RFP- 1900

CONF-720529--7

RECEIVED BY TIC MAR 5 1973

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EXCEPTION REPORTING OF NUCLEAR MATERIALS CONTROL

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Figure 1

11 pages

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ABSTRACT

Described is a new capability designed by the Rocky Flats Division of Dow Chemical U.S.A. for reporting control of nuclear materials measurements. The needs for measurement control are reviewed, and Rocky Flats methods for assessing the uncertainties of measurements are outlined. Comparison follows of the reporting method in contrast to the current system. Advantages of exception reporting to Nuclear Materials Managers are emphasized. The report includes test statistics, capabilities and advantages that are natural corollaries to exception reporting, and future plans.

EXCEPTION REPORTING OF NUCLEAR MATERIALS CONTROL

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Introduction

As fabrication, reprocessing, and residue streams of a nuclear plant tend to stabilize so do the procedures governing quality and material control and measurement points. Measurement control procedures, acting as measurement monitors of nuclear materials, also tend to show a constant capability. That is, the systematic error or bias frequently retains the same algebraic sign, and the variability of the measurement remains within limited parameters. Surveillance of measurement control may be necessary, but perusal of measurement control summaries and data that do not change within the historical and capability parameters is undesirable. The nuclear materials manager is vitally interested in drastic measurement changes or the occurrence of out of control data. These are data that the manager must have to evaluate and act.

Exception reporting of measurement control precludes examining consistent data because they simply are not there. The exception report flags unusual data and brings them to management attention. In the case of the RFD system, the report also informs the manager why certain data are exceptional and provides supporting statistics. These advantages have been recognized by both RFD's nuclear material managers and those of the Division's customers.

But why is measurement control necessary at all?

Nuclear Materials Measurements

Measurement Control is essential in a nuclear materials processing plant because of the necessity of periodic physical inventories. The method used to inventory nuclear material involves several separate and distinct measurements. Each batch of material must be weighed and sampled for laboratory analysis or be measured in some nondestructive way. Mankind has yet to invent a system that will measure without error or repeat without deviation. Additional difficulties are introduced by taking a sample. For these reasons, the quantities of nuclear material used in computing the total inventory are inexact, preventing balanced accounts of nuclear material.

In what terms can discussion relate to such an intangible characteristic as the inexactness of a measurement method? Of necessity discussion must be in terms of weighing, sampling and analysis, or in terms of direct measurement. Qualifying statements may be made for each component of the total measurement system by using statistical techniques of data analysis. A qualifying statement then becomes the maximum deviation to be expected with a given probability. The probability associated with a given deviation should be established at a predetermined level, say, 95%; i.e., the true error will be more than the reliability statement 5% or less of the time. Reliability statements are calculated from data collected on each measurement method used in obtaining the material balance.

Rocky Flats recognizes the following sources of measurement variability for nuclear material determination - weighings, volume measurements, chemical analyses and isotopic analyses. It is necessary that reliable estimates be made of the uncertainties in these measurements.

Variability due to sampling is an important contributor to the total uncertainty in a material transfer. Measurement of this variability should be on a scheduled basis. Special programs must be devised for estimating its contribution to material balance reliability, but such programs are not discussed here.

The RFD procedure for measuring nuclear material involves the following exclusive operations: (1) appropriate batches of material are weighed or measured by volume, sampled and analyzed for nuclear material content, or (2) appropriate batches of material are measured nondestructively for total nuclear material content.

Because the analysis is inexact, and the sample is not truly representative, the quantities of nuclear material used in computing a material balance also are inexact. The determination of just how inexact or biased the measurements are becomes extremely important.

Measurement Control Program

The Rocky Flats measurement control program evaluates bias and variability. Measurements of a given characteristic are compared with other measurements of the same characteristic made with an accepted standard. The latter measurement may be considered the standard because it is vastly superior to the first, or observed measurement. The standard measurement is comprised of a standard sample which has been synthesized by measurement methods, traceable to national standards as are the parent chemicals. The average of the differences between the observed and the standard values is the bias of the measurement. The standard deviation of the bias is a measure of its variability.

The measurement control program is divided into categories of process materials and residues which are assayed for nuclear material content. Each program is assigned a Nuclear Materials Management (NMM) description code number. The Rocky Flats Chemistry Standards Laboratory submits known standards or standard samples to the Analytical Laboratories for measurement. Laboratory personnel measure the nuclear material content in each sample and transmit the observed value to the Chemistry Standards Group. A comparison of the observed value with the standard value establishes the validity of the measurement method for each category. At the end of the month, the standard values, the observed values, and the applicable statistics are summarized by computer according to measurement control program identification.

Previous Measurement System

The Rocky Flats previous system of nuclear measurement control reporting included both an internal and an external report. The internal included all data and summaries of a month's control measurements and summaries of all data for the previous six months plus some non-nuclear material measurement control results. The external report contained only summaries of the previous six months' data for all nuclear measurement control programs.

Both the former and current reports result from a system administered by the RFD Chemistry Standards Laboratory. This system measures and reports the biases and variabilities of nuclear materials measurements made at RFD. These are accomplished by comparing observed values (OV) which are determined independently on standard samples to the standard values (SV). (OV minus SV).

Data resulting from these comparisons are checked daily or weekly to provide floor control of the measurement facilities. The data are processed each month.

Current Measurement System

The Nuclear Materials Measurement Control System has been designed to run on an IBM 360/40 computer. Documentation is on file at Rocky Flats.

The new program is made by exception per measurement control program per month. Outlying data are listed and summarized statistically to indicate all atypical measurements made on standard samples during the month and any significant shifts in bias plus those where insufficient data have been gathered.

Computer programs test measurement data for unusual differences and for trends, as explained in Appendix I. Programs summarize statistically only the categories that contain unusual data, those that show trends, and those that have insufficient measurements to allow the data to be evaluated statistically.

The new reporting system includes the following features.

1. Use of data processing equipment.
2. Brief and specific reports.
3. Current status of the measurement control program.
4. Statistical testing.
5. Data editing.
6. Provisions for corrections prior to report publication.
7. Statistical summaries of current and historical data.
8. Descriptive rhetoric accompanying atypical conditions.
9. Easily accessible history data file.
10. Audit capability.
11. Availability of complete reports.
12. Computer prepared cover letter.

The exception report includes the following information in the sequence listed. In figure 1, the flow chart gives full details for producing an exception report.

1. Descriptive Information

- a. Control program identification number.
- b. Brief description of the attribute measured.
- c. The sample material.
- d. Method of measurement.
- e. Range of the standard values of the standard samples.
- f. Units of measurement.

2. A statistical summary of the current month that includes the following:

- a. Number of standard samples measured and reported.
- b. The mean of the differences, i.e., observed value (OV) minus standard value (SV); this reflects the measurement bias.
- c. Standard deviation of the differences. This reflects the variability of the bias.

3. "Statistics Accumulated During the Previous Six Months" includes:

- a. Number of standards measured.
- b. The mean (measurement bias).
- c. Standard deviation of the bias.
- d. Average standard value of the standard samples measured during the six-month period.
- e. The quotient, expressed in percent, of the standard deviation divided by the average standard value.

Fig. 1

SEQUENCE OF EVENTS WHICH PRODUCE AN EXCEPTION REPORT

Future Plans

Future plans for Rocky Flats Measurement Control Program and Reporting System include programmatic use of the information which is generated, plus constant review to determine the applicability and meaningfulness of testing.

The nuclear materials managers envision a system that could and would factor measurement bias and variability into the nuclear materials control system automatically. Hopefully, the reports generated by the nuclear control system could then be made by exception also, where a significant MUF (Material Unaccounted For) could be reported as actually MUF rather than hiding behind the skirts of the state of the measurement art.

Additional statistical tests will be employed to further their sensitivity. The proposed tests are: (1) departures from normality, (2) an additional outlier test, and (3) least squares enabling a test for significant slope.

References

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3. Yardley Beers, Introduction to the Theory of Error, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts, 1957.
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Appendix I - Statistical Testing

Grubbs's test and Student's "t" test are employed for exception reporting. These tests detect unusual measurements and trends. Thus, they are ideal for exception reporting of measurement control. Each is described below.

Grubbs's Test for Spurious Data

The calculated statistic is:

$$T = \frac{\Delta_n - \bar{\Delta}}{S_v} \quad \text{or} \quad \frac{\bar{\Delta} - \Delta_1}{S_v} \quad (1)$$

Where: Δ_i = Observed Value_i - Standard Value_i

$$\Delta_1 \leq \Delta_2 \leq \dots \leq \Delta_n$$

$$\bar{\Delta} = \frac{\sum_{i=1}^n \Delta_i}{n} = \text{mean difference for current month}$$

SD_v = standard deviation of the differences for the previous six months

The exact distribution has been tabulated for selected values of n (1 and 4), but is of limited use, extending only to $n = 12$. Using a standard nonlinear regression technique, a curve was found which fit the data to the accuracy specified by the original data.

$$y = \frac{x}{b_0 + b_1 x} + b_2$$

Where: x = the tabular T' values for the 95% confidence level.

b_0, b_1, b_2 = coefficients determined by least squares. There is a different set of coefficients for each degree of freedom in the table.

y = the extrapolated T' value

The purpose of Grubbs's test is to identify highly variable current data as compared to the variability displayed historically. When the largest Δ value and the smallest Δ value are equidistant from the mean (i.e., $\Delta_n - \bar{\Delta} = \bar{\Delta} - \Delta_1$), they will be tested simultaneously. A Δ is deemed an outlier if the calculated T' is greater than the tabular T' .

Student's "t" Test for Bias Trend

The calculated statistic follows (the propagated standard deviation shown in the determinator was developed by Y. M. Ferris).

$$t = \frac{(\bar{x} - \mu)}{\sqrt{\frac{\sum_{i=1}^J \frac{S_i^2}{n_i}}{J}}} \quad (2)$$

Where: $\bar{x}$ is the sample mean of the current month

μ is the mean of the previous six months

S_i is the standard deviation calculated from one month's data

n_i is the number of observations from which S_i is calculated

J is the number of months from which μ is calculated. $J \leq 6$

The purpose of the "t" test is to discover subtle trends in the data. A significant trend exists if the calculated t value is larger than the tabular t value at the 99% confidence level.