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ISOTOPE PRODUCTION IN THE FFTF BY NEUTRON TRANSMUTATION

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Abstract: A calculational study has identified long-lived radioisotopes or rare stable isotopes that can be efficiently produced in the Fast Flux Test Facility. This study was restricted to isotopes produced by neutron transmutation of selected target materials and mainly involves (n,γ) reaction processes. The entire table of isotopes was considered in selecting 441 target/product isotopes for study. There were 25 highly attractive candidates and 91 additional possible candidates identified from these calculations. In addition, information on the application of several of the product isotopes was reviewed, with most of the emphasis in medical areas. Finally, in-depth analyses were made on the present production in the Fast Flux Test Facility of Gd-153 and possible future production of Cf-252.

Introduction

Radioisotopes have extensive and important uses in many areas of health care. The energy from decaying radioisotopes is used to treat different forms of cancer. Some radioisotopes are uniquely suitable as tracers for the detection of certain diseases and the analysis of organ functions. Radioisotopes also provide a compact energy source for various types of medical scanners that allow the visualization of inaccessible internal structures, such as the bones. In addition, radioisotopes are used in medical irradiators to sterilize instruments or blood.

The Isotope Distribution Office (IDO) at the Oak Ridge National Laboratory (ORNL) has been involved with supplying a large number of different types of radioactive and stable isotopes to medical, defense, and industrial users for many years.[1] These isotopes were produced in a number of different type machines, including thermal-nuclear reactor systems. The IDO has played a very important role in making these important products available to the user community. Recently, two radioisotopes were produced in the Fast Flux Test Facility (FFTF) Hydride Assembly.[2] One of these, Gd-153, was sent to ORNL for chemical processing and has been sold by IDO to the medical instrument suppliers.

Gd-153, which is also currently being produced in the FFTF, is an example of an energy source used in medical scanners. This radioisotope is used in dual photon scanners to detect the bone-thinning disease Osteoporosis (Figure 1). Osteoporosis affects as many as 20 million Americans. In a dual photon scanner, a small amount of the gadolinium is placed to one side of a patient's hip or spine. The amount of energy passing through the patient's limb can be monitored and displayed on a computer. From this information, the patient's bone density can be calculated. X-ray technology does not detect bone mass loss, a sign of Osteoporosis, until much of the bone mass is already lost. The dual-photon scanners provide a method for earlier detection and, therefore, earlier treatment of this crippling and painful disease.

Certain radioisotopes, such as Gd-153, can be more effectively produced in the epithermal (Hydride) and/or fast (core center) neutron spectrum environment of reactors such as the FFTF than in thermal reactors. The production of medical isotopes is not only crucial for improving the quality of health care, but it is also very important for improving the public's perception of nuclear energy.

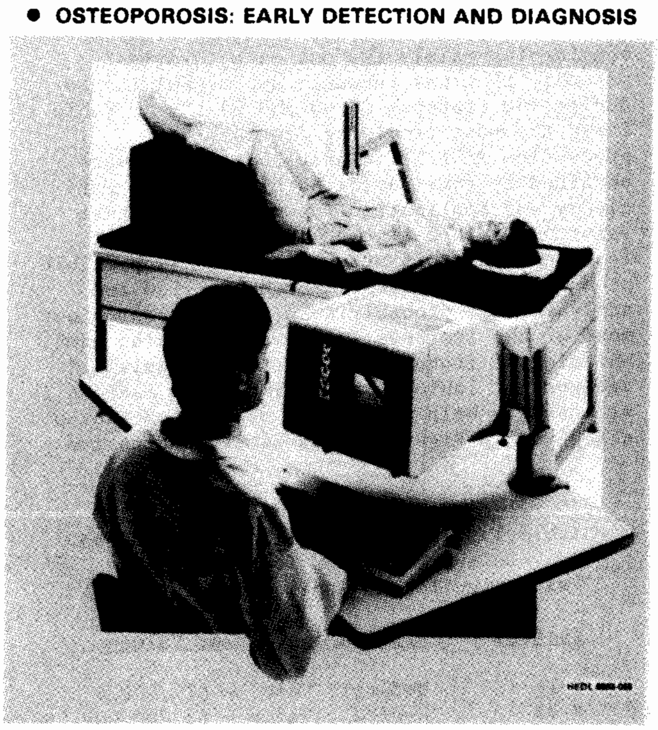

Fig. 1. Dual Photon Absorptiometer

To find other isotopes needed by the medical profession and other areas of application (e.g., defense and industrial), a computer data base was established. This data base contains information necessary for the scientific examination of possible isotope candidates along with information about the uses of many of the isotopes. From the combined data and a series of computer calculations, it can be determined what other useful isotopes, in addition to Gd-153, could be produced in the FFTF.

SUMMARY

Computer programs and nuclear data libraries have been developed to determine which long-lived radioisotopes or rare stable isotopes can be efficiently produced in the FFTF. Using these "tools", a study which screened the complete table of isotopes resulted in the consideration of over 440 nuclides. Only the production of isotopes by neutron transmutation was considered (no fission product production) with predominantly (n,γ) reactions as the focus. Other reactions such as (n,p), (n,2n), and (n,α) will play a more important role in future studies. In addition, information on application and market value of the product isotopes was collected. These data, which primarily involved medical applications, were included in this study and used to help identify future candidates for FFTF production. It should be recognized that this study (survey) is a starting point for determining target/product isotopes. In-depth production analyses will be required for each individual case, as well as studies of reactor operation impact, post irradiation handling, etc. Detailed production analyses for FFTF have been made for the isotopes Gd-153 and Cf-252.

Most of the analysis for this study involved considering mainly the use of a "Hydride" assembly that was recently successful in producing the isotopes Co-60 and Gd-153.[2] Table 1 lists the most promising isotopes for production in FFTF. These 25 isotopes were obtained by considering both production efficiency and application importance or market value.[1] Table 2 lists the complete set of isotopes that this study indicates as possible production candidates. Further review and analysis will probably result in screening out most of the isotopes in Table 2 and also some shifting of isotopes to the "most promising" category of Table 1. Four important factors that are used to help prioritize production isotopes are given in Figure 2, and semi-quantitative

Table 1. Isotopes Efficiently Produced in the Fast Flux Test Facility with Significant Application Potential

	Isotope	Application and/or Value*
1.	C-14	Medical, Value - $11,000/G
2.	P-33	Medical, Value - $3,000,000,000/G
3.	CA-41	Value - $2,000,000/G
4.	SC-46	Medical
5.	SE-75	Medical
6.	SR-85	Medical
7.	NB-95	Medical
8.	RU-103	Medical
9.	CD-109	Medical, Value - $50,000,000/G
10.	I-125	Medical
11.	CE-141	Medical
12.	PM-147	Defense
13.	GD-153	Medical, Value = $17,000,000/G
14.	EU-155	Medical
15.	HO-166M	Defense
16.	YB-169	Medical
17.	TM-170	Medical, Defense
18.	TM-171	Medical
19.	TA-182	Medical
20.	IR-192	Industrial, Value = $12,000/G
21.	TL-204	Defense, Value = $11,000,000/G
22.	Np-237	Defense
23.	Pu-238	Defense
24.	Pu-242	Defense
25.	CF-252	Medical, Defense

* Pure Gold Value - $16/G

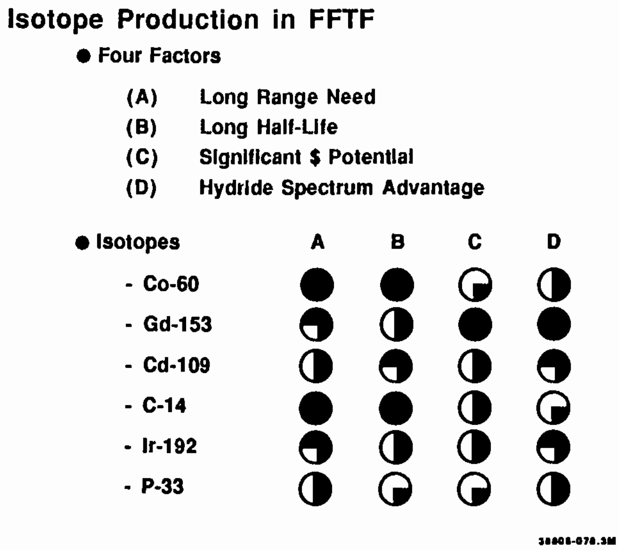

Fig. 2. Four factors used to determine which isotopes should be considered for Fast Flux Test Facility Production.

values for these factors are given for five of the isotopes in Table 1. A completely darkened circle indicates fulfillment of that particular factor. Medical application importance is illustrated in Table 3, where 8 of the 20 radioisotopes listed are given in Table 1. The other 12 radioisotopes are missing because of low production value and/or too short half life.

Figures 3 and 4 show examples of production calculation results for the isotopes Gd-153 and Cf-252. These data were obtained from detailed and extensive calculations involving long transmutation chains of isotopes. Figure 5 illustrates this for Gd-153 production.

8.0 REFERENCES

1. "Isotopes - Products and Services," U. S. Department of Energy, c/o Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory - Isotope Distribution Office, Oak Ridge, TN (October 1985).
2. D. W. Wootan, L. L. Carter, J. A. Rawlins, R. W. Schaefer, D. W. Maddison: "Analysis of ZPPR Experiments Supporting Production of Co-60 in FFTF," Trans. Am. Nucl. Soc., 54, 377 (1987).

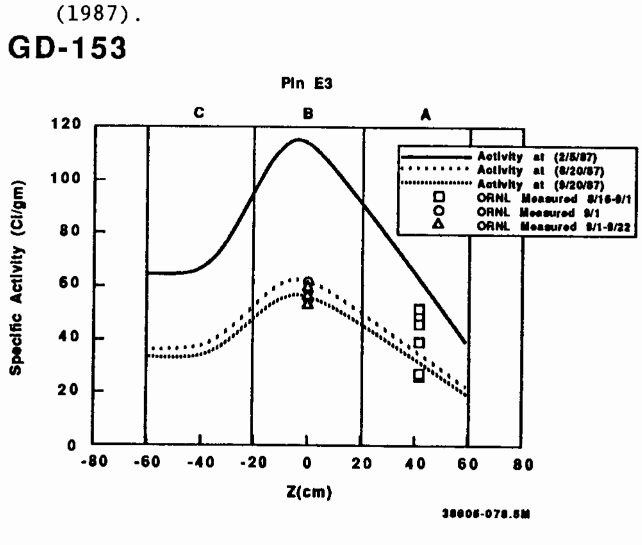

Fig. 3 Gd-153 Ci/gm Axial Variation

Table 3. Radioisotopes Important in Medical Application and Possible Fast Flux Test Facility Production Candidates

Isotopes	Applications
Cd-109	Pediatric Imaging
Tm-170	Portable Blood Irradiations for Leukemia and Lymphoma Treatment
Ta-182	"Oddly-Shaped" (Bladder) Cancer
Se-75	Brain Imaging Analyses
Eu-155	Dual Photon Source (THALF = 4.76 Yr.) Osteoporosis Detection
I-125	Diagnostic Imaging, Osteoporosis Detection, Prostate Cancer Treatment
C-14	Isotopically Labeled Compounds
Pd-103	Prostate Cancer Treatment
Cf-252	Cervical Cancer Treatment
P-32	Leukemia Treatment, Blood Cell Disease Treatment (Polycythaemia Rubra Vera), Bone Disease Diagnosis and Treatment
Au-198	Cancer Gun Treatment
I-131	Lymphoid Tissue Tumor Treatment, Hyper-thyroidism Treatment, Antibody Labeling
Cs-131	Intracavity Implants for Radiotherapy
In-111	Rejection of Heart Transplant Detection
Os-191	Ir-191M "Generator" used for Cardiovascular Angiography
Re-186	Bone Cancer Pain Relief
Sm-153	Bone Cancer Pain Relief
Sr-89	Bone Cancer Pain Relief
Mo-99	Tc99M "Generator" used for Brain, Liver, Lungs, Heart Imaging
Y-90	Liver Cancer Radiation Therapy

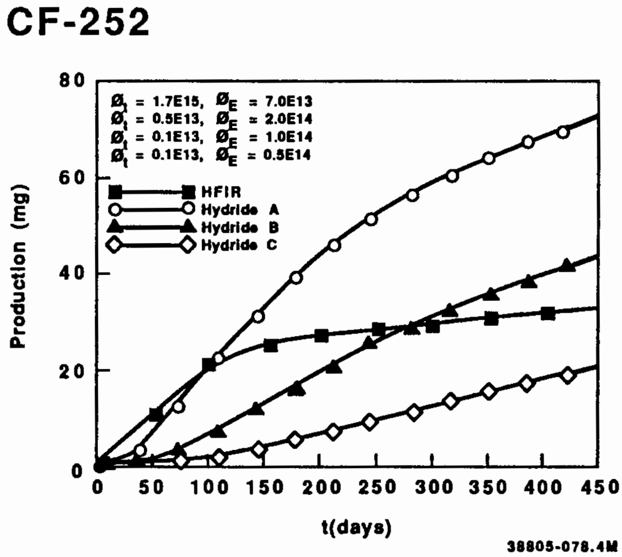

Fig. 4 Cf-252 Production -- Milligrams