199
10-16

GEAP-12114-1
BHO-68-1
UC-15
AEC RESEARCH AND
DEVELOPMENT REPORT
JULY 1970

Dr-1590

MASTER

PLANT INSTRUMENTATION PROGRAM

FIRST QUARTERLY REPORT
APRIL-JUNE 1970

D. M. BISHOP
E. A. AITKEN

U. S. ATOMIC ENERGY COMMISSION
CONTRACT AT(30-1)-68

BREEDER REACTOR DEVELOPMENT OPERATION • GENERAL ELECTRIC COMPANY
SUNNYVALE, CALIFORNIA

GENERAL ELECTRIC

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

GEAP-12114-1
BHO-68-1
UC-15
AEC Research and
Development Report
July 1970

PLANT INSTRUMENTATION PROGRAM

First Quarterly Report

April-June 1970

compiled by:

D. M. Bishop and E. A. Aitken

Approved: *E. F. Kurtz*
E. F. Kurtz, Manager
Plutonium Laboratory

B. F. Judson
B. F. Judson, Manager
Plutonium Fuels Development

Prepared for the
United States Atomic Energy Commission
Contract No. AT(30-1)-68

Printed in U.S.A. Available from the
Clearing House for Federal Scientific and Technical Information
National Bureau of Standards, U.S. Department of Commerce
Springfield, Virginia 22151

Price: \$3.00 per copy

BREEDER REACTOR DEVELOPMENT OPERATION • GENERAL ELECTRIC COMPANY
SUNNYVALE, CALIFORNIA

3300-BRDO-29
260-DAC-8/70

GENERAL **ELECTRIC**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
II. SUMMARY	2
III. TASK A. PASSIVE ASSAY OF PLUTONIUM FUELS	2
IV. TASK C. CALORIMETRIC DETERMINATION OF PLUTONIUM IN SCRAP	8
CONTRIBUTORS	10

ILLUSTRATIONS

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	Double, Single-Channel Analyzer Instrumentation	11
2.	Multichannel Analyzer Instrumentation	11
3.	Rod Scan Test Station	12
4.	Scrap-Waste Discard Test Station	12
5.	Germanium (Lithium) Detector System	13
6.	Rod-Slit Positioning Fixture Assembly	13
7.	Rod Positioning Fixture in Operation	13
8.	Differentiated Fuel Rod Standard	14
9.	Spectrum-Group 2 Fuel Standards 20 cc Germanium (Lithium) Detector 1024 Nuclear Data Analyzer	15
10.	Spectrum-Group 3 Fuel Standards 20 cc Germanium (Lithium) Detector 1024 Nuclear Data Analyzer	16
11.	Spectrum-Group 4 Fuel Standards 20 cc Germanium (Lithium) Detector 1024 Nuclear Data Analyzer	17
12.	Spectrum-Na-22 Calibration Source 20 cc Germanium (Lithium) Detector 1024 Nuclear Data Analyzer	18
13.	Spectrum Group 5 Fuel Standards 50 cc Germanium (Lithium) Detector 1024 Nuclear Data Analyzer	19
14.	Spectrum-Americium-241 Calibration Source 50 cc Germanium (Lithium) Detector 1024 Nuclear Data Analyzer	20
15.	Encapsulated Fuel Rod Standards	21
16.	Typical Thermal and Fast Fuel Rod Standards	22
17.	Fuel Scrap Standards Packaging	23
18.	1/2 Radius Waste Discard Standards	24
19.	Sample Container — 1/2 Radius Waste Discard Standard	24
20.	Calorimeter Assay Equipment Station	24

PLANT INSTRUMENTATION PROGRAM

First Quarterly Report

April-June 1970

compiled by

D. M. Bishop* and E. A. Aitken†

ABSTRACT

Work was initiated on the Plant Instrumentation Program during mid-April 1970 immediately after contract receipt. The program is directed toward the evaluation of nondestructive techniques and equipment for assaying special nuclear materials under fuel fabrication plant conditions. Work scope and fuel standards are defined. Gamma counting assay techniques and calorimetric assay equipment are described. A spectral stripping technique is proposed to permit the assay of plutonium content in mixed oxide fuels with a sodium iodide gamma counting system.

I. INTRODUCTION

The General Electric Company has entered into a contract with the United States Atomic Energy Commission, Contract Number AT(30-1)-68, to support technical activities associated with the Plant Instrumentation Program. The program is sponsored by the Office of Safeguards and Materials Management and administration is provided by the Brookhaven office. The definition of program technical objectives as well as provisions for necessary equipment and technical direction are administered through the Brookhaven National Laboratory — Technical Support Organization.

The Plant Instrumentation Program is an integrated experimental program directed toward the demonstration and evaluation of nondestructive techniques for the assay of special nuclear materials under actual fuel fabrication and processing plant conditions. Over-all program objectives were formulated to result ultimately in the development of a technological basis for a complex system of analytical instruments intended to increase assurance that high strategic value materials are not missing or diverted from intended use. At the same time, said equipment will provide in-plant inventory verification after events that might render past measurements doubtful or invalid.

Pursuant to these objectives, the initial phase of the Plant Instrumentation Program consists of the installation of suitable instrumentation in private plants engaged in processing special nuclear materials of high strategic value. Existing guidelines provide for instrument testing and evaluation under the following typical in-plant situations:

Task A — Passive Assay of Plutonium Fuels

Task B — Active Assay of Highly Enriched Uranium Scrap

Task C — Calorimetric Determination of Plutonium in Scrap

Technical efforts were initiated by the General Electric Company in mid-April 1970, in the areas of Tasks A and C. The existing work scope includes: (a) the assembly of prototypical rod, scrap, and waste discard fuel standards; (b) the evaluation of supplied and General Electric Company assay equipment and techniques using these standard fuel specimens; (c) the demonstration of the utility of selected assay equipment as a materials balance tool during routine fuel rod fabrication campaigns.

This is the first in a series of quarterly progress reports written in partial fulfillment of Contract Number AT(30-1)-68. The reporting period is April-June 1970.

* Plutonium Fuels Development

† Nucleonics Laboratory

II. SUMMARY

Work efforts were initiated during mid-April 1970, under Brookhaven National Laboratory — Technical Support Organization technical direction to define technical objectives and to procure and to qualify assay equipment in time for their application to scheduled fuel rod fabrication programs. Toward this end, consultation interfaces were established with Lawrence Radiation Laboratory, Los Alamos Scientific Laboratory, and Mound Laboratory.

General Electric Company gamma counting equipment and Mound Laboratory calorimetric assay equipment were installed in the Plutonium Fuels Laboratory. The preparation of rod, scrap, and waste discard fuel standards from previously categorized fuel selected from existing inventories was completed. Multichannel gamma spectral analysis of typical fuel specimens disclosed a significant bias inherent in conventional 0.3 to 0.5 MeV Plutonium-239 gamma counting. This interference was attributed to Plutonium-241 daughter product (Americium-241 and Uranium-237) contributions. Uranium-238 was identified as a source of additional interference. A technique was proposed for the elimination of Americium-241, Uranium-237, and Uranium-238 sources of interference within the characteristic 0.3 to 0.5 MeV Plutonium-239 spectral region.

III. TASK A. PASSIVE ASSAY OF PLUTONIUM FUELS

A. TASK A1. QUALIFICATION TESTING

1. Supply of Test Equipment

Work was initiated immediately upon contract receipt (mid-April 1970) to ensure the availability of qualified assay equipment for scheduled fuel rod fabrication campaigns. The procurement and installation of equipment progressed as follows:

1. Installation of a cable system was completed to link the Plutonium Laboratory with the Nucleonics Laboratory Counting Room multichannel analyzer equipment. The addition of balanced attenuators to the system was necessary to eliminate capacitance discharge noise problems.
2. General Electric Company dual single-channel gamma counting instrumentation was installed in the Plutonium Fuels Laboratory (Figure 1). This equipment was remotely calibrated with Counting Room multichannel analyzer instrumentation (Figure 2).
3. Assembly of a rod scan station incorporating a sodium iodide detector with necessary shielding and mechanized rod drive was completed (Figure 3).
4. Assembly of a scrap or waste-discard counting station incorporating a sodium iodide detector with appropriate shielding and mechanized scrap-can rotation capability was completed (Figure 4).
5. A 50 cc Germanium (Lithium) detector system was procured (Figure 5); satisfactory operating efficiency and resolution were verified. A mobile cart was fabricated to house the detector during testing.
6. It was determined that appropriate neutron coincidence equipment would be supplied by the Brookhaven National Laboratory. Los Alamos Scientific Laboratory personnel, however, would provide technical instruction and support in the use of neutron equipment.

2. Equipment Calibration

The calibration and qualification of gamma equipment, equipped with a sodium iodide detector, were completed. As a result, sources of both random and systematic error in the mechanical setup, the electronic equipment, and in the

originally proposed spectral region subtraction technique were defined and eliminated. A discussion of the significance of these errors follows:

1. Preliminary rod scan qualification data attributed a 10% variability in relative count rate to rod movements within the existing positioning fixture. This source of error was eliminated by the design and fabrication of an adjustable collet-type positioning fixture (Figures 6 and 7).
2. Preliminary equipment qualification rod scan tests were conducted with a special rod containing four different plutonium enrichment thermal fuels separated by urania pellets (Figure 8). Subtraction of the originally proposed 0.5 to 0.7 MeV from the 0.3 to 0.5 MeV spectral regions was greater than zero at the urania pellets. This bias was attributed to U-238 Compton interference in the 0.3 to 0.5 MeV spectral region. Urania fuel geometry was also determined to be critical in the elimination of this interference. For this reason a urania fuel rod standard containing no plutonia was fabricated from the urania feed materials utilized for the production of thermal (Pu,U)O₂ fuel standards under test as part of the Plant Instrumentation Program. This rod was designed and fabricated to simulate the geometry of (Pu,U)O₂ fuel rod standards.
3. Significant drift problems were encountered with existing dual single-channel analysis equipment. Sources of instability were traced to a defective sodium iodide detector phototube, an unstable multichannel analyzer, and a faulty system biased amplifier. The drift problem was eliminated by (a) selecting another sodium iodide detector (2 inches by 2 inches) because of its better over-all stability; (b) a stable multichannel analyzer was introduced into the system; (c) routine operation was conducted without a biased amplifier.

As a further means for the continuing verification of in-line test instrument stability a Na-22 source was prepared in prototypical fuel rod form. This source will be utilized as a calibration check during routine testing.

4. Germanium (Lithium) spectral data were obtained on the five thermal fuel rod standards with the multichannel analyzer. Typical spectra are shown in Figures 9 through 11. Spectral analyses of these data disclosed that Americium-241 and Uranium-237 (both Plutonium-241 daughters) contributed significantly to the integral count rate between 0.3 to 0.5 MeV.
5. The significance of the above-mentioned interferences cannot be determined on the basis of originally proposed dual single-channel gamma counting techniques. However, a method has been developed whereby Americium-241, Uranium-237, and Uranium-238 sources of interference can be accounted for by counting in four spectral regions with existing dual single channel analysis equipment. The specific spectral regions to be evaluated, and the significant contributing isotopes involved, are outlined as follows:

<u>Spectral Region, MeV</u>	<u>Major Contributing Isotopes</u>
1. 0.20 to 0.30	Pu-239 U-237 Am-241 U-238 daughter
2. 0.30 to 0.50	Pu-239 U-237 Am-241 U-238 daughter
3. 0.50 to 0.75	Am-241 U-238 daughter
4. 0.75 to 1.20	U-238 daughter

Pu-239 contributions to region 3 (above) were determined to be significant.

6. To determine the calibration constants required for the spectral data stripping techniques, an Americium-241 source was fabricated in prototypical thermal fuel rod form. Lead shavings were blended with the source material to approximate the self-absorption effects of the characteristic mixed oxide fuel. Further, Americium-241 analyses were initiated on the plutonia feed materials used for the preparation of thermal fuel rod standards. In conjunction with these tests spectral data were collected for the Sodium-22, UO_2 feed material, and Americium-241 sources (Figure 12 through 14, respectively). Thus, an Americium-241 rod source, a urania feed material fuel rod, and existing Plutonium-241 concentration differences between the 90 and 80% fissile thermal fuel rod plutonia feed materials will be utilized to determine the calibration constants required for spectral data stripping.
7. Calculations showed that significant contributions to the integral count rate results from the transmission of gamma radiation above 0.7 MeV through the existing 1-inch thick lead slit assembly. Further calculation showed that a 1-1/2-inch thick slit would satisfactorily eliminate this "transparency" problem. On the basis of these calculations, the fabrication of two 1-1/2-inch thick slits assemblies with slit heights of 1/4 and 1/2 inch, respectively, was completed.

3. Preparation of Fuel Standards

The collection and assembly of appropriate $(\text{Pu,U})\text{O}_2$ fuel standards was accomplished by utilizing previously categorized fuels selected from existing inventories. Nine different product fuel batches, originating from five feed material groups, were utilized in the preparation of these standards. A detailed summary of available chemical and physical characteristics is presented in Tables 1 and 2. A discussion of individual fuel standard types follows:

1. Fuel Rod Standards. The preparation of prototypical $(\text{Pu,U})\text{O}_2$ fuel rod standards (five thermal fuel and one fast fuel) was completed. Typical examples are shown in Figures 15 and 16. Typical thermal reactor fuel rods were prepared from sintered pellet fuel of the following plutonia enrichments in natural urania: 1.632, 2.553, 5.493, 9.160, and 2.540*% Pu/Pu+U. One typical fast reactor fuel rod was prepared containing 24.716% Pu/Pu+U in fully enriched urania. The appropriate fissile data for these fuel rod standards are given in Table 3A.
2. Fuel Scrap Standards. The preparation of representative fuel scrap standards (twelve thermal fuel and three fast fuel) was completed. Sintered pellet form fuel was selected for this phase of testing because the preponderance of in-line scrap is generated in this form. Figure 17 shows the typical packaging container for scrap specimens. Thermal fuel scrap specimens were prepared from fuel at each of the following plutonia enrichments in natural urania: 2.553, 5.493, 9.160 and 2.540*% Pu/Pu+U. Fast fuel scrap specimens were prepared from plutonia-urania fuel containing 24.716% Pu/Pu+U in fully enriched urania. Appropriate fissile data for these fuel scrap standards are given in Table 3B.
3. Fuel Waste-Discard Standards. The preparation of fuel waste-discard standards (seven thermal fuel and three fast fuel) was completed. Point source samples consist of unsintered green powder contained in a small plastic vial heat sealed in plastic bags. The vial is located in the geometric center of a 1-gallon can and surrounded with hydrogenous material (shredded composite absorbent pads). One-half radius samples were prepared by blending the prescribed amount of green fuel powder with shredded composite absorbent pads (Figure 18) containing the mixture in two individually heat-sealed plastic bags and packing the remaining void space within the 1-gallon can with shredded composite absorbent pads. A typical one-half radius packing container is illustrated in Figure 19. Full-radius samples were prepared in a similar manner with no void space within the 1-gallon can. Appropriate fissile data for these waste discard fuel standards are given in Table 3C.

*80% fissile PuO_2 ; all other 90% fissile

TABLE 1. Fuel Standards

A. Plutonium Enrichment Data

<u>Group</u>	<u>Fuel Batch</u>	<u>Samples, No.</u>	<u>Plutonium Enrichment</u>	
			<u>Mean Pu/Pu+U, wt %</u>	<u>95% Confidence Limits on Mean</u>
1	M0052	12	1.514	± 0.014
2	M0066	20	1.632	± 0.012
2	M0070	12	2.553	± 0.058
2	M0074	7	2.563	± 0.047
2	M0078	11	9.160	± 0.029
2	M0081	8	5.493	± 0.020
3	M0089	18	2.540	± 0.067
4	B0548	7	24.716	± 0.137
5	U0090	—	Trace	—

*Pu/Pu+U analysis not corrected for atomic weight

B. Nominal Isotopic Analysis Data*

<u>Group</u>	<u>Samples, No.</u>	<u>Fuel Batch</u>	<u>Plutonium, wt %</u>					<u>Uranium, wt %</u>			
			<u>238</u>	<u>239</u>	<u>240</u>	<u>241</u>	<u>242</u>	<u>234</u>	<u>235</u>	<u>236</u>	<u>238</u>
1	2	M0052	0.04	87.33	9.88	2.49	0.28	0.005	0.70	0.008	99.26
2	18	M0066	0.10	86.95	10.15	2.51	0.29	0.005	0.74	0.00	99.13
		M0070									
		M0074									
		M0078									
		M0081									
3	4	M0089	0.27	75.26	18.29	5.00	1.20	0.005	0.74	0.00	98.96
4	6	B0548	0.03	90.61	8.44	0.93	0.07	0.592	91.13	0.28	7.94
5	22	U0090	—	—	—	—	—	0.005	0.74	0.00	99.13

*Data normalized for vendor Pu-238 analysis

C. Plutonium Homogeneity—Particle Distribution Data

<u>Group</u>	<u>Fuel Batch</u>	<u>Mean % Pu/Pu+U</u>	<u>Mean Particle Size, μm</u>	<u>95% Confidence</u>
				<u>Upper Limit for 95 wt % of Particles μm</u>
1	M0052	1.514	—	—
2	M0066	1.632	29	77
2	M0070	2.553	39	76
2	M0074	2.563	44	73
2	M0078	9.160	46	75
2	M0081	5.490	45	77
3	M0089	2.540	55	98
4	B0548	24.716	—	—

TABLE 1. Fuel Standards (Cont'd.)

D. Impurities Analysis Data, ppm

Element	Group 1	Group 2					Group 3	Group 4
	M0052	M0066	M0070	M0074	M0078	M0081	M0089	B0548
Al	15	100	<4	<4	<4	<4	14	<4
B	<0.5	<0.5	<0.2	0.2	<0.3	<0.5	<1	<1
Cd	<2	<1	<2	<2	<2	<2	<2	<2
Ca	<25	16	<25	<25	<25	<25	<10	<25
C	14	6	11	184	0	25	19	24
Cl	5	28	9	13	19	5	14	12
Cr	<5	15	3	3	3	30	20	8
Co	—	<1	<1	<1	<1	<1	<1	<1
Cu	10	1.5	1.5	<0.5	<0.5	2	<1	<1
F	3	<6.1	<37	<4.7	<9.5	<3.9	<13.2	17
Fe	250	120	20	20	15	120	70	60
Pb	5	<0.5	<1	<1	<1	<1	<1	<1
Mg	5	4	2	2	2	5	<2	<2
Mn	9	8	<1	<1	<1	4	2	15
Mo	<10	<60	<6	50	<6	<6	<11	<6
Ni	<20	15	<6	<6	<6	10	<12	4
N	41	62	45	98	36	21	14	63.5
Si	10	<4	15	10	10	14	12	6
Ag	1	<0.1	<0.1	1	<0.1	<0.1	<0.1	<0.1
Na	<40	<15	<15	<15	<15	<15	<15	<15
Sn	10	12	<1	<1	<1	<1	<2	<1
W	—	<200	<200	<200	<200	<200	<200	<1
V	<20	<250	<3	<3	<3	<3	<3	<3
Zn	<50	<4	<10	<10	<10	<10	<10	<10
Total	<559.5	<929.7	<417.8	<655.4	<370.4	<508.5	<449.3	<282.6
Dy	—	0	<1	<1	<0.5	<1	<5	<2
Eu	—	<8	<1	<8	0	<1	<5	<2
Gd	—	<1	<1	<1	<0.2	<1	<1	<1
Sm	—	<8	<1	<1	<0.5	<1	<5	<10
Total Rare Earth	—	<17	<4	<11	<1.2	<4	<16	<15

TABLE 2. Fuel Pellet Standards

Mean Pellet Physical Characteristic Data

Group	Fuel Batch	Pellet Fuel Form	Diameter, in.	Annulus, in.	Nominal Length, in.	Theoretical Density, %
1	M0052	Annular	0.4703	0.1000*	0.375	88.93
2	M0066	Annular	0.4720	0.1480	0.375	92.06
2	M0070	Annular	0.4713	0.1478	0.375	91.96
2	M0074	Annular	0.4716	0.1476	0.375	91.62
2	M0081	Annular	0.4716	0.1466	0.375	91.52
3	M0089	Annular	0.4707	0.1496	0.375	92.11
4	R0548	Solid	0.2153	—	0.250	93.90
5	U0090	Solid	0.4715	—	0.375	94.48

*Nominal dimension reported

TABLE 3. Fuel Weight Data[≠]

A. Fuel Rod Standards

Rod	Fuel Batch	Mean Fuel	Fuel O:M	Calculation Constants			Weight, g						
		Enrichment		SS	Fissile		Net	SS			Fissile		
		wt %		Factor *	Factor			Pu	U	Total	Pu	U	Total
		Pu/Pu+U		Pu+U	Pu	U							
1	M0066	1.632	1.9986	0.8815	0.8946	0.0074	156.89	2.25	136.05	138.30	2.01	1.01	3.02
2	M0074	2.563	1.9963	0.8816	0.8946	0.0074	164.82	3.72	141.59	145.31	3.33	1.05	4.38
3	M0081	5.493	1.9922	0.8818	0.8946	0.0074	159.68	7.73	133.08	140.81	6.91	0.98	7.89
4	M0078	9.160	1.9932	0.8818	0.8946	0.0074	163.31	13.19	130.82	144.01	11.80	0.97	12.77
5	M0089	2.540	1.9974	0.8815	0.8026	0.0074	159.01	3.56	136.61	140.17	2.86	1.01	3.87
6	B0548	24.716	1.9786	0.8818	0.9154	0.9113	37.46	8.16	24.87	33.03	7.47	22.66	30.13
7	U0090	0.0	2.0940	0.8809	0	0.0074	181.00	0	159.44	159.44	0	1.18	1.18

B. Fuel Scrap Standards

8	M0070	2.553	1.9963	0.8815	0.8946	0.0074	51.08	1.15	43.88	45.03	1.03	0.32	1.35
9	M0070	2.553	1.9963	0.8815	0.8946	0.0074	102.09	2.30	87.69	89.99	2.06	0.65	2.71
10	M0074	2.563	1.9963	0.8815	0.8946	0.0074	496.91	11.23	426.80	438.03	10.05	3.16	13.21
11	M0081	5.493	1.9922	0.8818	0.8946	0.0074	54.07	2.62	45.06	47.68	2.34	0.33	2.67
12	M0081	5.493	1.9922	0.8818	0.8946	0.0074	107.97	5.23	89.98	95.21	4.68	0.67	5.35
13	M0081	5.493	1.9922	0.8818	0.8946	0.0074	504.99	24.46	420.84	445.30	21.88	3.11	24.99
14	M0078	9.160	1.9932	0.8818	0.8946	0.0074	50.62	4.09	40.55	44.64	3.66	0.30	3.96
15	M0078	9.160	1.9932	0.8818	0.8946	0.0074	101.85	8.23	81.58	89.81	7.36	0.60	7.96
16	M0078	9.160	1.9932	0.8818	0.8946	0.0074	506.30	40.90	405.56	446.46	36.59	3.00	39.59
17	M0089	2.540	1.9974	0.8815	0.8026	0.0074	50.22	1.12	43.15	44.27	0.90	0.32	1.22
18	M0089	2.540	1.9974	0.8815	0.8026	0.0074	100.18	2.24	86.07	88.31	1.80	0.64	2.44
19	M0089	2.540	1.9974	0.8815	0.8026	0.0074	500.88	11.21	430.31	441.52	9.00	3.18	12.18
20	B0548	24.716	1.9786	0.8818	0.9154	0.9113	50.90	11.09	33.79	44.88	10.15	30.79	40.94
21	B0548	24.716	1.9786	0.8818	0.9154	0.9113	101.20	22.06	67.18	89.24	20.19	61.22	81.41
22	B0548	24.716	1.9786	0.8818	0.9154	0.9113	500.80	109.15	332.46	441.61	99.92	302.97	402.89

C. Fuel Waste Discard Standards

23	M0052	1.514	2.1161	0.8755	0.8982	0.0070	1.032	0.014	0.890	0.904	0.013	0.006	0.019
24	M0052	1.514	2.1161	0.8755	0.8982	0.0070	10.010	0.133	8.631	8.764	0.119	0.060	0.179
25	M0052	1.514	2.1161	0.8755	0.8982	0.0070	1.116	0.015	0.962	0.977	0.013	0.007	0.020
26	M0052	1.514	2.1161	0.8755	0.8982	0.0070	10.054	0.133	8.669	8.802	0.119	0.061	0.180
27	M0052	1.514	2.1161	0.8755	0.8982	0.0070	1.043	0.014	0.899	0.913	0.013	0.006	0.019
28	M0052	1.514	2.1161	0.8755	0.8982	0.0070	10.018	0.133	8.644	8.770	0.119	0.061	0.180
29	M0089	2.540	2.1257	0.8750 [†]	0.8026	0.0074	1.006	0.022	0.858	0.880	0.018	0.006	0.024
30	B0548	24.716	2.1086	0.8750 [†]	0.9154	0.9113	1.023	0.221	0.674	0.895	0.202	0.614	0.816
31	B0548	24.716	2.1086	0.8750 [†]	0.9154	0.9113	1.062	0.230	0.699	0.929	0.211	0.640	0.851
32	B0548	24.716	2.1086	0.8750 [†]	0.9154	0.9113	1.040	0.225	0.685	0.910	0.206	0.624	0.830

* SS factor derived from actual fuel O:M data using Oxygen-16 base.

[†] SS factor based on nominal O:M data for green powder.[≠] Analysis performed November – December 1969.

B. TASK A2. PERFORMANCE TESTING

The testing of appropriate fuel standards with passive neutron and gamma sensing test instrumentation is a precursory step to the selection of appropriate assay equipment for in-process application during routine fuel rod fabrication programs. As an initial phase of this segment of the program, thermal fuel rod standard testing was initiated by using a sodium iodide detector with dual single-channel analyzer instrumentation. A typical test sequence is:

1. Verify calibration with Na-22 rod source (static test);
2. Scan fuel rod (dynamic test);
3. Recheck calibration with Na-22 rod source (static test).

IV. TASK C. CALORIMETRIC DETERMINATION OF PLUTONIUM IN SCRAP

A. TASK C3. QUALIFICATION TESTING

Activities were initiated during mid-April 1970, following discussions of technical objectives with the Brookhaven National program office. Work interfaces were established with the Brookhaven National Laboratory program office. Work interfaces were established with Mound Laboratory to determine specific objectives and responsibilities and reflect the needs of industry in the utilization of calorimeters for assay.

1. Equipment Requirements

The tentative range of applicability of calorimeters for plutonium assay was determined as follows:

<u>Application</u>	<u>Pu Quantity (gm)</u>	<u>Power Range (W)</u>	<u>Calorimeters Type</u>
1. On-Line Pu Assay	~ 1	~ 0.0026	Micro
2. Feed Material			
Oxide Powder	~ 1000	~ 2.6	Low watt
Nitrate Solution	250	~ 0.1	
3. Fuel Rods	~ 15 gm/in.	0.1	Special design
4. Scrap and Waste	0-250	0-0.6	Marginal; use with low watt

Each application listed requires a specific calorimeter design to measure power outputs accurately in each power range. On-line plutonium assay of small batches of blended oxide can be readily accomplished with a twin type microcalorimeter. This type calorimeter will require few operational constraints, such as criticality and size. Its principal design problem will be to keep the equilibrium time compatible with production throughput rates. This application, however, is not of primary concern in the Plant Instrumentation Program. The calorimeter for assay of feed material would be larger and would dissipate power in the watt range. This type calorimeter will receive initial attention in the Plant Instrumentation Program since its power output matches existing calorimeter systems designed by Mound Laboratories. Preliminary criticality hazard require that up to 1500 grams of dry fissile material (< 5% wt % water) would be acceptable if contained in 1-gallon cans. The sample chambers must be limited physically to only 1-gallon cans to prevent double-batching as a credible accident.

An alternate need is a calorimeter system to measure nitrate feed material. Preliminary nuclear safety analysis indicates concentrations up to 440 grams/liter of fissile material are acceptable provided the container diameter is below 4 inches. The principal concern for aqueous solutions is the stray heat generated by reactions with container materials and reactions within the aqueous solution. This aspect would have to be determined in existing calorimeters before special design is initiated.

A calorimeter for measuring the heat output from finished fuel rods appears to be technically feasible and should be examined further. Fuel rods standards being fabricated for Task A measurements could be used for determining the feasibility of heat measurement in a calorimeter.

The utilization of a calorimeter for scrap and waste recovery is difficult to assess at this time. Containers tend to be large with relatively low-power density. Hence, the thermal output may be difficult to detect in a watt range calorimeter. The quantity of fissile materials to be packaged as part of Task A for calibration of scrap in 1-gallon containers appears to be marginal with existing calorimeters designed to accept this size of container.

2. Supply of Test Equipment

Work efforts were directed toward receiving a calorimeter for assaying feed materials for the upcoming thermal recycle fuel rod fabrication program. The program is scheduled to start in early August 1970. Toward this end, the procurement and installation of calorimetric equipment progressed as follows:

1. Familiarization was gained within calorimetric equipment operating and maintenance procedures at the Mound Laboratory.
2. Two calorimeters, with appropriate instrumentation, were received from Mound Laboratory. One calorimeter will measure the heat output of PuO_2 powder feed material contained in a standard size container. The power will be in the range of 1 to 5 watts. The second calorimeter will measure the power generated in smaller quantities of plutonium bearing material in the range of tens of milliwatts. Both calorimeters will be operated within a single water bath for environmental control and can operate simultaneously. Standard heat sources calibrated by Mound Laboratory will be utilized on both calorimeters for calibration during the early period of operation. Calorimetric equipment has been installed in the Plutonium Fuels Laboratory (Figure 20).
3. The checkout and calibration of calorimetric equipment and procedures was initiated.

3. The Preparation of Fuel Scrap Standards

The preparation of fuel scrap standards was completed (as described under Task A1, Section 3).

CONTRIBUTORS

The following General Electric Company personnel contributed to the work performed on the Plant Instrumentation Program during the quarter ending June 30, 1970:

Task A — Passive Assay of Plutonium Fuel

G. C. Berg, D. M. Bishop, G. C. Martin, and M. L. Thompson

Task C — Calorimetric Determination of Plutonium in Scrap

E. A. Aitken and J. L. Simpson

Other Contributors

L. T. Hagie, E. F. Kurtz, and W. W. Sabol

FIGURE 1. DOUBLE, SINGLE-CHANNEL ANALYZER INSTRUMENTATION

FIGURE 2. MULTICHANNEL ANALYZER INSTRUMENTATION

FIGURE 3. ROD SCAN TEST STATION

FIGURE 4. SCRAP-WASTE DISCARD TEST STATION

FIGURE 5. GERMANIUM (LITHIUM) DETECTOR SYSTEM

FIGURE 6. ROD-SLIT POSITIONING FIXTURE ASSEMBLY

FIGURE 7. ROD POSITIONING FIXTURE IN OPERATION

PELLET LOCATION PREFIX NUMBER

FUEL IDENTITY

PREFIX NO.

DESCRIPTION

1	U0090 PELLETS — GROUP 5 FUEL — NATURAL UO_2
2	M0066 PELLETS — GROUP 2 FUEL — 1.632 wt % Pu/(Pu + U)
3	M0070 PELLETS — GROUP 2 FUEL — 2.553 wt % Pu/(Pu + U)
4	M0081 PELLETS — GROUP 2 FUEL — 5.493 wt % Pu/(Pu + U)
5	M0078 PELLETS — GROUP 2 FUEL — 9.160 wt % Pu/(Pu + U)

FIGURE 8. DIFFERENTIATED FUEL ROD STANDARD

FIGURE 9. SPECTRUM—GROUP 2 FUEL STANDARDS
20 cc GERMANIUM (LITHIUM) DETECTOR
1024 NUCLEAR DATA ANALYZER

FIGURE 10. SPECTRUM—GROUP 3 FUEL STANDARDS
20 cc GERMANIUM (LITHIUM) DETECTOR
1024 NUCLEAR DATA ANALYZER

FIGURE 11. SPECTRUM—GROUP 4 FUEL STANDARDS
20 cc GERMANIUM (LITHIUM) DETECTOR
1024 NUCLEAR DATA ANALYZER

FIGURE 12. SPECTRUM—Na-22 CALIBRATION SOURCE
20 cc GERMANIUM (LITHIUM) DETECTOR
1024 NUCLEAR DATA ANALYZER

FIGURE 13. SPECTRUM-GROUP 5 FUEL STANDARDS
50 cc GERMANIUM (LITHIUM) DETECTOR
1024 NUCLEAR DATA ANALYZER

FIGURE 14. SPECTRUM-AMERICIUM-241 CALIBRATION SOURCE
50 cc GERMANIUM (LITHIUM) DETECTOR
1024 NUCLEAR DATA ANALYZER

MATERIAL DESCRIPTION:

	<u>THERMAL RODS</u>	<u>FAST ROD</u>
1. CLADDING MATERIAL	ZIRCALOY - 2	TYPE - 304 STAINLESS STEEL
2. ROD OUTSIDE DIAMETER	0.523 $\pm$ 0.004 INCH	0.250 $\pm$ 0.010 INCH
3. CLADDING WALL THICKNESS	0.040 $\pm$ 0.003 INCH	0.015 $\pm$ 0.001 INCH

FIGURE 15. ENCAPSULATED FUEL ROD STANDARD

FIGURE 16. TYPICAL THERMAL AND FAST FUEL ROD STANDARDS

FIGURE 17. FUEL SCRAP STANDARDS PACKAGING

FIGURE 18. 1/2 RADIUS WASTE DISCARD STANDARDS

FIGURE 19. SAMPLE CONTAINER - 1/2 RADIUS WASTE DISCARD STANDARD

FIGURE 20. CALORIMETER ASSAY EQUIPMENT STATION

DISTRIBUTION

	<u>Copies</u>
W. C. Bartels, Chief Technical Studies Branch Office of Safeguards & Materials Management U.S. Atomic Energy Commission Washington, D.C. 20545	10
D. L. Crowson, Director Office of Safeguards & Materials Management U.S. Atomic Energy Commission Washington, D.C. 20545	1
W. A. Higinbotham Associated Universities, Inc. Brookhaven National Laboratory Upton, New York 11973	3
D. Schweller U.S. Atomic Energy Commission Brookhaven Office Upton, New York 11973	1
Division of Technical Information Extension U.S. Atomic Energy Commission P.O. Box 62 Oak Ridge, Tennessee 37830	199
L. Bryan, Area Manager U.S. Atomic Energy Commission Brookhaven Area Office Upton, New York 11973	1
H. S. Potter, Chief N. Y. Patent Group U.S. Atomic Energy Commission Upton, New York 11973	1
W. A. Higinbotham Brookhaven National Laboratory Upton, New York 11973	3
W. Marcuse Brookhaven National Laboratory Upton, New York 11973	3