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U. S. ATOMIC ENERGY COMMISSION
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PACIFIC NORTHWEST LABORATORY
MONTHLY REPORT TO THE
DIVISION OF ISOTOPES DEVELOPMENT
FOR FEBRUARY 1971

Compiled by J. E. Hansen

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PACIFIC NORTHWEST LABORATORY
MONTHLY REPORT TO THE
DIVISION OF ISOTOPES DEVELOPMENT
FOR FEBRUARY 1971

08-01. RADIOISOTOPES PRODUCTION AND
MATERIALS DEVELOPMENT

08-01-03. FISSION PRODUCTS

I. LOW COST CESIUM AND STRONTIUM SOURCES - H. H. Van Tuyl,
and L. K. Mudge

The objective of this program is to provide technology for the production of inexpensive Cs and Sr sources by using the purified compounds generated in the Hanford Waste Management Program (HWMP). Large scale use of these radioisotopes will require an assessment of the capabilities of HWMP for producing suitable radiation and heat sources, acceptance of the HWMP product by the customer, licensing of the sources, and market development activities.

The goal in FY-1971 is to develop equipment for fabricating smaller diameter sources in the HWMP facility. The incremental cost of producing smaller sources will be evaluated. Prototype sources will be fabricated with nonradioactive feeds, including loading capsules, welding, and NDT. The sources will be tested to determine mechanical integrity. Potential customers will be contacted to stimulate interest in the HWMP sources.

The recently announced closure of the remaining reactors at Hanford is not expected to have an appreciable effect on the Hanford Waste Management Program (HWMP). Accumulation of cesium

will continue as a partially purified crude, with final purification being scheduled in facilities now under construction. All of the required strontium purification is being done currently, but flowsheets are still being changed occasionally to obtain higher purities, better recovery, or lower operating cost. It is still premature to state the purity or fractional recovery of the strontium.

Strontium fluoride from HWMP will contain some Ca, Ba, and Na as impurities. The effect of Ca and Ba on the properties of the as-produced material can be precisely evaluated by the laws of solid solution and the properties of the pure components. Sodium fluoride and strontium fluoride do not form a solid solution under any conditions, according to work by G. A. Bukhalova in 1955.⁽¹⁾ They do form an equimolar eutectic with a melting point of about 850 °C. Thus, the thermal equilibrium composition expected in the HWMP strontium product is a bulk phase consisting of alkaline earth fluorides along with the equimolar eutectic. The properties of the impurity phase cannot be evaluated adequately from existing data. Some additional laboratory work appears to be necessary to characterize the total system.

In its simplest form the encapsulated SrF_2 would consist of strontium fluoride, zirconium daughter, and a certain amount of impurity sodium fluoride. The introduction of daughter zirconium into the SrF_2 system produces significant complexity.

(1) N. K. Voskresenskaya, Editor. Handbook of Solid-Liquid Equilibria In Systems of Anhydrous Inorganic Salts, Vol. I., p. 565. Israel Program for Scientific Translations, Jerusalem, 1970.

The stoichiometry of the resulting zirconium compound is ZrF_2 . One would expect the presence of ZrF_2 in SrF_2 to produce phase behavior similar to mixtures of other divalent fluorides. If a series of solid solutions is formed, this would probably mean a maximum freezing point depression of only a few hundred degrees. In the absence of SrF_2 - ZrF_2 solid solutions, a eutectic with a much lower freezing point might be obtained. The presence of sodium fluoride in such a mixture would be expected to lower the freezing point still more, the result being a bulk phase of nearly pure SrF_2 and a small-mass phase containing the mixture.

The chemistry of the fluorides of zirconium is of interest in the effort to estimate the Zr species that will control the phase behavior of aged SrF_2 . Compounds of ZrX_2 and ZrX_3 have been reported for all the halides, but the fluorides are less well described than the others. Zirconium metal will reduce ZrCl_4 to ZrCl_3 at 450 °C and to ZrCl_2 at 675 °C. The ZrF_3 compound is reported to exist and ZrF_4 has been reduced at 350 °C by atomic hydrogen to ZrF_2 . The ZrF_2 compound disproportionates at 800 °C, which indicates that daughter zirconium exists as ZrF_2 in the beginning and as a mixture of Zr metal and ZrF_4 if the material in the capsules becomes hot enough.

The phase behavior might change significantly above a temperature at which disproportionation of ZrF_2 takes place. The ZrF_4 compound itself melts at about 920 °C, which is significantly lower than what one would estimate for ZrF_2 . ZrF_4 forms a series of compounds with alkali and (presumably) alkaline earth fluorides, which form eutectics with each other, some melting as low as 500 °C. The phase diagrams of ZrF_4 with the alkali halides indicates, however, that at lower ZrF_4 concentrations the lowest melting point mixture would probably be a

eutectic with either the compound M_3ZrF_7 or a compound containing whatever cations are available (perhaps Sr^{+2}). Such a eutectic could melt below 700 °C and, if there were several different cations, maybe well beyond that.

Studies of the disproportion of ZrF_2 would be worthwhile, particularly to find if there is a drastic change in behavior when the temperature of the zirconium containing systems goes through the disproportion temperature of ZrF_2 .

II. UTILIZATION OF FISSION PRODUCTS Rh, Pd, Ru, and Tc

The traditional view of fission products as waste materials has been supplanted by their role as a national resource. Pursuant to this revised status, a resource strategy is now being formulated to direct optimum technological and economic application of the fission products Rh, Pd, Ru, and Tc created in operation of nuclear power reactors. This program seeks to evaluate the potential of these artifacts as supplements to the natural reserve of precious metals, and emphasizes the practical aspects of their safe use. The program comprises the following tasks:

1. *Evaluation of rhodium and palladium produced in power reactors.*
2. *Technology for recovery of Rh, Pd, Tc, and Ru.*
3. *Market analysis of Rh, Pd, Tc, and Ru.*
4. *Economic analysis of Rh, Pd, Tc, and Ru production from nuclear wastes.*
5. *Fabrication process development for nuclear source (Rh, Pd, Tc, and Ru) products.*

A. Radiation Characteristics -- F. P. Roberts

1. ^{102m}Rh Half-Life -- Acquisition of data for the measurement of the half-life of ^{102m}Rh continues.

2. Isotopic Composition of Rh in Spent Reactor Fuels -- Final purification of the rhodium separated from samples of Yankee Reactor fuel has been completed, and efforts are now underway to measure the rhodium isotopic composition. Measurement of the burnup of the fuel from which the rhodium was recovered is also in progress.

3. Dose Rate from Fission Product Palladium -- It is expected that the dose rate from the decay of ^{107}Pd in fission product palladium will be quite small because of the very low energy of the beta. To verify the low dose rate, a foil is being prepared by plating a base metal with fission product palladium metal. Attempts are being made to deposit sufficient palladium to give a thickness equal to or greater than the range of the ^{107}Pd beta. This will simulate a source of infinite thickness and maximum dose rate. Three grams of palladium separated from Hanford fuel have been purified for this purpose. This material contains 16 wt% ^{107}Pd . Techniques for preparing a uniform adherent plate on platinum are being tested.

B. Fabrication Process Development -- R. G. Nelson

Nothing to report.

C. Market Analysis -- J. C. Sheppard

1. Analysis of World Production of Platinum Metals -- Further effort was made to analyze the future production of the platinum

metals. Part of the effort involved the projection of future production with the assumption that the world reserve of platinum metals is finite and exhaustible. Three alternative situations were assumed: (1) the presently known platinum metals reserves represent those that will be exploited by present-day technology, and it is unlikely that large ore bodies comparable to the Merensky Reef (2×10^8 oz) will be found; (2) a platinum metal ore body comparable to the Merensky Reef will be found; and (3) the platinum metals reserve is actually smaller than the presumed world reserves by an amount equivalent to the Merensky Reef.

If it is assumed that the world's platinum metals reserves are finite, it cannot be assumed that the annual production rate increase of 8.6% per year can continue indefinitely. In view of this, the Lotka-Volterra logistic growth curve was used.

$$\text{Cumulative Production(oz)} = \frac{\text{Total Reserves}}{1 + e^{kt^1}}$$

The term "k" is the growth rate constant, assumed to be about 8.0% per year, and $t^1 = t_{\max} - t$, where $t_{\max}$ represents the time (approximate data) at which half of the reserves have been consumed. It should be pointed out that this type of analysis has been used to examine the adequacy of the nation's oil reserves. The data in Table I is a summary of calculations using the logistic growth curve.

TABLE I. DATE WHEN HALF OF PLATINUM METAL RESERVES WILL HAVE BEEN CONSUMED

<u>Case</u>	<u>Total Reserves, oz</u>	<u>$t_{\max}$</u>
1	4.6×10^8	1997
2	6.6×10^8	2002
3	2.6×10^8	1989

These calculations indicate that by the turn of the twenty-first century, half of the presently known platinum reserves will have been consumed. It is more informative to examine the derivative of the growth curve because it shows the deviations that can be expected from a pure exponential growth of platinum metals production. The results of these calculations are shown in Table II.

These calculations suggest that there may be an impending shortage of the platinum metals in the short-term future. However, these calculations should be qualified by the observation that large platinum ore bodies may be found. It should also be observed that the probability of finding such a body is small. Furthermore, the possibility remains of exploiting lower grade ores. All these observations should temper conclusions based on Table II.

The future nuclear production of the platinum metals (Ru, Rh, and Pd) is being examined.

2. Examination of Uses and Potential Uses of Ru, Rh, Pd, and Tc --
A survey has been made of the current and potential uses of the platinum metals. At the same time a review of dispersal modes for the various uses has also been made as the first step in a hazards analysis. Table III summarizes the significant uses of these platinum metals and technetium. The potential uses of Ru, Rh, and Pd are based upon the observation that these platinum metals are better hydrogenation catalysts than Pt itself. Since the reactions for hydrogenation and pollution control are essentially the same, Ru, Rh, and Pd could be used as catalysts if they were available in sufficient quantity.

TABLE II. PRODUCTION RATES OF PLATINUM METALS (oz per year)

Year	Observed Production Rate	Exponential Growth	Calculated Production Rate					
			6.6 (a)	Deviation (b)	4.6 (a)	Deviation (b)	2.6 (a)	Deviation (b)
1960	2.4	2.7	2.7	0	2.7	0	2.7	0
1970	3.8	3.8	3.5	-0.3	3.5	-0.3	3.3	-0.5
1980	---	8.4	7.1	-1.3	6.5	-1.9	4.6	-3.8
1990	---	18.5	10.5	-8.0	8.5	-10.0	5.0	-13.5
2000	---	40.0	12.9	-27.1	9.1	-30.9	4.3	-35.7

(a) Reserves multiplied by 10^{-8} (See Table I).

(b) Difference between exponential and calculated Lotka-Volterra values times 10^{-6} .

TABLE III. USE MATRIX FOR PLATINUM METALS, TECHNETIUM

<u>Use</u>	<u>Ru</u>	<u>Rh</u>	<u>Pd</u>	<u>Tc</u>
Nitric Acid Production	P	M	P	O
Hydrocarbon Cracking	P	P	P	P
Pollution Control	P	P	P	O
Electrical Contacts	S	S	M	O
Glass Manufacture	O	S	O	O
Rayon Manufacture	O	VS	O	O
Cl ₂ Manufacture	VS	O	O	O

P = potential use
M = major use at this time
S = small use at this time
VS = very small use at this time
O = no use at this time

It is interesting to note that the quantity of Pd used for electrical contacts may be significantly altered by advances in electronic switch technology. A large fraction of the palladium is now used for telephone switches; however, Bell Telephone, and presumably other telephone companies, are converting to electronic switches. This change may significantly alter the future demand for Pd.

3. Dispersal Modes for Ru, Rh, Pd, Tc -- As a first step in the hazards analysis and for the uses shown in Table III, a survey is being made of dispersal modes. The most likely dispersal modes are shown in Table IV.

TABLE IV. DISPERSAL MODES FOR Ru, Rh, Pd, Tc

<u>Use</u>	<u>Ru</u>	<u>Rh</u>	<u>Pd</u>	<u>Tc</u>
Nitric Acid Production	Vap.	Vap.	Vap.	0
Hydrocarbon Cracking	Vap.	Vap.	Vap.	0
Pollution Control	Vap.	Vap.	Vap.	0
Electrical Contacts	Eros.	Eros.	Eros.	0
Glass Manufacture	0	Corr.	0	0
Rayon Manufacture	0	Negl.	0	0
Cl ₂ Manufacture	?	0	0	0

Vap. = vaporization

Eros. = erosion

Corr. = corrosion

Negl. = negligible

0 = no use at this time

Losses due to vaporization should be predictable from vapor pressure-temperature data. The data for platinum and platinum-10% rhodium obey the typical Arrhenius plots and are represented by the following equations:

$$\text{loss rate (Pt, g/cm}^2\text{)} = 44.5 \exp\left\{-\frac{39,900}{R} \times T\right\}$$

$$\text{loss rate (Pt-10\% Rh, g/cm}^2\text{)} = 23.0 \exp\left\{-\frac{39,900}{R} \times T\right\},$$

where R and T are the gas constant and absolute temperature, respectively. These equations can be used to calculate losses for a wide variety of conditions. Similar equations will be developed for pure Ru, Rh, and Pd.

Examination of the losses caused by the erosion of these metals at electrical contacts has been started. It appears that the process is best described as a material transfer from one electrode to another through the formation of a molten metal bridge. Actual dispersal appears to be minimal.

4. Radiological Hazards -- Nothing to report.

D. Ru-106 Recovery for ORNL -- E. J. Wheelwright
(Funded under related services)

A request has been received from the AEC to recover approximately 70 Ci of Ru-106 from aged Purex IWW, purify the material and package for shipment to ORNL as the sulfide. The required IWW has been transferred to the 325-A Facility from 324 Building. Distillation equipment is being fabricated. When completed, the equipment and process flowsheet will be tested with simulated IWW. It is anticipated that this project will be completed during the month of March.

III. EVALUATION OF LARGE SCALE USES FOR PURIFIED FISSION PRODUCT
XENON - C. A. Rohrman

Of all the fission products, Xe has the highest fission yield. Although many of the Xe isotopes are radioactive, they all have such short half lives that their activity would be insignificant after allowing time for normal fuel reprocessing.

In the past, the extreme rarity of Xe in nature has clearly inhibited its consideration for specific large scale uses even where its properties give it definite and unique advantages. But now, Xe could be made available in surprisingly large quantities. Perhaps the most important and beneficial uses of Xe would be for human surgical anesthesia. Another of the potential uses is a filler gas in incandescent light bulbs with significant increase in both brightness and efficiency.

The scope of the PNL program is to: (1) establish the quality of Xe which can be accepted or generally licensed for consumer uses, (2) determine what industries would be interested in evaluating fission product Xe for large scale application, (3) distribute specimens to participating evaluators, (4) compile evaluation results, and (5) prepare a final report on the results of this total effort.

Analysis of fission product xenon for common gaseous impurities after treatment for their removal continues at ORNL as requested. No specific results have been reported during this period.

IV. ISOTOPE PRODUCTION EVALUATIONS - R. W. McKee, B. M. Cole,
R. G. Rau, and W. W. Waddel

This program is designed to evaluate major aspects of isotope production. Until recently, the principal source of isotopes has been the AEC production reactors. Now, however, power reactors are rapidly becoming important sources of isotopes. Power reactors also offer attractive prospects for target irradiations. The future availability and cost of these unique isotopes depend on full and efficient utilization of the production potential of power reactors, and the inherent value of these materials can have a significant impact on nuclear power costs.

The scope of this program includes analysis of fast and thermal reactor fuel cycles within the framework of an expanding nuclear power industry to identify the sources, quantities, timing and cost of production of isotopes of potential importance.

A new task to develop an Isotope Data System was initiated in FY-1971. The objective is a computerized, quick-response system for answering queries on isotope properties, availability, applications, shielding requirements, decay compositions, toxicity, and other factors.

A. Fission Product Profitability Studies

Except for some minor revisions in output formats, the two new computer codes being developed for the market simulation studies were completed and debugged. One code, called RASOR, computes a replenishment schedule for either a one or two-component radiation source material. Certain constraints can be specified. The other code, called RAMARK, combines the

results from RASOR with one of several optional market projection equations. For a base market defined in terms of ^{60}Co , or any other material, the code apportions the market among a number of (up to three) source materials and identifies the separate market requirements for each one.

These programs are now being combined with the CAESR program to examine the economics of various possible market situations.

B. Nuclide Tables

Revision and updating of the Nuclide Data File continued. Approximately 10,000 punched cards have now been prepared. An estimated 6,000 additional cards will be required to complete the presently scoped updating. Of these, about 2,000 are now ready for keypunching.

C. Isotope Data System

Nothing to report.

08-01-04. SOURCE DEVELOPMENTI. NONDESTRUCTIVE TESTING OF SOURCESA. NDT Research and Development Support - D. R. Newman

The scope of this program is to develop methods of nondestructive examination of isotopic heat sources developed by DID contractors. Through a number of programs, DID is developing applications for various radioisotopes as heat sources for specific applications. The PNL program will concentrate on the development of methods to assure the long-term mechanical and thermal integrity of the as-manufactured sources.

Because it is important that NDT methods are compatible with capsule design, (e.g. welds should be physically accessible for inspection), the approach of this program is to become involved early with contractors who have design and development responsibilities. Continuing liaison will ensure that NDT methods are available for the sources under development.

The main advantage of the multielectrode transducer system is that it allows fast testing while maintaining good spatial resolution of flaws. Spatial resolution was measured this month by drilling small holes in a metal plate. Holes down to 40 mils in diameter could be imaged. 20 mil holes produced inconsistent indications; this was expected since the electrodes are on approximately 20 mil centers.

The pulsed schlieren system was moved into another laboratory and was used to image the high resolution pulses used in the differential transducer technique.

A 10-level signal quantizer was designed and fabricated. This instrument allows 10 rather than 2 levels of signal amplitude from an ultrasonic test system, such as the multielectrode or differential transducer systems, to be presented on an oscilloscope.

Continued contact with AEC contractor personnel concerned with DID's heater programs further established the need for new technology to be developed for assuring integrity and reliability of small isotope heat sources, especially those with thin walls.

B. Neutron Radiography Using ^{252}Cf -- K. L. Swinth

The objective of this program is to develop and investigate low-flux neutron radiography techniques and applications using ^{252}Cf . Previous efforts have led to the development of a portable shield and exposure facility for ^{252}Cf thermal neutron radiography. Evaluation of this facility is underway and will lead to recommendations for future designs. Applications of ^{252}Cf neutron radiography will be identified and efforts will be extended to fast neutron radiography.

A major effort in the program is development of imaging techniques for low-flux imaging. A position-sensitive proportional counter is under development that provides for instantaneous readout of data representing the imaged objective. Various converter foils, such as Eu and ^6LiF thermoluminescent foils, are under investigation, as a means of radiographically recording the images.

The design for the imaging counter is complete and fabrication is about to start. Special materials needed for the counter are on hand and trial run pressings of the ^6LiF for the converter foil have been successful. Attempting to press a 4-in. foil will be more difficult than pressing the 1/2-in. foils now being produced, but the problems, such as obtaining uniform thickness, do not appear insurmountable.

Following fabrication and checkout of a prototype preamplifier for the position-sensitive counter, it became apparent that modifications of the circuit board and some parts changes were needed. These changes are underway and the mounting for the preamplifiers at the rear of the counter is being designed. Review of necessary commercial electronics needed for the system is complete and selection of specific items has begun.

A number of new neutron source holder concepts have been conceived and recorded. These concepts are improvements over the present holder (NC-1). A simple experimental shield for the ^{252}Cf source will be fabricated to explore these concepts. It is expected that this shield will be adequate for the 2-mg source expected in June.

II. TECHNOLOGY PUBLICATIONS - E. J. Wheelwright

The objective of this program is to provide technology for the use of Pm as a radioisotope heat source in aerospace or terrestrial applications. In the past, the program has included development of scientific and engineering data pertinent to: (1) the purification of Pm and conversion to a useful fuel form, (2) the design and fabrication of Pm heat sources and (3) hazards analyses associated with radioisotopic heat sources. Presently, principal emphasis of the program is directed to the dissemination of Pm technology to the technical and scientific community.

The FY-1971 goal is to complete arrangements for the publication of a book on Pm technology.

Very little work was performed during the month since the manuscript is still in review. Dr. Therald Moeller, Head of Chemistry Department, Arizona State University, gave tentative agreement to write a "Foreword" for the book.

III. ADVANCED SOURCE DEVELOPMENT - J. H. Jarrett

A. Advanced Alpha-Photon Source Development

The objective of this program is to evaluate present and future heat and radiatic source application requirements and to relate them to present and future encapsulation technology.

The goal of the current work is concerned primarily with the development of thin-film encapsulation and evaluation techniques for alpha/photon sources. Emphasis will be directed toward the technique of sputtering as a means to obtain thin films of radio-isotope and containment materials.

Four of the $^{241}\text{AmO}_2$ alpha photon sources prepared in December are now being evaluated in the ORNL Source Safety Testing Program. Completion of the testing is anticipated by late March. As a result of the testing, information on the licensability of sources of this design will be obtained.

As indicated in the January monthly report, BNWL-B-61, preliminary evaluation of the alpha photon sources prepared in December was conducted at PNL. Source No. 5 was placed in boiling water for five days at the end of January and no unacceptable americium-241 leaks were detected. The test was continued throughout February with similar results. The test will be continued in March.

Both the glove-box sputtering system and the cold (nonradioisotopic) sputtering system are fully operational. Each system was cleaned in February and, where needed, maintenance was completed.

08-02. THERMAL APPLICATIONS

08-02-01. CIRCULATORY SUPPORT SYSTEMS - F. T. Cross & J.C. Sheppard

The objective of this program is to determine the dose from radioisotopic heat sources suitable for circulatory support systems. This is accomplished by measuring the dose rates within and surrounding various tissue equivalent phantoms.

Part of the program concerns the prediction of the measured dose rates by the development of computational codes. The computer codes are also used in parametric studies and for the prediction of the in-phantom dose rates from sources not available for measurement.

A. Radiation Characteristics - Nonpromethium Systems

Measurements of the neutron dose rates from the Rankine dosimetry model placed in the Remab phantom have been initiated, and ^{252}Cf is being used as a substitute for the $^{238}\text{PuO}_2^{16}$.

No effort has been applied to the in-phantom dose predictions this month.

08-03. RADIOISOTOPE SYSTEMS DEVELOPMENT

08-03-03. OCEANOGRAPHIC AND NATURAL RESOURCE APPLICATIONS

I. MARINE SYSTEMS

A. Nuclear Techniques for Seabed Mineral Exploration -

R. W. Perkins and N. A. Wogman

In recent PNL studies of the composition of deep ocean sediments, it has been demonstrated that various mineral deposits and commercial-grade ores can readily be identified by neutron activation and instrumental analysis. From preliminary analysis, it is evident that the elemental composition of most mineral deposits can be easily identified at concentrations well below those of economic importance. In-place experience with Cf-252 as a neutron source has confirmed these conclusions. Two methods for in-place seabed mineral exploration are being investigated. The first involves placing a neutron source and detector system on the ocean floor. The second method involves bringing the samples on board ship and employs a shipboard Cf-252 irradiator and a Ge(Li) spectrometer. The former technique has the advantage of very rapid analyses, and the latter technique has the advantage that mineral depth profiles can be defined from core sampling.

The main emphasis during the past month has been on improving the calibration factors for the measurement of gold, uranium, silver, selenium, arsenic and indium in simulated seabed and fresh water substrates. These measurements are being made in the mockup facility that simulates the actual seabed irradiation and counting conditions. For this work, known amounts of the elements of interest are homogeneously mixed with 200-lb dunite samples and

saturated with either fresh or ocean water. These measurements indicate that where a 12 in. diameter by 12 in. high paraffin moderator surrounds the ^{252}Cf source, the overall detection efficiencies for fresh water are only 5 to 7% greater than for salt water; therefore, a relatively small correction will be necessary when calibration factors required for the ocean floor are applied to the floor of fresh water basins. Major emphasis is also being placed on defining the efficiency for detecting elements as a function of the density of the substrate. The efficiency is a function of energy, however, it was shown that for the density range of 1.7 to 4, only a 25% reduction in the counting efficiency of the 1778-keV ^{28}Al photon resulted.

Work continues on the construction of the prototype seabed nuclear probe, and it is anticipated that in situ tests of this instrument will be possible early this summer.

PROMETHIUM INVENTORY - February 28, 1971

Received from ARHCO		<u>16,361,900 Ci</u>
Transfers and Shipments	1,498,520 Ci	
Concentrated Feed	4,732,425	
Product		
Run 22, 408 Ci/g	17,412	
Run 40, 468 Ci/g	31,816	
Run 55, 606 Ci/g	71,610	
Run 57, 851 Ci/g	67,801	
Unaccounted	1,196,062	
Decay	8,152,162	
Waste	594,087	
Total	<u>16,361,900 Ci</u>	

Production and Transfers

None

DID BUDGET STATUS - FY-1971 Through February 28, 1971

	<u>Cost</u>	<u>Cost to Date</u>	<u>Budget</u>
08-01 <u>Radioisotope Production and Materials Development</u>			
08-01-03 Fission Products			
I. Low-Cost Cs/Sr Sources	3.7	48.8	50
II. Rhodium, Palladium, Ruthenium, and Technetium	6.5	26.0	40
III. Xenon	0.4	4.4	20
IV. Evaluation of Isotopes Production	<u>11.8</u>	<u>93.0</u>	<u>100</u>
Subtotal 08-01-03	22.4	172.2	210
08-01-04 <u>Source Development</u>			
I. Nondestructive Testing of Sources			
A. NDT R&D Support	3.8	24.8	25
B. Neutron Radiography	6.3	11.1	30
II. Technology Publications	---	19.6	20
III. Advanced Source Development	<u>3.6</u>	<u>45.7</u>	<u>50</u>
Subtotal 08-01-04	13.7	101.2	125
Subtotal 08-01	36.1	273.4	335
08-02 <u>Thermal Applications Development</u>			
08-02-01 <u>Circulatory Support Systems</u>			
I. Circulatory Support	<u>4.6</u>	<u>60.3</u>	<u>85</u>
Subtotal 08-02	4.6	60.3	85

	<u>Cost</u>	<u>Cost to Date</u>	<u>Budget</u>
08-03 <u>Radioisotope Systems Development</u>			
08-03-03 <u>Oceanographic and Natural Resource Applications</u>			
I. Marine Systems	<u>17.9</u>	<u>50.2</u>	<u>60</u>
Subtotal 08-03	17.9	50.2	60
 Total 08 Operating Budget	58.6	383.9	480
 08 Equipment Budget	<u>---</u>	<u>4.2</u>	<u>65</u>
Subtotal 08	58.6	388.1	545
 Pm Inventory Account	<u>26.9</u>	<u>111.4</u>	<u>210</u>
 PROGRAM GRAND TOTAL	<u>85.5</u>	<u>499.5</u>	<u>755</u>