruses
Chief, Isotope Operations Euratom, Brussels, Belgium	Discuss cooperation between Euratom and IIC
TRW Systems, Inc.	Discuss sized $^{90}SrTiO_3$ powder and testing of filters
Ridge Instruments	Discuss secondary X-ray sources
Coastal Engineering Research Center, Washington, D. C.	Discuss RIST program
Vanderbilt University Nashville, Tennessee	Discuss medical sources and blood irradiator
AEC-DID	Discuss SO_2 analyzer and RIST program
Industrial Nucleonics	Discuss SO_2 analyzer

INTERNAL DISTRIBUTION

1. A. L. Allen
2. M. A. Baker
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18. E. H. Kobisk
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26. F. M. O'Hara
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29. M. E. Ramsey
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31-32. R. A. Robinson
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36. K. A. Spainhour
37. M. R. Skidmore
38-39. H. F. Stringfield
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41. J. C. White
42-43. Central Research Library
44. Document Reference Section
45-49. Laboratory Records Department
50. Laboratory Records - RC

EXTERNAL DISTRIBUTION

51. G. A. Andrews, ORAU, Medical Division, Oak Ridge, Tennessee
52. Hal Atkins, Brookhaven National Laboratory, Upton, New York
53. D. S. Ballantine, AEC, Washington, D. C.
54-57. R. F. Barker, AEC, Washington, D. C.
58. N. F. Barr, AEC, Washington, D. C.
59. O. M. Bizzell, AEC, Washington, D. C.
60. C. R. Buchanan, AEC, Washington, D. C.
61. R. L. Butenhoff, AEC, Washington, D. C.
62. T. D. Chikalla, PNL, Richland, Washington
63. D. F. Cope, AEC Site Representative, ORNL
64. D. C. Davis, AEC, Oak Ridge, Tennessee
65. J. C. Dempsey, AEC, Washington, D. C.
66. W. K. Eister, AEC, Washington, D. C.
67. E. E. Fowler, AEC, Washington, D. C.
68. J. D. Goldstein, AEC, Washington, D. C.
69. A. Gottschalk, Argonne Cancer Research Hospital, Chicago, Illinois
70. F. D. Haines, AEC, Washington, D. C.
71. J. W. Irvine, MIT (Consultant)
72. J. Lawrence, Lawrence Radiation Laboratory, Berkeley, California
73. J. E. Machurek, AEC, Washington, D. C.
74. J. N. Maddox, AEC, Washington, D. C.
75. J. C. Malaro, AEC, Washington, D. C.
76. W. E. Mott, AEC, Washington, D. C.
77. J. A. Powers, AEC, Washington, D. C.
78. J. G. Rotariu, AEC, Washington, D. C.

79. B. A. Ryan, AEC, Richland, Washington
80. W. D. Sandberg, AEC, Aiken, S. C.
81. S. J. Seiken, AEC, Washington, D. C.
82. W. F. Sheely, PNL, Richland, Washington
83. R. W. Shivers, AEC, Washington, D. C.
84. P. E. Smith, ARHCO, Richland, Washington
85. L. G. Stang, Jr., BNL, New York
86. G. Taplin, University of California, Los Angeles, California
87-92. D. H. Turno, SRL, Aiken, S. C.
93. A. R. Van Dyken, AEC, Washington, D. C.
94. Laboratory and University Division
95-109. Division of Technical Information Extension