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ROD SCANNER ASSAY
OF FFTF FUEL

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Paul Goris

January 1978

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ABSTRACT

Rod scanner results for over 40,000 FFTF Cores 1 and 2 fuel pins are summarized. An improved rod scanner calibration technique for FFTF Cores 3 and 4 fuel pins is described. Data are compared with chemical assay measurements.

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ROD SCANNER ASSAY OF FFTF FUEL

I. INTRODUCTION

The Hanford Engineering Development Laboratory (HEDL), operated by the Westinghouse Hanford Company at Richland, Washington, is the prime contractor for construction and operation of the Fast Flux Test Facility (FFTF) for the United States Department of Energy (DOE). The FFTF is the primary test facility for development of the Liquid Metal Fast Breeder Reactor (LMFBR).

Figure 1 shows the components of an FFTF fuel pin. The fuel section is 36 inches long and consists of approximately 145 mixed oxide pellets. Fuel composition is approximately 25% PuO_2 and 75% UO_2 , containing either normal or depleted uranium. Fissile plutonium content is 30 to 39 grams per pin.

HEDL Safeguards and Materials Management evaluated a Cf-252 rod scanner on FFTF Cores 1 and 2 fuel to demonstrate the scanner's feasibility for shipper-receiver measurements of fissile plutonium in the LMFBR program.^(1,2) The Cf-252 rod scanner evaluated (Figure 2) was designed and built by the Los Alamos Scientific Laboratory.⁽³⁾ To date, 40,271 Cores 1 and 2 fuel pins and 6,281 Cores 3 and 4 fuel pins have been assayed at HEDL with this instrument. FFTF fuel pins were supplied by commercial vendors.

Rod scanner assay was improved for Cores 3 and 4 assay by means of a point-cluster calibration technique utilizing six new calibration fuel pins prepared at HEDL. Other factors taken into account to improve the method were variations in fuel density and U-235 content. The improved rod scanner technique has replaced chemical assay as the official fissile plutonium measurement method for 36,000 fuel pins for Cores 3 and 4.

FFTF DRIVER FUEL PIN

FIGURE 1. FFTF Driver Fuel Pin Components. (Neg. No. 730325-1cn)

FIGURE 2. HEDL Cf-252 Rod Scanner. (Neg. No. 772522-1cn)

II. CONCLUSIONS

Improved HEDL rod scanner assay utilizing a point-cluster calibration is competitive with a chemical assay technique based on 6,281 fuel pins for FFTF cores 3 and 4. Differences in both U-235 content and fuel density between calibration and assayed fuel pins can result in significant error and must be corrected. Densitometer and U-235 sensing attachments should be provided on rod scanners so that necessary measurements can be obtained as a unit operation independent of supporting laboratory measurements.

III. FFTF CORES 1 AND 2 FISSILE ASSAY - SUMMARY

Supplier contracts for FFTF Cores 1 and 2 fuel pins called for shipper-receiver agreement within 0.5% for total fissile plutonium in fuel pin shipments. The official HEDL measurement was based on a coulometric wet chemical technique. Fuel pellets sampled under HEDL surveillance from each vendor production lot were forwarded to HEDL laboratories for assay. Each fuel pin received was assayed with the Cf-252 rod scanner at HEDL to evaluate the rod-scanning technique for use in the LMFBR Program. (References 1 and 2 provide details in connection with Cores 1 and 2 fissile assay.)

Fifty-eight Cores 1 and 2 fuel pin shipments were received, averaging about 695 pins per shipment. A comparison of HEDL chemical assay and rod scanner shipper-receiver differences showed that four times as many shipper-receiver differences greater than 0.5% were associated with the rod scanner. The rod-scanning method would have to be improved to be competitive with chemical assay.

Since the same chemical measurement is used for chemical assay of fissile plutonium and standardization of calibration pins, rod scanner results should agree very closely with chemical results for large numbers of pins. Higher shipper-receiver differences associated with rod scanner assay on Cores 1 and 2 fuel pin shipments were attributed to the simple two-pin calibration technique, which is subject to significant short-term bias. Figure 3 illustrates the ways that deviations may affect the two-pin calibration. A single fuel pin standard was used at each of two fissile plutonium levels and a single observation was made on each fuel pin standard. A least-squares fit was carried out for these data at each calibration. The extent to which an observation may be expected to deviate from the true calibration curve is indicated by Figure 4, showing typical quality control data for Cores 1 and 2 rod scanner assay. Magnitude of the variance for single observations on calibration pins is believed to be a major contributor to significant differences between rod-scanner and chemical assay results for Cores 1 and 2 fuel pins.

FIGURE 3. Deviations in Rod Scanner Two-Point Calibration. (Neg. No. 755163-2)

FIGURE 4. Rod Scanner Quality Control Typical for FFTF Cores 1 and 2 Assay. (Neg. No. 755759-3)

A study comparing precision rod scanner and chemical assay results showed no significant differences between the two techniques at the 95% confidence level. In this study, selected fuel pins were each scanned six times. A different calibration was associated with each scan. Fuel pellets from each pin were then chemically assayed. Table I summarizes this study. These data suggested that a cluster calibration technique would make the rod scanner method competitive with the chemical method.

TABLE I
PRECISION ROD SCANNER ASSAY VS CHEMICAL ASSAY
OF FFTF CORES 1 AND 2 DESTROYED FUEL PINS
(grams, fissile plutonium)

	<u>HEDL Chemical Assay*</u>	<u>HEDL Rod Scanner**</u>	<u>Difference***</u>
<u>Inner Core (15 Pins)</u>			
Totals	447.68	447.82	-0.14 (-0.03%)
Mean	29.845	29.855	
Std. Dev.	0.2261	0.2319	
<u>Outer Core (34 Pins)</u>			
Totals	1240.83	1244.72	-3.89 (-0.31%)
Mean	36.495	36.609	
Std. Dev.	0.2853	0.2640	

*HEDL chemical assay values were based on averages of 3 to 6 pellet samples per pin.

**HEDL rod scanner values were based on averages of 6 scans per pin. Each scan is associated with a different calibration.

***Differences not significant at the 95% confidence level.

IV. FFTF CORES 3 AND 4 FISSILE ASSAY

Thirty-six thousand fuel pins for Cores 3 and 4 will be supplied to HEDL by a commercial vendor. To date, 6,281 pins have been received and analyzed by both the chemical and rod scanner methods. Fuel pellets randomly sampled under HEDL surveillance at the vendor shop were forwarded to HEDL for chemical assay. The rod scanner method utilized a point-cluster calibration based on six standard pins prepared at HEDL. Corrections were made for U-235 content and fuel density differences between calibration standards and production fuel pins. Significant errors can be attributed to both these factors. Table II indicates agreement of the improved rod scanner method with chemical assay of initial Cores 3 and 4 fuel pins.

TABLE II
FISSILE ASSAY OF FFTF CORES 3 AND 4 FUEL PINS
(grams, fissile plutonium)

<u>Shipment</u>	<u>No. Pins</u>	<u>HEDL Chemical Assay</u>	<u>HEDL Rod Scanner Assay</u>	<u>Difference</u>
1	174	5,881	5,913	-0.54%
2	1,440	48,710	48,567	+0.29%
3	1,200	40,565	40,586	-0.01%
4	1,361	46,156	46,098	+0.13%
5	931	31,522	31,489	+0.10%
6	1,175	39,797	39,909	-0.27%
7	<u>1,240</u>	<u>42,368</u>	<u>42,419</u>	<u>-0.12%</u>
	7,521	254,999	254,981	(+0.007%)

Table III compares chemical and rod scanner statistics for Cores 1 and 2 and Cores 3 and 4. The chemical method was used to calibrate fuel pin standards. Under this condition, both techniques should give essentially the same results provided that the rod scanner is unbiased. (Section III describes possible bias conditions in the 2-point calibration technique associated with rod scanner assay of Cores 1 and 2.) A much smaller variance associated with differences between chemical and rod scanner measurements for Cores 3 and 4 is attributed primarily to the point-cluster calibration technique.

TABLE III
STATISTICAL COMPARISONS OF CHEMICAL AND ROD SCANNER ASSAY
OF FFTF FUEL PINS

	<u>Cores 1 and 2*</u>	<u>Cores 3 and 4**</u>
No. of Shipments Compared	58	6
Std. Dev. of Differences, Chemical - Rod Scanner	0.352%	0.099%
Range of Differences, Chemical - Rod Scanner	+0.54% to -1.16%	+0.23% to -0.27%

* Rod scanner results were based on a two-point calibration technique using two standard pins.

** Rod scanner results were based on a point-cluster calibration technique using six standard pins.

Tables II and III reflect the capability of the improved rod scanner technique to indicate significant shipper-receiver differences. These data suggest that the rod scanner can be competitive with chemical assay for shipper-receiver measurements of LMFBR fuel.

Calibration

The relation between the delayed high energy gamma response and the fissile content of a fuel pin is given by:

$$R = A(1 - e^{BP}) \quad (1)$$

where R is the background-corrected, delayed high energy gamma count rate,

A is a calibration parameter relating count rate and fissile plutonium content of standard fuel pins,

B is the curve shaping parameter,

P is the fissile plutonium content of the fuel pin.

Figure 5 is a plot of R vs. P. The curvilinear response is due to neutron flux depression at higher fissile plutonium levels.

(1) is rearranged to give P in terms of R:

$$P = \frac{1}{B} \ln \left(1 - \frac{R}{A} \right) \quad (2)$$

The calibration parameter A is a function of R and P in calibration fuel pins and is evaluated from (1):

$$A = \frac{R_c}{(1 - e^{BP_c})} \quad (3)$$

where R_c is the count rate and P_c is the fissile content of calibration fuel pins.

HEDL 7708-017.1

FIGURE 5. Rod Scanner Count Rate vs. Pu Fissile Content of Fuel Pin.

Substitution into (2) defines the fissile plutonium content of an assayed fuel pin:

$$P_a = \frac{1}{B} \ln \left[1 - \frac{R_a}{R_c} (1 - e^{-BP_c}) \right] \quad (4)$$

where R_a and P_a refer to the count rate and fissile plutonium content, respectively, for assayed fuel pins,

and R_c and P_c refer to the count rate and fissile plutonium content, respectively, for calibration fuel pins.

For the point-cluster calibration technique:

$$P_a = \frac{1}{B} \ln \left[1 - \frac{R_a}{\bar{R}_c} (1 - e^{-B\bar{P}_c}) \right] \quad (5)$$

where $\bar{P}_c$ is the mean of a number of standard pins having very nearly the same fissile plutonium content,

$\bar{R}_c$ is the mean count rate corresponding to the mean fissile plutonium content of calibration pins.

The curve shaping parameter B can be evaluated through iteration by a relation derived from (1), based on R and P values at two different standard fuel pin fissile plutonium levels. Table IV gives data associated with the B shaping parameter for FFTF Cores 3 and 4 rod scanner assay. From equation (1), this relation is:

$$R_1 e^{-BP_2} - R_2 e^{-BP_1} = R_1 - R_2 \quad (6)$$

TABLE IV

B SHAPING PARAMETER FOR FFTF CORES 3 AND 4 ROD SCANNER ASSAY

N	P_1	P_2	B
	(30.28 gm Fissile Pu) R_1	(35.410 gm Fissile Pu) R_2	
1	4121.0000	4608.0000	-0.020400
2	4100.0000	4587.0000	-0.020135
3	4107.0000	4620.0000	-0.017499
4	4121.0000	4585.0000	-0.022905
5	4099.0000	4571.0000	-0.021745
6	4127.0000	4588.0000	-0.023315
7	4103.0000	4612.0000	-0.017864
8	4119.0000	4576.0000	-0.023665
9	4102.0000	4595.0000	-0.019524
10	4080.0000	4565.0000	-0.020095
11	4118.0000	4574.0000	-0.023765
12	4107.0000	4600.0000	-0.019589
13	4125.0000	4597.0000	-0.022075
14	4122.0000	4606.0000	-0.020735
15	4102.0000	4593.0000	-0.019734
16	4085.0000	4582.0000	-0.018884
17	4091.0000	4571.0000	-0.020775
18	4098.0000	4590.0000	-0.019579
19	4120.0000	4584.0000	-0.022895
20	4082.0000	4584.0000	-0.018319
21	4086.0000	4586.0000	-0.018579
22	4114.0000	4585.0000	-0.022045
23	4092.0000	4583.0000	-0.019609
24	4099.0000	4571.0000	-0.021745
25	4104.0000	4585.0000	-0.020830
26	4126.0000	4621.0000	-0.019619
27	4122.0000	4594.0000	-0.022035
28	4132.0000	4618.0000	-0.020645
29	4118.0000	4586.0000	-0.022425
30	4118.0000	4574.0000	-0.023765
31	4083.0000	4590.0000	-0.017814
32	4106.0000	4592.0000	-0.020315
Mean	4107.1562	4589.7812	-0.020717
Std.Dev.	14.9691	14.6260	0.001822
Std.Dev. of Mean	2.6462	2.5855	0.000322

Point-Cluster Calibration Standards

Reliability of rod scanner assay depends to a great extent on calibration and assayed fuel pins having the same chemical, physical, and geometrical characteristics. FFTF Cores 3 and 4 mixed oxide fuel contains depleted rather than normal UO_2 . The normal UO_2 in Cores 1 and 2 calibration fuel pins would not be suitable for assay of fuel pins with depleted UO_2 mixed oxide fuel.

In order to simulate characteristics of Cores 3 and 4 production pins, new calibration pins were prepared in HEDL plutonium facilities. Mixed oxide fuel was blended from typical FFTF PuO_2 and depleted UO_2 . Hardware was provided conforming to RDD specifications so that characteristics of calibration and production fuel pins matched to every extent possible. Table V lists make-up values for point-cluster calibration standards at the inner core level. The alternative to preparing a number of standards for a cluster calibration is to observe a mean count rate on a single accurately known standard pin. However, a minimum cooling time of one hour is required between observations, and this approach is not practical in routine operation.

Even though depleted U-235 abundance is very close in calibration and production fuel pins, some Cores 3 and 4 production lots were blended with residual Cores 1 and 2 mixed oxide containing normal UO_2 , and the U-235 content was increased. Corrections were made accordingly to account for significant differences in U-235 content between calibration and production fuel pins.

TABLE V
POINT-CLUSTER CALIBRATION FUEL PIN STANDARDS
FOR FFTF CORES 3 AND 4 ROD SCANNER ASSAY

Pin Number	Fuel Column Wt. Grams	Wt. Fraction (Pu-239 + Pu-241) in Pu	Wt. Fraction Pu-Total in Mixed Oxide	Grams (Pu-239 + Pu-241) Per Pin
H307FA	171.255	0.8822	0.2241	33.858
H308FA	171.250	"	"	33.856
H309FA	171.215	"	"	33.849
H310FA	171.101	"	"	33.827
H311FA	171.439	"	"	33.894
H312FA	171.294	"	"	33.865

(Fuel Pin Length = 36 ± 0.15 inches)

$$\bar{P}_C = 33.858$$

Rod scanner results for 6,281 fuel pins described by Table II are based on the above calibration standards. Production fuel pin specifications require that the fissile plutonium content fall in the range 33.82 grams $\pm$ 3%. The mean value for calibration standards is in excellent agreement with the median of this range. None of the outer core production fuel pins (39.39 grams fissile plutonium per pin) has been received at this time.

In routine operation, rod scanner calibration is updated every four hours with the cluster calibration standards. The observed mean count rate $\bar{R}_C$ and the mean fissile plutonium standard value $\bar{P}_C$ complete the short-term calibration requirements of equation (5). Frequent calibration updating accounts for Cf-252 source decay, and provides a degree of protection against any instrument drift that may occur subsequent to a given calibration.

Corrections For U-235 Content and Fuel Density Variations

U-235 corrections are necessary in Cores 3 and 4 rod scanner assay due to differences in U-235 content in some production lots. Residual Cores 1 and 2 mixed oxide is blended with Cores 3 and 4 mixed oxide

containing depleted UO_2 , and a significant difference is noted between U-235 content of calibration and production fuel pins. This condition did not occur in Cores 1 and 2 fissile assay since all production pins and calibration pins contained normal UO_2 . Unless corrections are made, U-235 differences will be reflected as fissile plutonium.

Relative contributions to the fission rate per atom of isotope in FFTF fuel are described in Reference 3, Page 4. The major contributors to the fission rate in FFTF fuel are Pu-239, Pu-241 and U-235. Relative contributions to the fission rate per atom of these isotopes are 45, 100, and 58, respectively, and a weighted relative contribution of fissile plutonium on this basis is ~46. A weighted correction factor for U-235 difference between calibration and assayed pins is applied according to the ratio $58/46 \times 239/235 = 1.28$. The correction formula for the observed fissile plutonium value $(P_a)_{obs}$ in the fuel pin is:

$$(P_a)_{U5 \text{ corr.}} = (P_a)_{obs.} + 1.28 (U5_{std. \text{ pin}} - U5_{\text{assay pin}}) \quad (7)$$

The effect of lower U-235 content in standard pins, for example, is to increase the assay value as Pu(239+241). The error due to 0.11 grams/pin more U-235, as noted in some production lots, is about 0.4%. A significant bias would be introduced unless a correction is made according to equation (7).

FFTF fuel density ranges between 9.8 and 10.1 gm/cc on Cores 3 and 4 production lots assayed to date. Fuel density, like U-235 content, should be the same for calibration and assayed fuel pins in order to attain a high degree of accuracy. Experimental results with FFTF fuel pin standards containing fuel of differing densities indicates that rod

scanner results may vary ~2.35% per density change of 1 gm/cc. A correction is applied to the observed fissile plutonium value $(P_a)_{obs.}$ as follows for fuel density differences between calibration and assayed fuel pins.

$$(P_a)_{density\ corr.} = (P_a)_{obs.} [1 - 0.02347(density_{calib.\ pins} - density_{assay\ pin})] \quad (8)$$

The effect of higher density in calibration pins over assayed pins, for example, is to increase the fissile assay value.

Corrections for U-235 and fuel density variations have been applied based on chemical analysis for U-235 and physical measurements on production lot pellet samples. Ideally, a rod scanner should be equipped with a densitometer and a capability to differentiate between fissile plutonium and U-235 to ensure that the instrument can function independent of supporting laboratory measurements.

Variance For Point-Cluster Calibration

Variance for rod scanner assay utilizing a point-cluster calibration is derived in terms of four independent variables, according to equation (5), and applies to a single fuel pin assay:

$$P_a = \frac{1}{B} \ln \left[1 - \frac{R_a}{\bar{R}_c} \left(1 - e^{B\bar{P}_c} \right) \right]$$

$$= f[B, \bar{P}_c, \bar{R}_c, R_a] \quad (9)$$

where P_a is the fuel pin assay value,
 B is the curve shaping parameter,
 $\bar{P}_c$ is the mean chemical standardization value
for the cluster calibration pins,
 $\bar{R}_c$ is the mean count rate for $\bar{P}_c$,
 R_a is the count rate for P_a .

Variance in P_a as a function of the four independent variables defined above is estimated by means of the error propagation formula:

$$(S)_{P_a}^2 \cong \left(\frac{\partial P_a}{\partial B} \right)^2 (S)_B^2 + \left(\frac{\partial P_a}{\partial \bar{P}_c} \right)^2 (S)_{\bar{P}_c}^2 + \left(\frac{\partial P_a}{\partial \bar{R}_c} \right)^2 (S)_{\bar{R}_c}^2 + \left(\frac{\partial P_a}{\partial R_a} \right)^2 (S)_{R_a}^2 \quad (10)$$

where

$$\left(\frac{\partial P_a}{\partial B} \right)^2 (S)_B^2 \cong \left(\frac{1}{B} \right)^2 \left[\left(\frac{R_a e^{B\bar{P}_c} \cdot \bar{P}_c}{R_c - R_a(1 - e^{B\bar{P}_c})} \right) - P_a \right]^2 (S)_B^2 \quad (11)$$

$$\left(\frac{\partial P_a}{\partial \bar{P}_c} \right)^2 (S)_{\bar{P}_c}^2 \cong \left[\frac{R_a e^{B\bar{P}_c}}{R_c - R_a(1 - e^{B\bar{P}_c})} \right]^2 (S)_{\bar{P}_c}^2 \quad (12)$$

$$\left(\frac{\partial P_a}{\partial \bar{R}_c} \right)^2 (S)_{\bar{R}_c}^2 \cong \left(\frac{1}{B} \right)^2 \left[\frac{R_a e^{B\bar{P}_c}}{R_c - R_a(1 - e^{B\bar{P}_c})} \right]^2 (S)_{\bar{R}_c}^2 \quad (13)$$

$$\left(\frac{\partial P_a}{\partial R_a}\right)^2 (S)_{R_a}^2 \equiv \left(\frac{1}{B}\right)^2 \left[\frac{1 - e^{B\bar{P}_c}}{\bar{R}_c - R_a(1 - e^{B\bar{P}_c})} \right]^2 (S)_{R_a}^2 \quad (14)$$

and, $(S)_B^2$ is the mean variance for the data of Table IV,

$(S)_{\bar{P}_c}^2$ is the variance for chemical standardization of cluster-calibration fuel pins (See Ref. 1, page 10),

$(S)_{\bar{R}_c}^2$ is the variance of the mean count rate for cluster-calibration fuel pins,

$(S)_{R_a}^2$ is the variance of the count rate for a single fuel pin scan, estimated from $(S^2)_{\bar{R}_c}$ for each calibration.

Variances in equations (11), (12) and (13) are combined as the systematic variance, and equation (14) represents the random variance in P_a .

Data Reduction

Fuel pin shipments usually consist of several hundred pins associated with fuel pellets from a number of production lots. Receiving acceptance is on a total fissile plutonium basis for the shipment; however, in cases where S/R differences for certain production lots result in a total shipment S/R difference out of range, these lots are accepted separately pending investigation of S/R differences. Consequently, S/R differences are necessary on pin, lot and shipment bases. Computer programs have been set up to provide S/R comparisons accordingly. In addition to these comparisons, all assay calculations including random and systematic errors are made on the same bases. Hardcopy printouts are provided for all these data.

V. REFERENCES

1. Goris, Paul, FFTF Fuel Pin Nondestructive Assay Measurements - Summary Technical Report-1, HEDL-TME 74-59, October 1974, Hanford Engineering Development Laboratory, Richland, WA.
2. Goris, Paul, FFTF Fuel Pin Nondestructive Assay Measurements - Summary Technical Report-2, HEDL-TME 75-111, October 1975, Hanford Engineering Development Laboratory, Richland, WA.
3. Menlove, H.O., et. al., Cf-252 Assay System for FBR Fuel Pins, LA-5071-M, Los Alamos Scientific Laboratory, Los Alamos, NM.

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