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TITLE EPIC--AN ERROR PROPAGATION/INQUIRY CODE

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EPIC—AN ERROR PROPAGATION/INQUIRY CODE*

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ABSTRACT

The use of the computer program EPIC (Error Propagation/Inquiry Code) will be discussed. EPIC calculates the variance of a materials balance closed about a materials balance area (MBA) in a processing plant operated under steady-state conditions. It was designed for use in evaluating the significance of inventory differences in the Department of Energy (DOE) nuclear plants. EPIC rapidly estimates the variance of a materials balance using average plant operating data. The intent is to learn as much as possible about problem areas in a process with simple straightforward calculations assuming a process is running in a steady-state mode. EPIC is designed to be used by plant personnel or others with little computer background. However, the user should be knowledgeable about measurement errors in the system being evaluated and have a limited knowledge of how error terms are combined in error propagation analyses. EPIC contains six variance equations; the appropriate equation is used to calculate the variance at each measurement point. After all of these variances are calculated, the total variance for the MBA is calculated using a simple algebraic sum of variances. The EPIC code runs on any computer that accepts a standard form of the BASIC language.

INTRODUCTION

The computer program EPIC (Error Propagation/Inquiry Code) estimates the variance of a materials balance closed about a materials balance area (MBA) in a processing plant. EPIC uses the simplifying assumption that the plant is operating under steady-state conditions. It was designed for use in evaluating the significance of inventory differences in the Department of Energy (DOE) nuclear plants and as a design aid. EPIC rapidly estimates the variance of a materials balance using average plant operating data.

*Work supported by the US Department of Energy, Office of Safeguards and Security.

PURPOSE

EPIC is designed to be used by plant personnel and/or DOE auditors. It assumes the user has no previous experience with computers. The user must, however, be knowledgeable about measurement errors in the system being evaluated or have access to someone who is. The user must also have a limited knowledge of how error terms are combined in an error propagation analysis.

The primary functions of EPIC are to provide a rapid calculation of the variance of a materials balance (MB) in an operating nuclear facility or to assess the MB variance for a proposed process under various design options and measurement strategies. The program is applicable to any process where the following simplifying assumptions are valid:

(1) The process operates under steady-state conditions in which the process inventories are constant and each transfer stream consists of identical batches of material.
(2) Each term in the MB equation can be represented as a single measurement or as the product of two measurements (such as a concentration times a volume).
(3) The error model (additive or multiplicative) for each measurement assumes a single random error and a single systematic error.
(4) Successive measurements for a given transfer stream are correlated by a common systematic error representing the effect of performing each measurement on the same instrument.

When these assumptions are not applicable, as in the case where frequent calculations of MB variance are required on real process data that includes nonsteady-state measurements, periodic instrument recalibrations, and large numbers of inventory and transfer terms, other variance calculation codes such as DECANAL,[1] AMASS,[2] or those using algebraic languages (for example, MACSYMA) may be more appropriate.

DESCRIPTION

The EPIC code was developed on a personal computer with the intention that it can be used on any computer that accepts a standard form of the BASIC language. It is written in Microsoft* BASIC, which is available on any CP/M or MS-DOS system.

Input for the EPIC code consists of information about a process in the form of measurement values and their uncertainties. These measurements reflect both process unit inventories, such as inventories in tanks, and transfers of material into and out of the MBA. The transfers are assumed to consist of a series of uniform batch transfers. The measurement uncertainties required are the combined standard deviation of systematic errors and the combined standard deviation of random errors for each measurement value. These standard deviations can be expressed as relative or absolute values (Table I).

EPIC calculates the materials balance variance over a materials balance time interval for a process assumed to be running in a steady-state mode; that is, the beginning inventory in a process unit is expected to be the same as the ending inventory. This assumption simplifies the necessary variance calculation.

In estimating the variance of the MB, EPIC uses a set of six equations (Table II) to calculate the variance for each measurement point. After all of these variances are calculated, the variance for the MB is approximated using a simple algebraic sum of variances. When correlations among individual components of the materials balance are known to be small, this approximation is quite reasonable.

At the present time, EPIC has the capacity to calculate variances for up to 40 process units (tanks, bulk measurements, and so forth) and up to 20 transfer streams. Transfers are assumed to consist of N equal batches, where N may be different for each transfer stream. Measurements on the same transfer stream are assumed correlated by a common systematic error.

EPIC saves all data input on a file for future use. An editing capability exists within the code that allows a user to change previously stored data or add new information to reflect process changes or try "what if" scenarios. This editing capability makes EPIC a useful system for comparing accounting system designs or identifying cost-effective improvements with existing systems.

USE

One use of the EPIC program is to determine the standard deviation of an MB from average process data. The example process shown in Fig. 1 will be used for this discussion. If we run the EPIC program with these data, we get the results in Table III, which show that the resulting standard deviation is ~1.8% of throughput. If we look at the estimated errors, it would appear that the waste stream needs much better measurement, but looking at the table of variances for the various measurement points (Table IV), we can see that the small amount of SNM in the waste stream contribute a very small variance compared to the total variance. From looking at Table IV we can determine that a better location for an improved measurement method is the concentration measurement in the RECEIPT tank. By improving this measurement to a 1% random error and a 0.5% systematic error, we can improve the standard deviation of the MB to 1.2% of throughput. We can verify this by rerunning EPIC and editing the file we created in the first example to reflect the proposed change. The results of a run such as this are shown in Table V with the variance table shown in Table VI. The results are probably obvious for this simple example, but EPIC will determine this information for more complicated cases and print or display information tables.

*Microsoft is a registered trademark of Microsoft Corporation, Bellevue, Washington 98004.

TABLE I

INFORMATION NECESSARY FOR INPUT TO EPIC CODE

FOR EACH PROCESS UNIT INVENTORY:

PROCESS UNIT IDENTIFICATION
PROCESS UNIT TYPE (tank, column, etc.)
NUMBER OF MEASUREMENT COMPONENTS
(required to establish a process unit inventory value; two maximum)

FOR EACH MEASUREMENT COMPONENT:

MEASUREMENT VALUE
UNITS OF MEASUREMENT
STANDARD DEVIATION OF RANDOM ERROR
STANDARD DEVIATION OF SYSTEMATIC ERROR
(always zero)

FOR EACH TRANSFER:

TRANSFER IDENTIFICATION
TRANSFER TYPE (input or output)
BATCH OR CONTINUOUS (always batch—for now)
NUMBER OF BATCHES (for this balance period)
NUMBER OF MEASUREMENT COMPONENTS
(required to establish amount transferred in a single batch; two maximum)

FOR EACH MEASUREMENT COMPONENT:

MEASUREMENT VALUE
UNITS OF MEASUREMENT
STANDARD DEVIATION OF RANDOM ERROR
STANDARD DEVIATION OF SYSTEMATIC ERROR

TABLE II

EQUATIONS USED IN ESTIMATING VARIANCE

TRANSFER VARIANCE EQUATIONS*

1. $V1 = n\sigma_s^2 + (n\sigma_q)^2$ $\quad V1 = var(EM_i)$ $\quad$ additive M

2. $V2 = M^2(n\sigma_s^2 + (n\sigma_q)^2)$ $\quad V2 = var(EM_i)$ $\quad$ multiplicative M

3. $V3 = C^2(M^2(n\sigma_{sC}^2 + (n\sigma_{qC}^2)^2)$

$+ n\sigma_{sM}^2 + (n\sigma_{qM}^2)^2)$ $\quad V3 = var(E(CM)_i)$ $\quad$ additive M multiplicative C

where

M = mass or volume per batch,

C = concentration,

I = inventory,

n = number of batches,

σ_s^2 = variance of the random error component, and

σ_q^2 = systematic variance of the so-called systematic error component.

The additive model uses absolute variances/standard deviations, and the multiplicative model uses relative variances/standard deviations

INVENTORY VARIANCE EQUATIONS*

1. $V1 = 2\sigma_s^2$ $\quad V1 = var(I_o - I_f)$** $\quad$ additive I

2. $V2 = 2(I\sigma_s)^2$ $\quad V2 = var(I_o - I_f)$ $\quad$ multiplicative I

3. $V3 = 2C^2(\sigma_{sM}^2 + (M\sigma_{sC})^2)$ $\quad V3 = var((CM)_o - (CM)_f)$ $\quad$ additive M multiplicative C

*These equations were supplied by Dante Stirpe, Safeguards Systems Group.

**Where $I_o = I_f$.

TABLE III

RESULTS FROM EPIC RUN OF SAMPLE PROCESS

Process inventory is	52.5000 kg
Input transfers equal	100.0000 kg
Output transfers equal	99.1000 kg
Difference between total input and total output is	0.9000 kg
Total variance of MB is	3.4000 kg^2
Total standard deviation of MB is	1.8439 kg

TABLE IV

TABLE OF VARIANCES FOR PROCESS UNITS OF SAMPLE PROCESS

Inventory Identification	Number of Inventories	Total Inventory (kg)	Total Inventory Variance (kg^2)
Receiver	1	20.0000	2.0018
Converter	1	2.5000	0.0053
Product	1	30.0000	0.0050
Totals		52.5000	2.0121

Transfer Identi-fication	Transfer Type	Number of Batches	Total Transfer Amount (kg)	Total Transfer Variance (kg^2)
Input	Batch	10	100.0000	1.3750
Waste	Batch	200	0.1000	0.0009
Product	Batch	20	99.0000	0.0120
Totals			0.9000	1.3879

TABLE V

RESULTS FROM EPIC RUN WITH REVISED DATA

Process inventory is	52.5000 kg
Input transfers equal	100.0000 kg
Output transfers equal	99.1000 kg
Difference between total input and total output is	0.9000 kg
Total variance of MB is	1.4800 kg^2
Total standard deviation of MB is	1.2166 kg

Another use of EPIC is the determination of the significance of an MB based on the use of historic or estimated errors. By representing a process with a simple flowsheet showing the major measurement points and estimating the standard deviation of the errors from history or experience with the process, one can use EPIC to estimate the standard deviation of the MB. One can therefore test the significance of an MB if the process obeys the simple model employed in EPIC.

The flow of material through a process can often be tracked better if the MBAs are broken into several smaller MBAs or if they are separated in a different manner. EPIC offers the opportunity to try different configurations of MBAs quickly to determine which is the best for the purpose. For example, possible improvements in the accounting for the sample process (Fig. 1) if it were broken into two MBAs could be examined.

LIMITS

The code does not handle continuous stre The user is expected to make the assumption that a continuous stream is made up of many small equal

TABLE VI

TABLE OF VARIANCES FOR PROCESS UNITS WITH REVISED DATA

Inventory Identification	Number of Inventories	Total Inventory (kg)	Total Inventory Variance (kg^2)
Receiver	1	20.0000	0.0818
Converter	1	2.5000	0.0053
Product	1	30.0000	0.0050
Totals		52.5000	0.0921

Transfer Identification	Transfer Type	Number of Batches	Total Transfer Amount (kg)	Total Transfer Variance (kg^2)
Input	Batch	10	100.0000	1.3750
Waste	Batch	200	0.1000	0.0009
Product	Batch	20	99.0000	0.0120
Totals			0.9000	1.3879

batches, or else that it is made up of one large batch, whichever simulates the process better.

As mentioned above, the EPIC code expects the beginning inventory to be equal to the ending inventory (as would be the case if the process were in steady-state mode).

The user must be aware that there often are nonmeasurement contributors to materials balance variability. Two such contributors are unmeasured holdup and unmeasured waste. The propagation of measurement/sampling errors alone often does not account for all observed variability in materials balances.

FUTURE PLANS

Enhancements planned for the EPIC code include allowing the input for the code to be from LOTUS 1-2-3 or some other spreadsheet.

Another enhancement that is being looked at is the addition of default values for the standard deviations of the errors of various types of measurements. These values would have to be set and approved by experts in the measurement field.

A frequently requested enhancement is the ability to handle different beginning and ending inventory for each inventory term. The decision

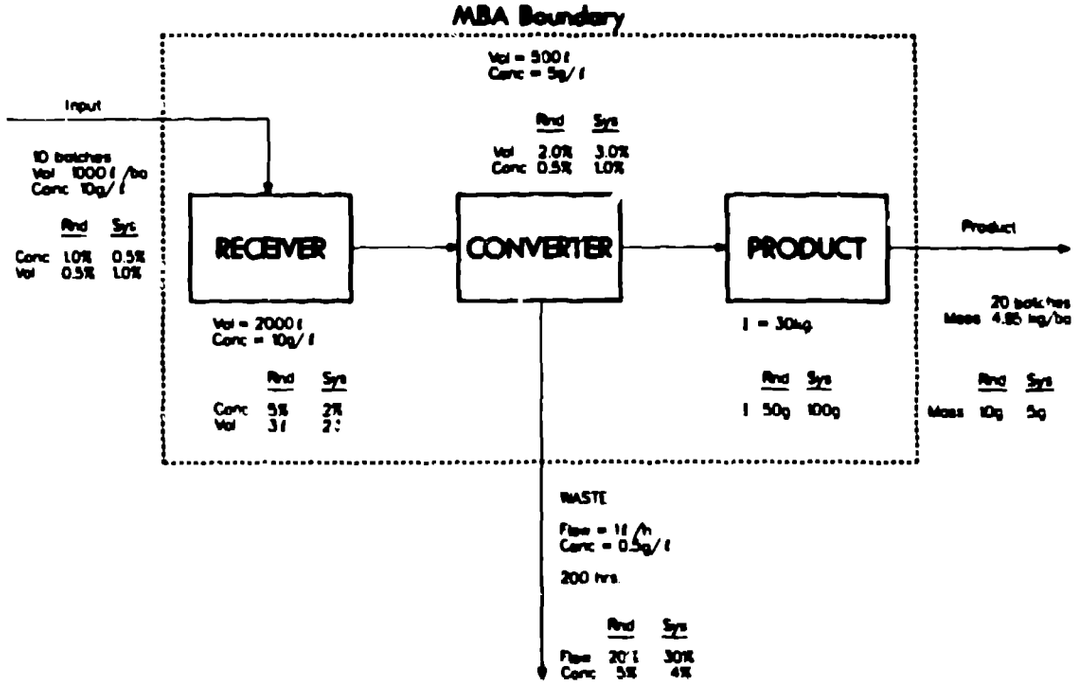

Fig. 1. Sample process.

to add this capability has not yet been made. It may be better to provide a different code that does not limit the user in this way.

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