NATIONAL BUREAU OF STANDARDS REPORT

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DETAILED ANALYSES OF MEASUREMENTS
IN THE
INTEGRATED SAFEGUARDS EXPERIMENT

NBS

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.

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REPORT ON THE

DETAILED ANALYSES OF MEASUREMENTS

IN THE

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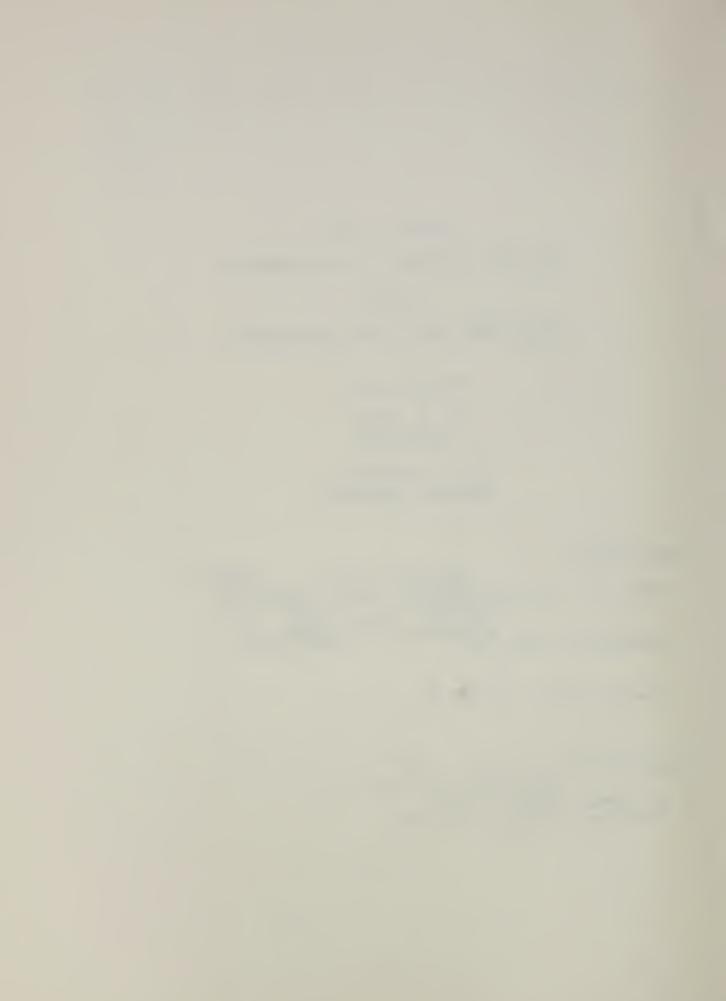

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An Integrated Safeguards Experiment (ISE) conducted within a nuclear fuels manufacturing plant is, in a broad sense, the tracing of fissile material through every stream in a process or processes under production conditions in an attempt to uncover those factors which contribute to the imbalance (specifically the material unaccounted for (MUF)) when a material balance for such plant is periodically calculated. The ISE, discussed in this paper, had as its primary objective the evaluation of the usefulness to Safeguards of material balance accounting based on all measurements being completely quantitative. This was accomplished by the utilization of non-destructive testing techniques (NDT) to measure difficult to measure materials. Generally, the fissile material content of these hard-to-measure materials was previously determined by either an educated guess or by a "by- difference" conclusion.

The ISE, from which material for this paper was drawn, will be reported in detail in a report to be issued by the USAEC. In conducting the experiment, however, many problems were encountered which required detailed effort not antici-pated in the planning of the project. These details are considered important enough to be reported separately in an effort to emphasize their significance. The intent of this paper, therefore, is to acquaint those interested

in possibly conducting similar integrated tests of some
of the details and problems associated with experimental
determination of plutonium content of the major flows of
a mixed-oxide fabrication process.

INTRODUCTION

In January 1968, the U.S. Atomic Energy Commission
(AEC), Office of Safeguards and Materials Management
established a Safeguards System Studies program which has
as a primary objective the study and analysis of the various
nuclear fuel manufacturing processes, for the purpose of
of developing a basis upon which criteria for acceptable
limits on material unaccounted for (MUF), normal operating
losses (measured discards), shipper-receiver (S/R) differ-
ences and unmeasured special nuclear material (SNM) inventory
could be established. Necessary information was to be com-
piled from both historical and current plant files and from
it develop analytical models which could be used to evaluate
plant data leading to the establishment of criteria for
acceptable limits for MUF, measured discards, S/R differences
and other critical factors. Visits to licensee plants soon
established the fact that historical data was lacking in
quality and depth and therefore not applicable to the
establishment of criteria. Also, current data was not
applicable since much of it was based on questionable
measurement data.

As a result of the findings of this early industry
survey the AEC decided to conduct Integrated Safeguards
Experiments (ISE) within licensee plants which were producing
nuclear fuel materials of major critical interest from a
need-to-safeguard viewpoint.

The Integrated Safeguards Experiment was conducted
at the General Electric Company Plutonium Laboratory,
Vallecitos Nuclear Center near Pleasanton, California.
This laboratory contains a fabrication process where plu-
tonium dioxide and uranium dioxide are physically mixed to
produce mixed oxide master blends of a given enrichment
(percent of plutonium in the mixed oxide); the material
is then prepressed, granulated, pressed, sintered, and
acceptable pellets loaded into fuel clad. The ISE consisted
of two campaigns of mixed oxide material: one utilized 90
percent fissile plutonium and the other 80 percent. Each
campaign consisted of two different enrichments, with each
enrichment made up of one or more master blends. The higher
of the two enrichments within a given campaign was fabricated
into annular pellets, while the material from the lower
enrichment was formed into solid pellets. The measure-
ments associated with the major flows of the fabrication
process are analyzed for the two jobs (campaigns) which
were run as part of the experiment. The major flows
considered for this paper are the plutonium dioxide feed,
the sintered mixed oxide product, and the scrap and measured
discards (waste) materials. For each of these flows the
details of each campaign are discussed; results are presented
for the various plutonium analysis techniques which were
applied. In each section, the procedures developed for
determining the uncertainties and for combining the random

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and systematic errors to obtain a total limit of error are discussed or referenced.

In addition, this paper contains a few comments and observations on the subject of plutonium concentration un-certainties in the propagation of errors; specifically, it deals with the coefficient of variation (CV) and limit of error (LE) values for the various blends of product.

FEED MATERIAL

Feed Material for each campaign is discussed separately in order to identify the difference in handling procedures.

Campaign 1 - Make-up and Treatment

The makeup of the feed material used in Campaign 1 was rather complex. The plutonium dioxide used in this first campaign was obtained in 1969. Six cans of PuO_2 were used; namely, cans designated as A, B, C, E, F, and G. Cans E, F and G were unopened, full cans. On the other hand, some of the contents of cans A, B and C had been used for other work in 1969. It was assumed that the atmosphere in the 3 unopened cans remained the same as when sealed by the shipper. According to information from the shipper, (ARCHO), the relative humidity (RH) of the loading box atmosphere was about 4 percent. Another assumption was that the 3 open cans (A, B and C) had picked up moisture during their use in 1969, since the RH of the GE plutonium fabrication laboratory is normally in the 30-60 percent range. Equilibration test data on plutonium dioxide powder, indicates a sharp rise in the powder weight within the first few hours when "very dry" powder is exposed to a 50% RH atmosphere. It was therefore assumed that the moisture content of the unopened cans was different than that for the opened cans of Campaign 1 feed material. This was confirmed by equilibration tests performed later. These equilibration experiments indicated that plutonium concentration in PuO_2 can change by

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as much as 1 percent depending upon temperature, humidity, particle size and surface area. For Campaign 1, samples were taken from cans B, C, E and G, for wet chemistry analysis of the plutonium concentration. It was generally agreed that any PuO_2 samples sent to the plutonium analytical laboratory would reach the equilibrium plateau before they were analyzed. Therefore, any "as received" plutonium concentration values were assumed to be stable insofar as the analyzing environment was concerned. Before the samples were destructively analyzed for plutonium content, the samples were "dried" at a selected temperature to drive off moisture. According to GE, plutonium concentration values obtained under "dried" conditions were supposed to represent the dry received plutonium dioxide. It was interesting to note that the average value of the 3 sub-samples taken from a composite sample was 87.27% Pu for a "dried" condition when the drying temperature was in the 200-300°C range. The average value for these same 3 sub-samples was 88.09% for a "dried" condition when the drying temperature was in the 700-800°C range. It is clear that the meaning of the word "dried" depends on conditions, and that it must be defined by a specific temperature range which will condition the sample in such a way that it may be considered representative of the feed. Since the drying process used by the plant to produce feed that was representative of the total lot could not be supported quantitatively, the results from

chemical assay were not considered usable in measured
material balance calculations.

The nondestructive technique of replacement calorimetry
was used for the measurement of plutonium content of the PuO_2
feed material. All cans of material used in Campaign 1 were
measured at least once. The limit of error (LE) associated
with the feed gPu value was due mainly to the uncertainty
associated with the contained Pu 238 and Am 241. The GE
Plutonium Laboratory did not have adequate analytical
capability for measurement of Am 241; therefore, the
vendor's value (corrected for growth) and uncertainty
had to be used in the calculation of the grams plutonium
as determined by calorimetry. The LE associated with the
gPu in the feed material was 4% for Campaign 1. (For details
on the procedure for calculating the total LE associated
with calorimetrically determined values, see reference 1).

Campaign 2 - Make-up and Treatment

The PuO_2 feed material was first calorimetrically
determined which revealed an error in the vendor's isotopic
values, then equilibrated, sampled and analyzed coulometrically,
reweighed, calorimetrically determined again and finally intro-
duced to the clean process line for fabrication purposes. The
80% fissile plutonium dioxide was contained in three cans.
The contents of each can and the accompanying composite
sample were equilibrated for several days. This equilibration
process consisted of allowing the material to pick up moisture

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from the glove box system until there was no additional weight change. This was accomplished by transferring the contents of the PuO$_2$ cans to flat pans permitting a greater surface of the oxide to be exposed to the glove box atmosphere. The change in weight averaged about 0.5 percent; this value representing a minimum since there was a lapse of time between the opening of the shipping containers and the transferring to the large tared equilibrating pans.

Relative humidity (RH) gauges indicated that the atmosphere in the analytical laboratory was in approximately the same range as that of the fabrication laboratory. Thus, this equilibration process eliminated or, at least, minimized a variable which Campaign 1 feed material was subjected to suggesting questionable results, and allowed for a meaningful value and LE to be obtained for Campaign 2 feed material by an accurate chemical analysis method.

After equilibration, eight samples were withdrawn for Pu analysis using the coulometry technique: 2 from each of the three cans as well as from the composite. The average of the 8 plutonium concentration values was used for the feed concentration value for the purposes of the material balance. The distribution of values was also used to calculate the limit of error associated with the mean concentration value. No additional uncertainty (e.g., due to moisture difference between fabrication and analytical laboratories) except for that due to weighing, was included

in the computation of the feed material LE value using chemical assay information. (See reference 1 for LE formulation details.)

The three cans of equilibrated PuO_2 material were removed from the fabrication line and each measured twice by calorimetry. The uncertainty of the calorimetry measurements was due to the uncertainty associated with the Pu 238 and Am 241 abundance determinations. As with Campaign 1, the vendor's value for Am 241, corrected for buildup, had to be used since the plant did not have that capability on a routine basis. The LE associated with the gPu value in the feed material was ∿8% for Campaign 2. This is twice as great as that in Campaign 1 and it reflects the percentage increase in the heat contribution from Pu 238 and Am 241 for 80% fissile plutonium.

Feed Results

Technique	Campaign 1	Campaign 2
Chemical Assay	NA	2425.1 ± 5.8 gPu
Calorimetry	4919. ± 197. gPu	2429. ± 190. gPu

Summary on Feed

1. The moisture problem which obscured true Campaign 1 feed values was solved in Campaign 2 by equilibrating the PuO_2 feed. Therefore an improvement over Campaign 1 was made and good chemical assay data was obtained for Campaign 2 feed.

2. No improvement was made on calorimetry. In fact, the percent LE was a factor of two larger for Campaign 2 than for 1 because the percent heat contribution from Pu 238 and Am 241 isotopic abundance was higher for the 80% fissile material.

3. There was remarkably good agreement between the chemical assay and calorimetry results for Campaign 2 feed.

PRODUCT MATERIAL

Discussion on Campaign 1

There were two master blends of material made up for
each of the two enrichments. The two master blends for a
given enrichment were supposed to be the same. For the
first enrichment, master blends MOO94 and MOO95 appeared
to be statistically different according to the F test* on
the product plutonium concentration variances. Because of
this, the grams of MOO94 mixed oxide and the MOO94 plutonium
concentration data were kept and treated separate from the
MOO95 information. Details are presented below. The master
blends of the second enrichment, MOO96 and MOO98, were not
statistically different, and therefore probably came from
the same material sources. Thus, for the second enrichment,
all the information was pooled together.

For the MOO94 material, the total grams plutonium was
calculated by multiplying the average MOO94 plutonium con-
centration value by the total grams of MOO94 mixed oxide that
were loaded into the rods. The percentage LE associated with
the MOO94 grams plutonium value was obtained by adding together
the LE values (in percentages) for the average plutonium

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* The F statistic is the ratio of the variances of the
two samples. The F test provides the probability that
the two samples came from normal distributions with the
same variance.

concentration and for the total weight of mixed oxide* The

same procedure was followed for MOO95. To obtain the LE

on the total grams plutonium in the first enrichment,

the LE values for MOO94 and MOO95, in absolute units, were

propagated in the usual manner. The usual error propagation

technique was again used to combine the two enrichment LE

values to obtain the Campaign 1 total product LE. The

usual propagation of error technique is applied in all situ-

ations except where the total grams of mixed oxide value is

multiplied by the average Pu concentration value. The treat-

ment of errors in this case requires a systematic procedure

because a collection of values is being multiplied by a

constant.

* See references 1 and 2 for discussion of the philosophy
  of this procedure.

The following tables give information about the Campaign 1 Product as determined by chemical assay.

Product Average Pu Concentration and LE

Enrichment		n*	Average Pu concentration	LE
1	M0094	13	0.03548	.00020
	M0095	12	0.03536	.00035
2	M0096, 98	26	0.03427	.00011

Product Grams of Mixed Oxide

Enrichment		Grams of Mixed Oxide	LE
1	M0094	26323.2	0.8
	M0095	28993.3	0.7
2	M0096, 98	61249.0	0.9

n* - Number of Production Samples.

Product gPu and LE

Enrichment	Grams Plutonium	LE
1	1959.1	11.5
MOO94	933.9	5.3
MOO95	1025.2	10.2
2	2099.0	6.8
1+2	4058.1	13.4

The fuel rods were gamma scanned twice; once using a NaI detector and later using a GeLi detector. Unfortunately, the analyses of the gamma scanning data were not completed in time to be used in this report. The same explanation applies to the 20 rods of Campaign 2.

Discussion on Campaign 2

The product consisted of two sets of fuel rods. One set of 10 rods contained solid pellets; the other set of 10 rods contained annular pellets whose plutonium concentration was slightly higher than that for the solid pellets.

Samples were withdrawn for purposes of plutonium concentration determination from the boats of sintered mixed oxide pellets in accordance with the fuel fabrication contract, one sample every fourth boat. Approximately 15 plutonium concentration determinations were made for each of the two enrichments. Since pellets within a given enrichment were supposed to come from the same population (master blend) an average plutonium concentration value was determined and used in determining the plutonium content of the sintered mixed oxide product. The distribution of values was also used to calculate the limit of error associated with the

average Pu concentration value for the enrichment. This
LE value, converted to a percentage, was added to the per-
centage weighing LE to obtain the percentage LE on the product
on an enrichment basis. To obtain the product LE for the
campaign, the absolute LE values for each enrichment were
combined using the usual error propagation techniques.

The following tables give information about the Campaign 2
Product as determined by chemical assay.

Product Average Pu Concentration and LE

Enrichment	n*	Average Pu Concentration	LE
1 MO100	15	0.02584	.000062
2 MO101	16	0.02388	.000143

Product Grams of Mixed Oxide

Enrichment	Grams of Mixed Oxide	LE
1 MO100	39260.5	0.8
2 MO101	43424.8	0.8

Product gPu and LE

Enrichment	Grams Plutonium	LE
1 MO100	1014.5	2.5
2 MO101	1037.0	6.2
Campaign 2	2051.5	6.7

*n - Number of Production Samples.

Product Results

Techniques	Campaign 1	Campaign 2
Chemical Assay	4058.1 ± 13.4 gPu	2051.5 + 6.7 gPu
NaI	Results not Available	
GeLi	Results not Available	

Summary on Product

1. The % LE for each campaign was 0.33%.

2. More blending work was performed on Campaign 2
    master blends than on Campaign 1 materials. One
    conclusion may be that the plutonium heterogeneity
    variance between pellets does not appear to be
    one of the dominant variances.

3. There was a factor of ∿ 1.7 difference between the
    LE associated with gPu of enrichment 1 and 2 of
    Campaign 1. For Campaign 2 the difference between
    the two enrichments was a factor of ∿ 2.5. In
    one campaign the annular pellets had the larger
    LE, in the other campaign it was the solid pellets.

Additional Comments

As indicated in the introduction of this paper, a few
observations and comments would be made on the uncertainty
of the product plutonium concentration values. The distri-
bution of n production samples (sintered pellets) produced
the following coefficients of variation for the various
blends:

Campaign	Master Blend	%CV	n
1	MOO94	0.93	13
	MOO95	1.57	12
	MOO96	0.90	14
	MOO98	0.61	12
2	MO100	0.43	15
	MO101	1.13	16

The above data may emphasize the importance of the complete blending process. For example, we observed that a longer blending time was performed on the fourth blend of Campaign 1 (MOO98) than on the first three blends. The %CV for (MOO98) blend is lower than any of the others, which may be attributable to the longer blending time.

In Campaign 2, however, the preparation and blending time for both blends involved (MO100 and MO101), were approximately the same and yet the difference between the %CV of these blends is a factor of approximately 2.6. Considering the similarity of preparation and blending time of both blends, why should there be such a large difference in the %CV? Possibly the non-homogeneity of the pellet sample or the lack of complete dissolution before analysis may be a logical conclusion. In the case of blend MO100 the GE-VNC analytical laboratory rejected the results of five of the fifteen samples as unusable and requested substitute samples from this blend. These were analyzed and results recorded. This was not repeated for blend MO101 since the analyses were considered normal.

Although considerably more effort was put into the blending preparation for Campaign 2 material than there was for Campaign 1, pooled CV values and the total % LE values indicated there was little difference between the results of the two campaigns.

A nested design experiment was performed by GE-VNC using samples from blend MO100 which had a 0.43 %CV value. The objective of this experiment was to evaluate the errors between and within plutonium determinations when using three different measurement techniques. This experiment also was expected to elucidate and segregate the several variance components, such as the analytical, dissolution, Pu hetrogeneity, lot-to-lot and others. The results of this experiment have not yet been reported; however, in light of the non-consistent behavior of the process, it is questionable whether results of such tests will be useful. Such results may be meaningful only if many nested design type experiments were conducted within the plant in order for the process to be characterized under its various conditions. Practical and economic considerations of this approach, however, would probably preclude doing this. Even if many sets of results were obtained, the usefulness of such information would be questionable in the propagation of error to obtain a meaningful LEMUF value. How would an inspector or plant operator know which set of results to use in the propagation? In plutonium fuel manufacturing plants where

the %CV values vary greatly between blends, the best type
of information to use for LEMUF calculations is the distri-
bution of current values. This will probably require more
samples than are normally taken, but it provides a means
for obtaining a meaningful LEMUF value which, after all, is
the judge of the MUF value.

Discussion on Campaign 1

The measured discards (waste) and scrap materials re-
sulting from the fabrication of mixed oxide pellets for
Campaign 1 were measured for plutonium content by passive
neutron coincidence counting. This method detects neutrons
from the spontaneous fission of isotopes such as Pu238,
Pu 240 and Pu 242. The standards used for calibration
purposes were fabricated from existing mixed oxide materials.
Element and isotopic content from previous analyses were
used. The standards were originally produced to meet the
needs of the Plant Instrumentation Program (PIP).* The
gPu limit of error (LE) values for several of the standards
are larger than one would normally use in materials balance
accounting. Another point to mention is that some of the
scrap packages were "hotter" than the largest standard used
in the calibration. In these cases the calibration curve
was linearly extrapolated. No additional uncertainty was
included to cover this procedure. The LE on the gPu in the
standards used for campaign calibration purposes ranged from
0.4% to 1.9% for scrap standards and for waste standards
was 3.2% or 3.5%. Most of this LE is due to the uncertainty

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* This program, sponsored by the AEC, will, hopefully,
  introduce non-destructive measuring techniques in the
  routine handling of nuclear fuel thus providing more
  effective and timely material control within the plant.

FIGURE 1. SCRAP AND WASTE

LE CALCULATIONS USING DATA FROM NEUTRON

COINCIDENCE COUNTING

$y = aX + b$ general equation   From calibration data:

a - slope
b - intercept

$X_i = (y_i - b)/a$ σ_a^2 - slope variance

$X = \sum X_i = (\sum y_i - nb)/a$ σ_b^2 - intercept variance

cov (a,b) - covariance between slope and intercept

y_i - net corrected coincidence counts of sample i.

X_i - calculated gPu 240 eq. of sample i.

$$\frac{\sigma_X^2}{X^2} = \frac{\sigma^2(\Sigma y - nb)}{(\Sigma y - nb)^2} + \frac{\sigma_a^2}{a^2} - \frac{2 \, \text{Cov}(\Sigma y - nb, a)}{(\Sigma y - nb)(a)}$$
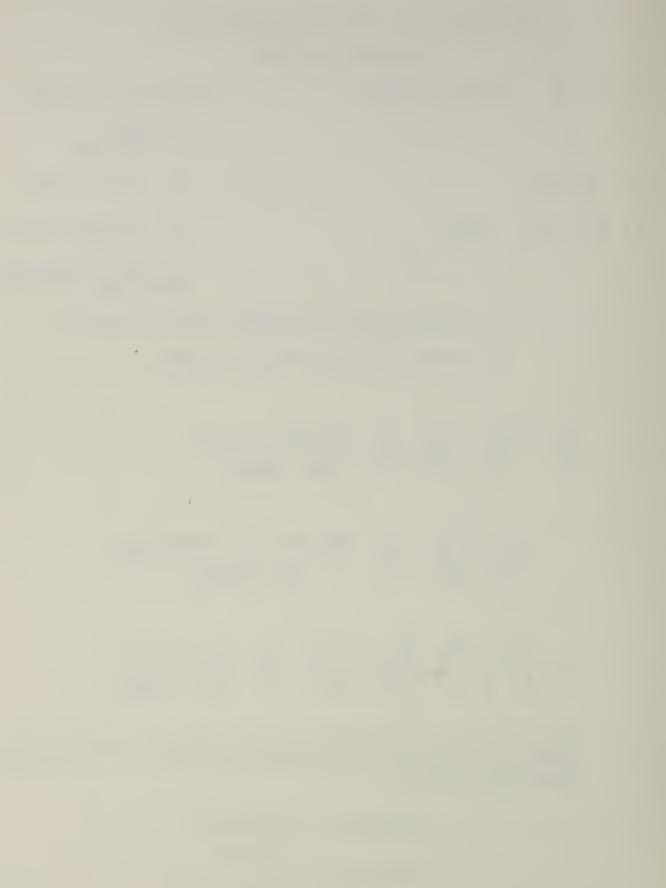
$$= \frac{\sigma_{\Sigma y}^2 + n^2 \sigma_b^2}{(\Sigma y - nb)^2} + \frac{\sigma_a^2}{a^2} - \frac{2[\text{cov}(\Sigma y, a) - n \, \text{cov}(b,a)]}{(\Sigma y - nb)(a)}$$

$$\sigma_X^2 = \left(\frac{\Sigma y - nb}{a}\right)^2 \left[\frac{\sigma_{\Sigma y}^2 + n^2 \sigma_b^2}{(\Sigma y - nb)^2} + \frac{\sigma_a^2}{a^2} + \frac{2n \, \text{cov}(a,b)}{(\Sigma y - nb)(a)}\right]$$

If there was one calibration curve for the waste (measured discards) and J calibration periods for the scrap the limit of error
expressions would be:

$$\text{LE (waste)} = 2\sqrt{\sigma_X^2 \text{ (waste)}}$$

$$\text{LE (scrap)} = 2\sqrt{\sum_{k=1}^{J} \sigma_{X_k}^2}$$

associated with the plutonium concentration determination
for the standards.

From the counting data collected on the known standards
a calibration curve was fitted by using the least squares
technique. The y axis, or ordinate, represented the coin-
cidence counts for a fixed time corrected for accidental
counts, dead time losses and background counts. The x axis,
or abscissa, represented the grams of plutonium 240 equivalent
in the standards. The weighting of calibration data had
no significant effect on the resulting calibration parameters.
From the least squares fit of the standards data the slope,
intercept, standard deviations of the slope and intercept,
and the covariance between the slope and intercept were
obtained. The standard deviation of the slope and intercept
represented the uncertainty associated with the standards
provided that all the standards did not come from the same
master blend. When the scrap and discarded materials were
coincidence counted, the count, Σy_i, was obtained with
information for the counting variance. The following figure
shows the pertinent expressions used to obtain the grams of
plutonium 240 equivalent, X, and the associated variance,
σ^2_X. Note that the summation of the individual gPu 240
equivalent values, X_i, takes place before the error propa-
gation is applied. If this procedure is carried out in
reverse order, the covariance effects among the individual
counts would have to be accounted for. The X_i values for all

of the material counted within a given calibration period were related through the use of the same calibration parameters. In other words, the variances associated with the individul X_i values are not independent and cannot be summed to obtain the variance on the total, σ^2_X . On the other hand, variances from different periods based on independent calibrations can be summed together in the usual manner since they are not related. The procedure followed in the ISE is shown at the bottom of Figure 1.

A point that should be emphasized concerns the gPu 240 equivalent of the standards. If the standards used to generate a calibration curve all came from the same isotopic lot and master blend, the abscissa may be biased. This systematic error would not show up in the standard deviation of the intercept and slope values. It would then be necessary to account for this systematic error separately.

Because the neutron equipment was not stable over the three month period that the Campaign 1 waste and scrap material was counted it was not possible to use just one calibration curve. A study of the scrap standards calibration data showed that the system drifted upward in a quasi step function fashion resulting in four calibration periods for the three month time interval. A weighted regression analysis (linear least squares fit) was performed on scrap standards data for each of the four periods. Coincidence counting statistics were used as weights. Data analysis on the very weak waste

standards did not show any statistically significant trend.
Therefore all neutron coincidence measurements on waste
standards were used in one weighted regression.

Discussion on Campaign 2

Much of the above discussion on Campaign 1 applies to Campaign 2. The counting times were the same - 10 min. independent of whether the material was low level waste or recoverable scrap. Some of the standards used for calibration purposes were the same ones used for calibration during the measurement of Campaign 1 materials. In addition, three other standards utilizing 80 percent fissile plutonium were incorporated into the calibration curves.

The problem of neutron counting equipment instability was present during the measurement of Campaign 2 waste and scrap. Therefore, there were several calibration curves and sets of parameters. The waste standards data and scrap standards data were not regressed separately by GE-VNC personnel within a given stable period as was done by NBS personnel in Campaign 1. This made the calculations within a given period simpler but caused complications when computing the LEMUF value because the waste and scrap values were not independent.

The problem of counting scrap packages which contained more plutonium than the standards was also present in Campaign 2.

For Campaign 2 regressions, weighting was done by GE-VNC on a mass-of-standard basis. An examination of the scrap standards data for a given period showed that the resulting intercept and slope values from least squares fits were

statistically the same when weighting was done by mass as when done by coincidence counting statistics.

Summary on Scrap and Waste

1. Campaign 2 measurement results were not expected to show improvement over those of Campaign 1 since the data collecting and data reducing procedures were the same for both campaigns.

2. On a percentage basis the scrap and waste uncertainties were larger for Campaign 2 because the plutonium in the standards came from different lots than was the plutonium used in Campaign 2. This created the situation where the impact of the isotopic abundance uncertainties as well as the spontaneous fission ratios uncertainties had to be evaluated and included in the limit of error calculations.

Feed Material - PuO$_2$

The moisture problem which affected the plutonium
dioxide of Campaign 1 was eliminated in Campaign 2 by
equilibrating before sampling; this procedure permitted
a meaningful chemical assay value to be obtained.

More effort on Pu 238 and Am 241 abundance determina-
tions is needed if calorimetry is to do the job that this
nondestructive technique is capable of performing for
materials balance accounting.

Product Material - Sintered Mixed Oxide

The product % LE value, obtained from chemical assay,
was the same for both campaigns, even though more blend
preparation work was performed on Campaign 2 material.

There was a factor of approximately two between
the % LE values of the two enrichments within each of the
campaigns.

The variation in the % LE or %CV values between
enrichments implies that this non-consistent process
behavior will render nested design results useless for
purposes of error propagation in material balance accounting,
thus necessitating the requirement to obtain sufficient data
for determining limits of error for each job.

Scrap and Measured Discards

The neutron coincidence counting procedure for measuring
Campaign 2 materials was the same as that for Campaign 1.

The percent uncertainty on a given scrap item was higher in Campaign 2 because of the additional uncertainty due to the isotopic abundance and spontaneous fission ratio considerations. This additional complex uncertainty existed because the plutonium in the standards came from different lots than that used in Campaign 2.

Overall Balance

Campaign 2 was more successful on the whole than was Campaign 1, mainly as a result of the improved quantification of the feed material. The MUF and LEMUF values for Campaign 2 were in the 10 grams plutonium range as compared to a factor of 10+ larger for Campaign 1.

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