MASTER

RECEIVED BY ... JUL 0 7 1986

TITLE: VARIANCE AND COVARIANCE CALCULATIONS FOR NUCLEAR
MATERIALS ACCOUNTING USING "PROFF"

AUTHOR(S): D. Stirpe and J. F. Hafer

SUBMITTED TO: 27th Annual Meeting of the Institute of Nuclear
Materials Management, New Orleans, Louisiana,
June 22-25, 1986

DISCLAIMER

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

VARIANCE AND COVARIANCE CALCULATIONS FOR NUCLEAR MATERIALS ACCOUNTING USING "PROFF"

D. Stirpe and J. W. Hafer

Los Alamos National Laboratory

Los Alamos, NM 87545

ABSTRACT

To determine the detection sensitivity of a
materials accounting system to the loss of Special
Nuclear Material (SNM) requires (1) obtaining a
relation for the variance of the materials balance
by propagation of the instrument errors for those
measured quantities that appear in the materials
balance equation and (2) substituting measured
values and their error standard deviations into
this relation and calculating the variance of the
materials balance. We have developed an inter-
active, menu-driven computer program, called PROFF
(for PROcessing and Fuel Facilities), that consid-
erably reduces the effort required to make the
variance and covariance calculations needed to
determine the detection sensitivity of a materials
accounting system. PROFF asks questions of the
user to establish the form of each term in the
materials balance equation, possible correlations
between them, and whether the measured quantities
are characterized by an additive or multiplicative
error model. Then, for each term of the materials
balance equation, it presents the user with a menu
that is to be completed with values of the SNM
concentration, mass (or volume), measurement error
standard deviations, and the number of measure-
ments made during the accounting period. On com-
pletion of all the data menus, PROFF presents the
variance of the materials balance and the square
root of this variance, so that the sensitivity of
the accounting system can be determined. PROFF
is programmed in TURBO-PASCAL for micro-computers
using MS-DOS 2.1 (IBM and compatibles).

I. INTRODUCTION

An important element in safeguarding nuclear
facilities against the loss of Special Nuclear
Material (SNM) is accounting for this material
through the measurement of all input and output
transfers and inventories over a specified ac-
counting period, substituting these measured val-
ues into the materials balance (MB) equation,

MB = Sum of input transfers + Sum of beginning
     inventories - Sum of output transfers -
     Sum of ending inventories,

and calculating the value of MB. The expected
value of MB is zero if no loss of SNM has oc-
curred. Errors in the measurement instruments,
however, limit the sensitivity of a materials
accounting system to the loss of such material
and, because the detection sensitivity is an ex-
cellent measure of the effectiveness of the mate-
rials accounting system, it is important to deter-
mine its value for specified values of the detec-
tion probability. Determination of the detection
sensitivity of a materials accounting system re-
quires:

(1) writing the MB equation for a materials bal-
     ance area (MBA), which may include the entire
     facility or some subdivision of the entire
     facility,

(2) obtaining a relation for the variance of the
     MB by propagation of the instrument errors
     for those measured quantities that appear in
     the MB equation,

(3) substituting measured values and their error
     standard deviations (SDs) into this relation
     and calculating the variance of the materials
     balance, and

(4) calculating the detection sensitivity for a
     specified detection probability by using σ,
     the square root of the variance of the MB.

Although application of these steps is necessary
for sensitivity studies of all facilities, details
of steps (1) through (3) will differ depending on
the facility process description. Implementation
of step (3), in particular, can be very tedious
for MB equations containing many transfer and in-
ventory terms. We have developed an interactive,
menu-driven computer program, called PROFF (for
PROcessing and Fuel Facilities), that considerably
reduces the effort required to make the variance
and covariance calculations needed to determine
the detection sensitivity of a materials account-
ing system.

Some guidance for the development of PROFF was provided by experience gained over the last several years by the Safeguards System Group at Los Alamos in performing sensitivity studies for chemical separation facilities, various kinds of processing and fuel fabrication plants, and gas centrifuge and laser isotope separation facilities. From this experience, it was decided that whatever computerized system was designed as a research tool to assist in implementing step (3), above, for performing sensitivity studies for different kinds of nuclear facilities, one of its most important features should be a wide range of permissible calculations.

A recent INMM paper[1] reported a computer program (EPIC) for performing only variance calculations of a few types of materials balance terms. PROFF has the added features of being able to make calculations of the covariance between different transfer terms; it can treat more complicated forms of both transfer and inventory terms using either additive or multiplicative error models; and, in the event that a facility is subject to inspection by the International Atomic Energy Agency (IAEA), PROFF permits the calculation of sigma of the MUF-D statistic (MUF, or Material Unaccounted For, is IAEA terminology for what is called the operator's Material Balance, or MB, in this paper). The MUF-D statistic combines the operator's and inspector's measurements in a way that eliminates the operator's correlated SDs from the equation for the variance of MUF-D.

PROFF is most conveniently used to make variance and covariance calculations for nuclear facilities where the terms in the MB equation can be expressed as a product of two measured quantities, such as SNM concentration and mass (or volume). One limitation is that the variance and covariance equations in PROFF assume steady-state facility operation. That is, in a series of batch transfers, the SNM concentrations and the batch masses (or volumes) are assumed to have the same nominal measured value, respectively. Although occasions have arisen where the assumption of steady-state facility operation was not valid, these occasions have been rare. In most of the sensitivity studies carried out during the last several years by the Safeguards System Group for various kinds of nuclear facilities, the assumption of steady-state operation has been an excellent one.

Another important feature that such a computer program should have is transportability between PCs. Hence, PROFF is programmed in TURBO-PASCAL for micro computers using MS-DOS 2.1 (IBM and compatibles).

PROFF is an interactive program that asks questions of the user to establish the form of each term in the materials balance equation and possible correlations between them. Then it presents the user with a menu to be completed with values for SNM concentration, mass (or volume), and their measurement error standard deviations. All the variance and covariance equations that

are stored in PROFF were derived using a multiplicative error model for concentration measurements. Variance equations for the mass (or volume) measurements are included for both additive and multiplicative error models. Presently, the number of calculations that can be performed by PROFF is limited to 100; that is, the number of transfer variance calculations plus the number of transfer covariance calculations plus the number of inventory variance calculations cannot be greater than 100.

II. TERMS OF THE MATERIALS BALANCE EQUATION

A type of transfer term that often occurs in the materials balance equations of processing or fuel fabrication facilities is of the form

$$T1 = \sum_{i=1}^{N} C_i (BX - LX)_i , \qquad (1)$$

where C is the SNM concentration of a solution (kg Pu/L) or of a bulk powder (in percent or fraction, such as kg Pu/kg oxide powder), BX and LX are the gross and tare volumes of the solution (or masses of the bulk powder), respectively, and N is the number of transfers measured during the accounting period (i runs from 1 to N). The form of (1) assumes that for each C measurement, there are corresponding measurements of BX and LX. In an MB equation, there may be several input or output transfers that have the form of Eq. (1), although the values of the measured quantities, C, BX, and LX may be different for the different MB terms.

A second type of transfer term that occasionally occurs in materials balance equations is of the form

$$T2 = \sum_{i=1}^{NC} C_i * \sum_{j=1}^{NX} (BX - LX)_{ij} . \qquad (2)$$

This form of MB term shows explicitly that there are NX measurements of BX and LX per C measurement and NC measurements of C during the accounting period. A term like Eq. (2) is necessary for dealing with material from a blender, for instance, where a single concentration measurement is made of a blended sample, but the blended material is subsequently apportioned among several bottles, whose individual masses are measured. Obviously, if NX = 1, T2 reduces to the form T1. PROFF contains several equations for calculating the variance of MB terms like T1 and T2 and also the covariance between such terms.

Beginning and ending inventory differences must also be included in MB equations, and these can have different forms. A type of inventory difference that sometimes appears has the form

Beginning inventory - Ending inventory

$$= IO - F*IO , \qquad (3)$$

where IO is the number of kilograms of SNM and F is a number less than or equal to 1. If F = 1, then the beginning and ending inventories are nominally the same, although they represent different measurements.

Another type of inventory difference that occurs in MB equations is given by

Beginning inventory - Ending inventory

$$
= \sum_{i=1}^{NC} c_i * \sum_{j=1}^{NX} (BX - LX)_{ij} - \sum_{k=1}^{NC} c_k * \sum_{l=1}^{NX} (BX - LX)_{kl} \quad .
$$
(4)

Such a form of inventory difference might be necessary for boats of material loaded into a calciner, for instance. A similar form is also used for a number of columns holding SNM solution. PROFF contains equations for calculating the variance of inventory differences like Eq. (3) and, for Eq. (4), PROFF will calculate the variance of the inventory difference when the initial and final values of the pairs (NC, HX), respectively, are equal or unequal.

III. PROFF - PRELIMINARY QUESTIONS AND DATA MENUS

In PROFF are stored five equations for calculating the variance of MB transfer terms like T1 and T2, four equations for calculating the covariance between MB transfer terms like T1 and T2, and six equations for calculating the variance of inventory difference terms like Eqs. (3) and (4). There are also three equations for calculating the sigma of MUF-D. Each of the five transfer variance equations and each of the six inventory difference variance equations has an associated menu that must be completed by the user so that the calculations can be carried out by PROFF. Depending on the variance equation to be used, values for some subset of the items C, BX, LX, IO, F, NC, and NX must be supplied in the proper menu, along with the SDs associated with the measurements of C, BX, LX, and IO. In order to be able to branch to the appropriate menu,

PROFF presents the user with several preliminary questions. We discuss an example problem to illustrate the procedure.

For our example, we will use a modified and highly abbreviated version of a sensitivity study recently carried out by the Safeguards System Group on a hypothetical, mixed uranium oxide-plutonium oxide (MOX) fuel fabrication facility. We assume a single input transfer to this facility, consisting of cans of $UO_2:PuO_2$ (1:1) powder, and two output transfers consisting of stacks of Fast Breeder Reactor (FBR) and Advanced Thermal Reactor (ATR) fuel pellets. In the original problem, there were many kinds of items held in interim storage as inventory at materials accounting times, but, for our simple example, we assume that the inventory consists only of cans of FBR MOX powder held as recycle material.

The specifications for these three transfer terms and one inventory difference are given in Table I. Before entering PROFF, it is advantageous to write out these data in a table of this type.

The plutonium concentration of the three transfer terms is determined by laboratory analysis, while the concentration of the MOX powder in inventory for recycle is determined by nondestructive assay (NDA) methods (a High-Level Neutron Coincidence Counter, for instance).

With this information before us, we enter the PROFF computer program by typing PROFF at the PC prompt. The first menu (Fig. 1) is presented sequentially, with the first paragraph presented first and a response expected. We answer the first question with an N because we do not wish to calculate the sigma of MUF-D. At the second paragraph, if we wanted to change some data entries in the menus of a problem that we had run previously, we would enter the file name of that problem here. Only data entries of the previously run problem can be changed, not the structure of the problem, such as the number of transfers,

TABLE I

DATA FOR THE EXAMPLE PROBLEM

Term Type	C (frac.)	BX (kg)	LX (kg)	NC	NX	Mass SD (kg) Rand.	Conc. SDs (%) Rand.	Cor.
MOX Input	0.441	2.75	0.25	8	1	0.0002	0.36	0.21
FBR Pellet	0.176	0.73	0.25	2	26	0.0002	0.58	0.11
ATR Pellet	0.0176	2.50	0.50	4	31	0.0002	0.58	0.11
MOX Inventory	0.176	6.45	0.25	2	1		3.0	1.0

inventories, etc. If a file name that does not already exist is entered here, an error will occur and PROFF will respond with an abort. Our particular example is a new problem, so we enter a carriage return, which we will subsequently denote by CR.


```
IS THIS A SIGMA[MUF-D] RUN:
   ENTER Y OR N    N

ENTER A FILE NAME IF THIS PROBLEM IS A RERUN
OF A PREVIOUSLY SAVED DATA SET - OTHERWISE
ENTER A RETURN
FILE NAME:

ENTER A FILE NAME FOR SAVING THE DATA SET
OF THIS RUN FOR A FUTURE RERUN - OTHERWISE
ENTER A RETURN
FILE NAME:   MOXSTORE

ENTER A FILE NAME FOR SAVING THE OUTPUT RESULTS
OF THIS RUN FOR PPINTING - OTHERWISE
ENTER A RETURN
FILE NAME:   MOXOUT
```

Fig. 1.
PROFF's first menu for the example problem. We answer the first question with a N(o), for we do not wish to calculate the sigma of MUF-D for this problem. We label the store file and output file MOXSTORE and MOXOUT.

Now we are presented with the third paragraph, asking for the name of a store file. If we feel we would want to run this problem again, with some of the data changed, a name must be entered here. Filenames in PROFF can have the two forms XXXXXXXX or XXXXXXXX.YYY, where there can be eight or fewer X's and three or fewer Y's (upper or lower case can be used throughout PROFF). If a store file (or output file, see below) already exists with the name chosen here, it will be overwritten. We have chosen the name MOXSTORE.

Finally, the fourth paragraph is presented, asking for the name of an output file where user-readable data and results are to be stored. We have chosen the name MOXOUT. Asking, at some future time, that this file be typed will give the data we have entered for this problem and the variance results.

On a CR, the next menu appears, as shown in Fig. 2. For our simple problem, we give as 1 the number of input transfer terms, 2 as the number of output transfer terms, and 1 as the number of inventory terms. We take 30 as the number of days in the accounting period. After entering the number 30, a CR at REFRESH SCREEN displays the data we have entered for a second time. This provision for examining the data again for possible mistakes is provided throughout PROFF. The cursor arrow keys on the micro-computer keyboard are used to move about the data menus for correcting data. However, data are entered only by keying in a value and following with a CR. If no

changes in the data are required, the cursor is moved to the EXIT MENU line (with a CR) and this menu is then exited with another CR.

```
MENU1

NO. OF INPUT TRANSFERS:            1

NO. OF OUTPUT TRANSFERS:           2

NO. OF INVENTORY TERMS:            1

NO. OF DAYS IN ACCOUNTING PERIOD:  30

REFRESH SCREEN:

EXIT MENU:
```

Fig. 2.
The numbers of the different kinds of terms and the number of days in the accounting period are specified in the second PROFF menu.

The next menu (Fig. 3) is presented sequentially, with the first item (ENTER ID) asking for an identifying name of the input transfer. This name cannot be more than 50 characters long, including spaces. As we shall see, this name appears in the list of results so, in large problems, identifying names should be chosen to avoid ambiguity. For our simple problem, we choose the name INPUT MOX.

```
INPUT TRANSFER NO.  1

ENTER ID:  INPUT MOX

IS THE BATCH MASS A SINGLE TERM X OR A PRODUCT OF TWO TERMS CXX?
   ENTER 1 OR 2    2

ARE THERE ERROR TERMS FOR C, X, OR BOTH?
   ENTER C OR X OR B    B

IS THE ERROR IN X EXPRESSED AS A % ?
   ENTER Y OR N    N

IS THIS DATA OK? - Y OR N:  Y
```

Fig. 3.
Preliminary questions for the input transfer term. An identifying name is entered, which is INPUT MOX in this case, along with the form of the term and the type of measurement error model for X.

On a CR after entering the ID, the next question is presented. PROFF offers the option of calculating the variance of MB terms like T1 and T2 where C = 1 (i.e., essentially pure SNM) and is not measured, although this option is rarely used in dealing with processing facilities, or where C is unequal to 1 and is measured, which is an option that is frequently used. From Table I, we see that C = 0.441 kg Pu/kg MOX when expressed as a fraction and has associated measurement SDs, so we respond with a 2 as the answer to this question.

The next question that appears in this sequence is clearly directed toward supplying the user with the menu that reflects whether there

are errors in one (C or X) or both (C and X) parameters. We have assumed that measurement errors are associated with both mass (X) and concentration (C) measurements, so we enter a R. Furthermore, we have assumed an additive error model for the scale so, in response to the question IS THE ERROR IN X EXPRESSED AS A %?, we enter an N. The last question that appears in this menu, which we answer with a Y, gives the user the opportunity of examining the entries made for correctness of response.

After entering a Y in the last menu, the complete data menu for the input transfer appears, as shown in Fig. 4. The first response required is the number of C measurements per day (NC). This number is multiplied by the number of days in the accounting period, entered in Fig. 2, to give the N in Eq. (1) above, which is the total number of measurements made during the accounting period. We enter 8 here, for 8 measurements per day. On the next line, we enter NX = 1, for there is an X measurement for each C measurement.

INPUT MOX
INPUT TRANSFER - 1	VALUE		UNITS
NO. OF C MEASUREMENTS PER DAY:	8	:	N.A.
NO. OF X MEASUREMENTS PER C MGMT:	1	:	N.A.
VALUE OF THE C MEASUREMENT:	.441	:	FR
GROSS VALUE OF X:	2.75	:	KG
TARE VALUE OF X:	.25	:	"
RANDOM STANDARD DEVIATION OF C:	.36	:	%
SYSTEMATIC STANDARD DEVIATION OF C:	.21	:	%
RANDOM STANDARD DEVIATION OF X:	.0002	:	KG

REFRESH SCREEN:

EXIT MENU:

Fig. 4.
The data menu for the input transfer term. The values and units are taken from Table I.

Next we enter the value of C, which is 0.441 when expressed as a fraction (zeros before the decimal can be suppressed in the data menus). On a CR here, the cursor moves to the UNITS column of this menu. PROFF offers the option of expressing the number of kg Pu/kg MOX as a fraction (FR = 0.441) or as a percent (44.1%). If 0.441 is entered in the VALUE column, FR must be entered in the UNITS column. If 44.1 is entered in the VALUE column, a % sign must be entered in the UNITS column.

We then enter the gross value of X in the VALUE column (2.75) and kg in the UNITS column (the UNITS column here will also accommodate solution density, such as kg Pu/L, if this were a transfer of SNM solution). Finally, we enter the tare value of X and the measurement standard deviations. Because the scales are described by an additive error model, the correlated SD in X is not called for in this menu.

On exiting this menu, we obtain the questions in Fig. 5, which are the same as those in Fig. 3, except that we are now dealing with the first output transfer. We give the ID as FBR PELLETS and answer the other questions as we did in Fig. 3. On completing these questions, the data menu of Fig. 6 is presented, which we complete as shown. Note that NX = 26 in this menu, indicating that each measurement of the plutonium concentration of the pellets is assigned to 26 pellet stacks, the mass of each of which is measured. Figures 7 and 8 are similar to Figs. 5 and 6, respectively, except they deal with the second output transfer, which we call ATR PELLETS.

OUTPUT TRANSFER NO. 1

ENTER ID: FBR PELLETS

IS THE BATCH MASS A SINGLE TERM X OR A PRODUCT OF TWO TERMS C*X?
ENTER 1 OR 2   2

ARE THERE ERROR TERMS FOR C, X, OR BOTH?
ENTER C OR X OR B   B

IS THE ERROR IN X EXPRESSED AS A % ?
ENTER Y OR N   N

IS THIS DATA OK? - Y OR N: Y

Fig. 5.
Preliminary questions for the first output transfer term. The ID here is FBR PELLETS.

FBR PELLETS
OUTPUT TRANSFER - 1	VALUE		UNITS
NO. OF C MEASUREMENTS PER DAY:	2	:	N.A.
NO. OF X MEASUREMENTS PER C MGMT:	26	:	N.A.
VALUE OF THE C MEASUREMENT:	.1764	:	FR
GROSS VALUE OF X:	.73	:	KG
TARE VALUE OF X:	.25	:	"
RANDOM STANDARD DEVIATION OF C:	.58	:	%
SYSTEMATIC STANDARD DEVIATION OF C:	.11	:	%
RANDOM STANDARD DEVIATION OF X:	.0002	:	KG

REFRESH SCREEN:

EXIT MENU:

Fig. 6.
The data menu for the first output transfer term. Again the values and units are taken from Table I.

OUTPUT TRANSFER NO. 2

ENTER ID: ATR PELLETS

IS THE BATCH MASS A SINGLE TERM X OR A PRODUCT OF TWO TERMS C*X?
ENTER 1 OR 2   2

ARE THERE ERROR TERMS FOR C, X, OR BOTH?
ENTER C OR X OR B   B

IS THE ERROR IN X EXPRESSED AS A % ?
ENTER Y OR N   N

IS THIS DATA OK? - Y OR N: Y

Fig. 7.
Preliminary questions for the second output transfer term. The ID for this term is ATR PELLETS.

ATR PELLETS
OUTPUT TRANSFER - 2

	VALUE		UNITS
NO. OF C MEASUREMENTS PER DAY:	4	:	N.A.
NO. OF X MEASUREMENTS PER C MONT:	31	:	N.A.
VALUE OF THE C MEASUREMENT:	.01764	:	FR
GROSS VALUE OF X:	2.5	:	KG
TARE VALUE OF X:	.5	:	-
RANDOM STANDARD DEVIATION OF C:	.58	:	X
SYSTEMATIC STANDARD DEVIATION OF C:	.11	:	X
RANDOM STANDARD DEVIATION OF X:	.0002	:	KG

REFRESH SCREEN:

EXIT MENU:

Fig. 8.
The data menu for the second output transfer term.

When we exit the menu of Fig. 8, we are pre-
sented with the questions of Fig. 9, which are
concerned with possible correlations between the
output transfers terms. For our example problem,
we assume that the concentration measurements are
correlated, so we answer the questions with a Y.
If there were more than two output transfers,
PROFF would cycle through each pair and ask if
correlations existed between each pair. No addi-
tional data menus need be completed for these
covariance calculations. PROFF picks out the data
necessary for these calculations from the menus
already completed. If our problem had had more
than one input transfer, we would have obtained a
similar set of questions concerning possible cor-
relations between input transfer terms after we
had completed the data menus for the input trans-
fers.

ARE THERE CORRELATIONS BETWEEN OUTPUT TRANSFER TERMS:
ENTER Y OR N   Y

1 FOR PELLETS
2 ATR PELLETS
ARE THEY CORRELATED?
ENTER Y OR N Y

IS THIS DATA OK? - Y OR N: Y

Fig. 9.
Questions concerning correlations between output
transfers. We respond with a Y(es) because the
concentration measurements are correlated.

After answering the questions regarding pos-
sible correlations, PROFF cycles through the in-
ventory terms. To know which inventory variance
equation to branch to, PROFF expects answers to
the questions of Fig. 10. We first give the ID
for our inventory term as RECYCLE MOX POWDER.
Questions 1 and 2 of Fig. 10 are for directing
PROFF to the variance equations of the inventory
difference given by Eq. (3), where measurements
of IO can be described by either an additive or
multiplicative error model. Question 3 directs
PROFF to a variance equation used to obtain an
approximate value of the inventory variance given
that the inventory is not measured because of its
inaccessibility, but it can be estimated through

knowledge of the process variability. Question 4
directs PROFF to the variance equations of the
inventory difference given by Eq. (4), where the
individual items are measured and the measurements
of X can be described by either an additive or a
multiplicative error model. The inventory for
our example problem consists of two cans of MOX
powder, so we respond with 4. We also assume that
the initial and final inventories are equal.
Then we are presented with the menu of Fig. 11,
which we complete as shown. Finally, PROFF asks
for possible correlations be- tween input and
output transfers, as seen in Fig. 12. We respond
with an N, for there are none.

INVENTORY NO. 1

ENTER ID: RECYCLE MOX POWDER

IS THE INVENTORY VARIANCE DETERMINED BY:

1 - NORMALLY ADDITIVE?

2 - NORMALLY MULTIPLICATIVE?

3 - PROCESS VARIABILITY?

4 - ITEM MEASUREMENT?

ENTER NUMBER 1 THRU 4   4

ARE INITIAL AND FINAL INVENTORIES EQUAL?
ENTER Y OR N   Y

IS THE ERROR IN X EXPRESSED AS A X ?
ENTER Y OR N   N

IS THIS DATA OK? - Y OR N: Y

Fig. 10.
Questions concerning the inventory term. We have
individual items as inventory, so we respond with
a 4. The initial and final inventories are equal
and the mass (X) measurements are described by an
additive error model.

RECYCLE MOX POWDER
INVENTORY - 1

	VALUE		UNITS
NO. OF C MEASUREMENTS PER DAY:	2	:	N.A.
NO. OF X MEASUREMENTS PER C MENT:	1	:	N.A.
VALUE OF THE C MEASUREMENT:	.1764	:	FR
GROSS VALUE OF X:	6.45	:	KG
TARE VALUE OF X:	.25	:	-
RANDOM STANDARD DEVIATION OF C:	3	:	X
RANDOM STANDARD DEVIATION OF X:	0	:	KG

REFRESH SCREEN:

EXIT MENU:

Fig. 11.
The inventory data menu. Table I again supplies
the values and units for this menu.

ARE THERE CORRELATIONS BETWEEN INPUT AND OUTPUT TRANSFER TERMS:
ENTER Y OR N   N

IS THIS DATA OK? - Y OR N: Y

Fig. 12.
Questions concerning correlations between input
and output transfer terms. We assume there are
no correlations between these terms.

After answering the questions of Fig. 12, PROFF calculates and presents the variance results along with sigma, the square root of the total variance, as shown in Fig. 13. Sigma is needed to calculate the detection sensitivity. Note that the IDs we assigned to each of the MB terms appear in the list of results. Note also that the individual C and X variance contributions are given. Such a separation of variance contributions makes it obvious which measurements are the largest contributors to the total variance. For our particular problem, it is clear that the concentration measurements would have to be improved to reduce the total variance and the detection sensitivity.

IV. SUMMARY

We have developed an interactive, menu-driven computer program that considerably reduces the effort required to make the variance and covariance calculations needed to determine the detection sensitivity of a materials accounting system. It is written in TURBO-PASCAL for micro-computers using MS-DOS 2.1 (IBM and compatibles) and therefore easily transportable.

REFERENCE

1. A. L. Baker, "EPIC--An Error Propagation/ Inquiry Code," Nucl. Mater. Manage. XIV (Proceedings Issue), 438-442 (1985).

```
RESULTS
              OPERATOR
INPUT TRANSFERS
INPUT MOX
   1 C: 3.125387E-01 X: 3.734035E-06
OUTPUT TRANSFERS
FBR PELLETS
   1 C: 3.089340E-02 X: 3.883397E-06
ATR PELLETS
   2 C: 2.567003E-02 X: 9.260407E-08
OPERATOR OUTPUT TRANSFER CORRELATIONS
   1- 2 C: 4.195187E-02
INVENTORIES
RECYCLE MOX POWDER
   1 C: 4.306089E-03

TOTAL VARIANCE = 4.153679E-01
SIGMA = 6.444904E-01
C:\>
```

Fig. 13.
Results of the variance calculations. Note that the ID of each MB term is given, along with the C and X variance contribution of each term, the total variance, and sigma, the square root of the total variance.