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Process Monitoring for Reprocessing Plant Safeguards A Summary Review

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Consolidated Fuel Reprocessing Program

PROCESS MONITORING FOR REPROCESSING PLANT SAFEGUARDS A SUMMARY REVIEW*

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ABSTRACT

Process monitoring is a term typically associated with a detailed look at plant operating data to determine plant status. Process monitoring has been generally associated with operational control of plant processes. Recently, process monitoring has been given new attention for a possible role in international safeguards. International Safeguards Project Office (ISPO) Task C.59 has the goal to identify specific roles for process monitoring in international safeguards.

As the preliminary effort associated with this task, a review of previous efforts in process monitoring for safeguards was conducted. Previous efforts mentioned concepts and a few specific applications. None were comprehensive in addressing all aspects of a process monitoring application for safeguards.

This report summarizes the basic elements that must be developed in a comprehensive process monitoring application for safeguards. It then summarizes the significant efforts that have been documented in the literature with respect to the basic elements that were addressed.

ACRONYMS

AGNS	Allied General Nuclear Services, Barnwell, South Carolina
BNFP	Barnwell Nuclear Fuel Plant, Aiken, South Carolina
CFRP	Consolidated Fuel Reprocessing Program
C/S	Containment and Surveillance
IAEA	International Atomic Energy Agency
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory
ISPO	International Safeguards Project Office
JASPAS	Japan Support Program for Agency Safeguards
MC&A	Material Control and Accounting
MPM	Microscopic Process Monitoring
NUSAC	Nulear Surveillance and Audit Corporation
ORNL	Oak Ridge National Laboratory
PNC	Power Reactor and Nuclear Fuel Development Corporation
SAGSI	Safeguards Advisory Group on Safeguards Implementation
TASTEX	Tokai Advanced Safeguards Technology Exercise
USNRC	U.S. Nuclear Regulatory Commission

1. INTRODUCTION

Process monitoring is an expression that has traditionally been identified as a functional capability associated with operation and control of complex industrial processes. Generally, the process monitoring function is motivated by potential improvements in process efficiency, safety, environmental protection, and other considerations, and the design of the monitoring system is dependent on monitoring objectives, regulatory requirements, and the design of the process facility.

As a preliminary effort in developing a process monitoring concept for the International Atomic Energy Agency (IAEA) safeguards application in nuclear fuel reprocessing plants, a survey of the literature was done to identify previous efforts addressing process monitoring for reprocessing plant safeguards. Numerous technical publications mention process monitoring, but a relatively small subset of those identified process monitoring as a viable tool for safeguards purposes. Within those safeguards-related publications, a range of process monitoring concepts are identified and described in varying degrees of detail. Many publications were found that gave superficial positive comments on the potential usefulness of process monitoring, but these publications provided no substantive details about a specific concept. A few publications were found that contained significant details on some aspects of a process monitoring concept, but these publications did not address other aspects necessary for concept evaluation. This second group of publications is listed in the attached bibliography, and descriptive excerpts from some documents are attached in the appendix. No reference was found that provides a comprehensive description of all aspects of any process monitoring concept; this situation indicates that process monitoring as a safeguards concept is in the very early stages of development.

In fact, a great majority of the useful publications related to safeguards applications were associated with a small number of significant process monitoring efforts. The organizations involved in the significant efforts and their published contributions are:

- Allied General Nuclear Services (AGNS):
  - process monitoring system at the Barnwell Nuclear Fuel Plant (BNFP).
- Idaho National Engineering Laboratory (INEL):
  - development and testing of specialized sensors,
  - monitoring scheme implemented at Idaho Chemical Processing Plant (ICPP),
  - monitoring demonstration for the plutonium product area of the Tokai plant, Tokai Advanced Safeguards Technology Exercise (TASTEX), Task I.
- Oak Ridge National Laboratory/Consolidated Fuel Reprocessing Program (ORNL/CFRP):
  - development of the microscopic process monitoring (MPM) concept,
  - demonstration of MPM in the BNFP miniruns,
  - process monitoring assessments for the U.S. Nuclear Regulatory Commission (USNRC).
- Japanese Science and Technology Agency:
  - monitoring demonstrations in the plutonium product area of Power Reactor and Nuclear Fuel Development Corporation (PNC) Tokai Works in cooperation with IAEA and INEL.

- USNRC
  - — study of advanced process monitoring for improved material control,
  - — assessment of material control and accounting (MC&A) reform amendment impacts on reprocessing plants.
- International Atomic Energy Agency (IAEA):
  - — STR-140 Part I, "An Advanced Safeguards Approach for a Model 200 T/A Reprocessing Facility,"
  - — STR-151, "Nuclear Material Safeguards for Reprocessing—Current Status and Problems."

The objective of this report is to summarize the publications containing significant process-monitoring-concept information and to identify the major elements to be addressed in development of a process monitoring concept for international safeguards application. Also, a definition of process monitoring is proposed. The perspectives obtained from this summary review will be useful in developing a comprehensive process monitoring concept.

2. A PROPOSED DEFINITION OF PROCESS MONITORING FOR INTERNATIONAL SAFEGUARDS

The expression "process monitoring" is widely used in the safeguards literature to denote some safeguards-related functional capability derived from information about process materials and/or equipment. In nearly every case, the "process data" are presumed to be available on a continuous (or nearly continuous) basis via a computerized data acquisition system. The traditional functional capabilities supported by process monitoring generally range from simple alarms for "out-of-limit" parameters to sophisticated automatic process control schemes. These functions are operator oriented and are usually incorporated into the process operations. The safeguards functions supported by process monitoring are dependent on whether the application is for domestic safeguards or international safeguards. Although a general definition of process monitoring has not been accepted, some basic considerations that would likely be incorporated are:

- Acquisition of data from sensors installed in a process environment that indicates directly or indirectly conditions of process materials and equipment.
- Operations on that process data with analysis systems to generate appropriate parametric tests.
- Provision of response criteria that are consistent with stated functional objectives.

If the definition were specifically directed for international safeguards applications, some additional considerations would likely be incorporated:

- A containment/surveillance concept (C/S) is followed in which continuous and direct access to "selected process data" is provided to the inspector.
- The process data are used to generate records and parametric test results that are available to the facility operator and the state but are secured so that modifications can be made only by the international inspector.
- The records and test results are used by the inspector for specified functional objectives.

A definition incorporating the previous features is consistent with the definition proposed by the International Working Group for Reprocessing Plant Safeguards in its final report to the IAEA.

3. BASIC ELEMENTS OF A PROCESS MONITORING CONCEPT

To provide a framework within which process monitoring publications can be compared and contrasted, it is necessary that certain key features or basic elements of a process monitoring system be identified. As a preparatory effort in developing a generic process monitoring concept for IAEA application in reprocessing plants, several basic elements have been proposed for detailed consideration. A brief description will be given for each of the following basic elements of process monitoring:

- Functional objectives.
- Logic structure and test parameters.
- Data requirements, characteristics, and acquisition.
- Performance criteria.
- Alarms, alarm resolution, and response.
- Hardware: sensors and data processing.
- Vulnerabilities, tamper resistance, verification.
- Resource requirements.

3.1 FUNCTIONAL OBJECTIVES

Careful consideration must be given to clearly defining the functional objectives of the process monitoring activity. The principal issue results from fundamental differences between applications in support of domestic safeguards versus international safeguards. For domestic applications, the monitoring activity may be active (i.e., with potential for intervention in process operations) or passive. For international applications, only passive functions are acceptable. Because the objective of Task C.59 is to develop a process monitoring concept appropriate for international application, only passive functions will be included. Most international functions for process monitoring are often described as C/S measures for verification of materials accountancy data. Functional objectives for detection of loss or unauthorized use are also investigated.

3.2 LOGIC STRUCTURE AND TEST PARAMETERS

The process monitoring logic structure is very closely associated with the functional objectives. The logic structure defines the type of information and analyses required to achieve the functional objectives, and test parameters are formulated that permit quantification of the logic structure. For example, if a functional objective is to verify that all materials transferred into and out of the material balance area do pass through a key measurement point, then the logic structure may be to monitor for spurious changes in solution volumes in process equipment that are not associated with declared batch additions. The test parameter may be a volume inventory difference calculated for process vessels in the balance area.

3.3 DATA REQUIREMENTS, CHARACTERISTICS, AND ACQUISITION

If the logic structure has been developed and the test parameters have been defined, the next major elements to consider are what are the data requirements, what are the characteristics of the data, and how are the data accessed from the process system. The needed information can be obtained in some cases from data process control instruments installed, operated, and maintained by the facility operator. These data may be in analog form or in binary form. Data may also be obtained from dedicated instruments installed for safeguards purposes. Analytic data may also be available and used for samples of process material that have been submitted to the operator's analytic laboratory or for which analytic determinations have been made by the inspector. The characteristics of all the data obtained for process monitoring will be important. The precision and accuracy of instrumentation as well as variances introduced by process noise determine the capabilities achievable with process monitoring tests. It is necessary, therefore, that assessments be made of variances associated with the data used for process monitoring. Another important data consideration is that computerized data acquisition will almost certainly be required for viable process monitoring concepts. Attention must be given to the timing and frequency of data acquisition. The sequence in which instruments are read by the computer can be important. The archival techniques used must allow efficient recall of information for safeguards analysis.

3.4 PERFORMANCE CRITERIA

Another major element of process monitoring is the performance criteria to be used for process monitoring tests. Clearly, the specific performance criteria will be dependent upon the functional objectives and the particular test formulation. However, the criteria will necessarily reflect some basic safeguards loss-detection criteria related to goal quantities of nuclear material. For example, IAEA has "as a goal" the detection of losses of 8 kg of plutonium within "a few days." Any process monitoring test can be structured so that the test parameter relates directly or indirectly to that goal. Frequently, the goal must be translated into some parameter (i.e., solution volumes or flow rate discrepancy) that permits a comparative test.

3.5 ALARMS, ALARM RESOLUTION, AND RESPONSE

Once the process monitoring performance criteria have been established and the characteristics of the process data are known, one can begin to address the questions of process monitoring alarms, the resolution techniques appropriate for those alarms, and the response activities associated with failure to resolve alarms. An important but often overlooked aspect of the alarm and alarm resolution activity is the mode of presentation of those alarms to the inspector.

3.6 HARDWARE: SENSORS AND DATA PROCESSING

Another major element of a process monitoring system is the sensors and data processing hardware. It is likely that all process sensors used for international process monitoring applications will be installed, operated, and maintained by the operator. This does not preclude specialized monitoring instruments that would be provided by the inspector but perhaps installed and maintained by the operator under inspector observation. These types of instruments will not have any active capabilities relative to the process, and the operator will have full access to the monitoring data from these instruments.

3.7 VULNERABILITIES, TAMPER RESISTANCE, VERIFICATION

The next major element of the process monitoring system concerns the vulnerabilities of the system, the tamper-resistance features that are appropriate for the process monitoring equipment, and the methods of verification of process monitoring data. Because the process monitoring system is intimately connected with the operator's data acquisition system, one of the most significant and obvious vulnerabilities is a situation in which the access to that process data is interrupted by deliberate operator actions or other similar situations. One might also expect that the process monitoring capabilities could be compromised by conditions that increase the noise aspect of the data and, thereby, limit the monitoring sensitivity. Also, consideration must be given to calibration changes that occur normally for process equipment and process instrumentation. Provisions must be made to either recalibrate or compensate for the calibration changes in terms of performance criteria and alarms. Also, one must consider as a vulnerability the opportunity for an unusual process operation that would defeat the logic associated with certain process monitoring tests.

In spite of these vulnerabilities, process monitoring does afford some opportunities for tamper resistance. Clearly, by providing real-time data access and subsequent protected archiving of that real-time data, limited opportunities occur for operator modifications of the data. Furthermore, by having secured software and hardware for data analysis, the inspector will be able to maintain confidence that the analysis software has not been compromised. Also, there is an inherent tamper resistance with process monitoring because the data used in the monitoring are coupled to other data in a sequential process operation, and this coupling permits some consistency checks that will, in essence, substantiate the data quality. Attempts to compromise any one data point would necessarily require the compromising of successive data points to avoid having a data anomaly occur in the process analysis.

Another verification concept for the data used in process monitoring would be afforded by comparison of process data with sample analysis. Also, the limited use of duplicate sensors dedicated to inspectors at specific process key measurement points would permit continuous comparisons with the process sensors. These inspector-dedicated monitors would be nonintrusive into the process and have no active interface with the process or the process material.

3.8 RESOURCE REQUIREMENTS

The final major element of a process monitoring system is the resource requirements associated with implementing that monitoring system. The description of the resource must be expressed in terms of equipment, manpower, and associated support capabilities. Consideration must also be given to the distribution of resource requirements between the facility operator, the state system, and the international inspector and support organization.

The preceding basic elements of the process monitoring system do not constitute an exclusive set of elements, but rather they provide a set of elements that define a framework within which process monitoring concept proposals can be described and evaluated.

4. MAJOR PROGRAMS FOR DEVELOPMENT OF PROCESS MONITORING CONCEPTS

A limited number of significant efforts have been identified for the development of process monitoring, and a brief overview will be given for each of those development efforts. Abstracts and excerpts from related publications are given in the Appendix.

4.1 IDAHO NATIONAL ENGINEERING LABORATORY

The most extensive process monitoring development has been associated with the INEL through its efforts in three principal activities: (1) the development of specialized monitoring instruments for use in process monitoring applications, (2) testing of basic features of process monitoring at the Idaho Chemical Processing Plan (ICPP), and (3) development and implementation of the plutonium product area monitoring demonstrations at the PNC Tokai Plant in Japan. The INEL effort has contributed significantly to the availability of specialized instrumentation and an understanding of the monitoring capabilities afforded by those instruments. Such devices as thermal flow meters and position switches may be necessary instrumentation for some process monitoring applications, and those instruments have been tested by the INEL under a variety of operating conditions.

The monitoring functions done in the ICPP have provided some practical experience in obtaining data and examining that data for use in process monitoring. However, functional objectives have not been fully developed for the monitoring activities at the ICPP, and performance criteria were not developed against which process data could be assessed. Consequently, the alarms and alarm resolution aspects were not developed sufficiently.

4.2 TASTEX TASK I AND JAPANESE SUPPORT PROGRAM FOR AGENCY SAFEGUARDS (JASPAS) AT TOKAI WORKS

The INEL efforts in the product area monitoring demonstrations at Tokai are based on a well-defined functional objective. The effort was to monitor material entering and leaving the product tanks, as well as transfers among product tanks. Too, specialized instrumentation was installed in the process to collect data and to provide analyses of that data to satisfy the functional objectives.

This effort recognized characteristics of process data. As a result, the project used specialized, precision instruments and included automatic calibration checks. These efforts form a basis for consideration of system vulnerabilities to calibration changes and perhaps data falsification.

Shortcomings of the original TASTEX task effort were identified. These included a lack of data outputs usable by operator and inspector personnel. The JASPAS was initiated to follow up on the TASTEX program. This program has addressed the interface of data to the inspector. In this sense, it addresses alarms, resolutions, and reporting for an applied process monitoring task.

The monitoring work at Tokai is clearly the best-developed example of process monitoring for international safeguards application, and considerable attention should be given to this effort in development of a general process monitoring concept for international application.

4.3 ALLIED GENERAL NUCLEAR SERVICES

Another major development for process monitoring was provided by the AGNS staff at the BNFP in South Carolina. This group was motivated primarily by process control and domestic safeguards concerns and subsequently developed a number of software capabilities which were labeled process monitoring.

The AGNS effort recognized that the focus of attention for international safeguards was 8 kg of plutonium. Domestic safeguards within the United States was evolving a focus of attention at a level of 2 kg of plutonium. In this sense, performance criteria were established for the various tests applied. For example, a specific test was developed to be responsive to an "abrupt" removal of 8 kg from a specific plant area.

Initially, the AGNS efforts were directed at the plutonium-nitrate storage area of the plant and were parallel to the INEL/TASTEX/JASPAS effort. However, later tests, associated with the mini runs of 1980-1981, began development of process monitoring for process areas of a typical reprocessing plant.

Most of these monitoring activities were in response to domestic safeguards functional objectives and as such were part of the operations software system. However, the demonstration of capabilities resulting from these process monitoring activities at the BNFP were indicative of the capabilities that could be expected in international application. Many of these monitoring functions were closely coupled to the development of near-real-time accounting.

4.4 OAK RIDGE NATIONAL LABORATORY

Another major process monitoring development resulted from ORNL/CFRP effort. This effort was originally focused on a mathematical formulation for process monitoring with the principal functional objective being to identify unusual process occurrences. The methodology was developed and documented (see bibliography) and tested during the so-called miniruns at the BNFP.

This effort was unique relative to other process monitoring activities because of the significant attention given to development of mathematical models for analysis of process data, parametric test definition, and identification of alarm conditions and measures for alarm resolution. Again, however, this process monitoring effort focused primarily on domestic application with little concern directed to use in international safeguards.

The CFRP effort involves continuing tests of monitoring concepts in a reprocessing plant test facility at ORNL. This work includes testing of some specialized instrumentation that might be used for monitoring, such as liquid in-line monitors, radiation monitors, and flow meters.

An additional effort from ORNL staff was an assessment of the implications for reprocessing plants of the USNRC's proposed material control and accounting (MC&A) reform amendments. Process monitoring tests were identified that might be employed in a reprocessing facility so that provisions of the reform amendment could be met. That study was completed in 1984.

4.5 U.S. NUCLEAR REGULATORY COMMISSION (USNRC)

The USNRC has for several years been interested in the potential usefulness of the process monitoring for domestic safeguards functions and has commissioned several studies to address potential usefulness of process monitoring. Two of these studies were related to the MC&A reform amendment; they resulted in a broader understanding of domestic applications of process monitoring. Those efforts were the USNRC study of advanced process monitoring for improved material control and the ORNL assessment of implications for reprocessing plants resulting from the MC&A reform amendment.

The USNRC has established definite performance criteria in its proposed domestic regulations. The studies mentioned define functional objectives for process monitoring tests to meet the objectives. In many cases, specific logic structure and test parameters are identified. The studies also identify specific data requirements for many tests.

The USNRC effort is, of necessity, focused on domestic safeguards. The domestic safeguards studies do not consider diversion possibilities at the state level. As such, the USNRC effort does not address vulnerabilities or resource requirements for an international safeguards application of process monitoring for safeguards. In research sponsored by the USNRC through Pacific Northwest Laboratories, the USNRC has investigated alarm mechanisms and response. The question of process monitoring in a regulatory environment, in terms of alarm reporting, has not been extensively evaluated.

4.6 INTERNATIONAL ATOMIC ENERGY AGENCY

The remaining significant efforts on process monitoring were associated with studies and documentation developed within the IAEA specifically relative to reprocessing plant safeguards. The conceptual approach described in STR-140 and some of the technical provisions that were acknowledged in STR-151 recognize the potential usefulness of process monitoring and give examples of potential application without fully developing the concept. Certainly, precedence for consideration of process monitoring in these papers was established by the Safeguards Advisory Group on Safeguards Applications (SAGSI) advisory group report in 1978 and through the efforts of the International Working Group for Reprocessing Plant Safeguards. These documents help define and structure process monitoring as a C/S concept for international safeguards applications.

4.7 OTHER EFFORTS

Numerous other efforts identify process monitoring as a potentially useful safeguards concept, and these other efforts provide some examples, but they do not give substantive detail to a particular process monitoring concept. The joint studies by Los Alamos National Laboratory and Sandia National Laboratory on integrated safeguards concepts for international safeguards at reprocessing facilities recognize the availability of useful information from process data and from specialized instruments installed for specific monitoring functions. In most cases, these studies assign a functional responsibility to the process monitoring system for ensuring the integrity of material-accountancy functions.

In particular, Sandia National Laboratory developed a closed-loop control system for a plutonium product area of a reprocessing plant. This closed-loop system featured a process monitoring application and active interlocks on solution handling equipment. It was demonstrated at the BNFP. The closed-loop control system was recognized as inappropriate for international safeguards because of the active nature of the control system. However, the concept was expanded for an "open-loop" control system that removed the active control on equipment and exploited the process monitoring capabilities for international safeguards.

In addition, efforts within the Federal Republic of Germany and the Japanese reprocessing programs have identified the use of process data for safeguards as a viable concept and have given some limited description of how that process monitoring concept might be incorporated into the overall safeguards system. Again, however, there is insufficient detail to permit comparison of these approaches with some of the more significant efforts previously described.

5. SUMMARY

There is almost universal recognition of the potential usefulness of data from the process for international safeguards whether the data are from operator control instrumentation or from specialized instrumentation. The precise nature of the functional objectives and the mechanisms and logic structure by which those objectives are implemented are not fully defined in any particular application. Table 5.1 shows the major efforts and the basic elements of a total process monitoring application that was addressed by specific programs. Furthermore, there is very little practical experience that will permit generalized statements about the quality of process data relative to the safeguards application. Consequently, there has been very little effort associated with alarm definition, methodologies for resolving alarms, and evaluations of resource requirements associated with implementing a fully developed process monitoring system.

This document is to summarize only those few practical attempts to demonstrate process monitoring for safeguards. It should be noted that process monitoring requires extensive computerized plant data acquisition capabilities. This capability does not yet exist in many operating facilities. As process monitoring for safeguards matures, each of the basic elements identified in this report should be addressed. Potentials of process monitoring for safeguards and its role in international safeguards are only beginning to be developed.

Table 5.1. Basic elements of a process monitoring application addressed by major programs

	Functional objectives defined	Logic structure test parameters	Data requirements characteristics acquisition	Performance criteria	Alarms resolution, reporting	Vulnerabilities	Resource requirements
INEL		X	X			X	
TASTEX	X	X	X			X	
JASPAS	X	X	X		X	X	
AGNS	X		X	X			
ORNL	X	X			X		
USNRC	X	X	X	X	X		
IAEA				X		X	

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Appendix

ABSTRACTS AND EXCERPTS FROM MAJOR PUBLICATIONS ON PROCESS MONITORING FOR REPROCESSING PLANT SAFEGUARDS

This appendix includes abstracts or excerpts from several publications reporting programs with significant efforts in the area of process monitoring for safeguards in reprocessing plants. These items are included to provide general descriptions of the specific work done by these groups. It was decided to use these excerpts to describe the work using the words of the actual investigators rather than to paraphrase or otherwise interpret the effort. As such, the appendix includes copies of pertinent sections of the subject reports. We apologize for the quality of some of the reproductions, particularly the cover pages that are included to show document numbers. The appendix is not meant to be inclusive of all documents in the bibliography. It is intended to show documents that are representative of the work.

ENICO-1126

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PROCESS INSTRUMENT MONITORING FOR SNM SOLUTION SURVEILLANCE

By
C. M. Armatys
C. E. Johnson
E. P. Wagner

February 1983

EXXON NUCLEAR IDAHO COMPANY, Inc.

PREPARED FOR THE
DEPARTMENT OF ENERGY
IDAHO OPERATIONS OFFICE
UNDER CONTRACT DE-AC07-79ID01675

I. INTRODUCTION

Safeguards tests and evaluations at the Idaho Chemical Processing Plant (ICPP) operated by Exxon Nuclear Idaho Company (ENICO) are evaluating the use of process instrument data for safeguards surveillance; in particular, the data are being considered as a means of providing assurance of special nuclear material (SNM) containment during the intervals between material balances.

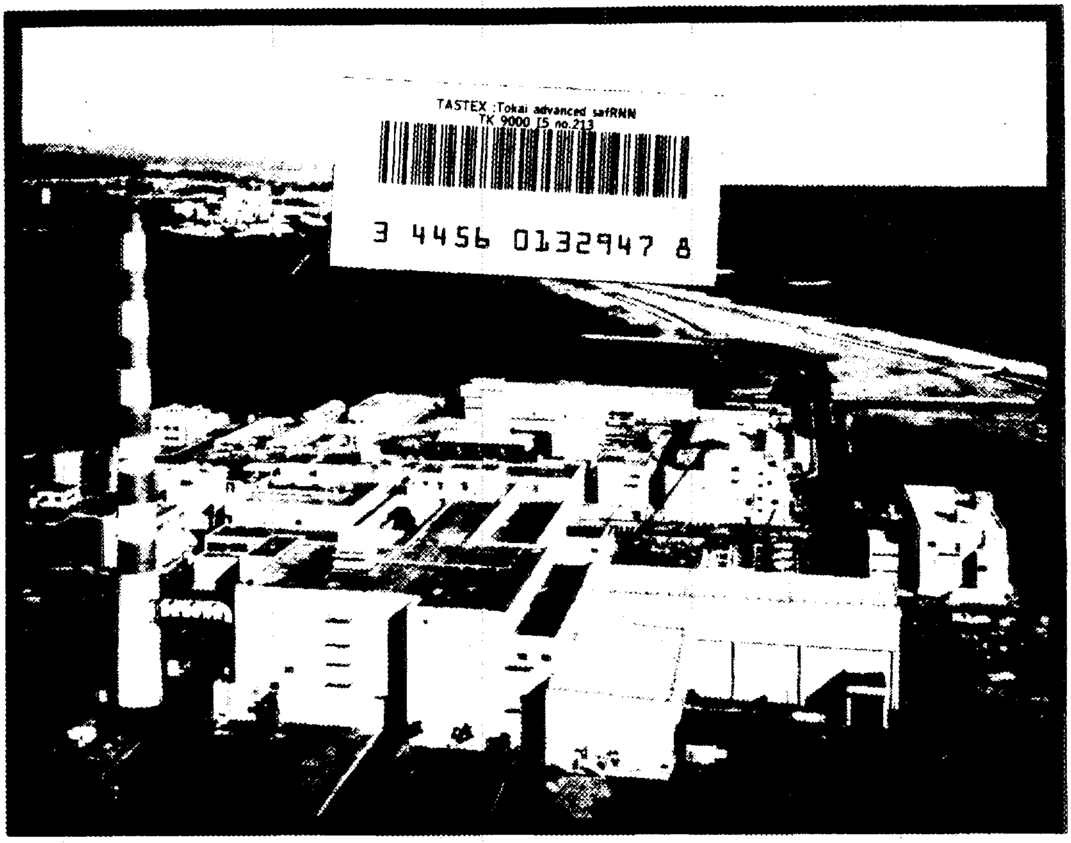
Tests show that several levels of monitoring can be applied, depending on the level of assurance required. A minimal system automatically records plant instruments used for accountancy measurements (such as electromanometers) to record bulk measurement of solution movements through accountability tanks. A second level of assurance is provided by adding past chemical analysis information from process samples to historical data to calculate past SNM mass movements between process areas. The highest level of assurance is obtained by using continuous observations of all process solutions containing SNM and using IAEA verified, on-line analysis instruments to provide a near-real-time measurement of SNM distribution in a facility. However, the on-line analysis instrument technology cannot currently achieve laboratory analysis accuracy, although improved technology is being demonstrated for on-line product solution measurements at the Tokai reprocessing plant using on-line K-edge densitometry and gamma analysis (Reference 5).

The IAEA has evaluated near-real-time materials accounting as a technique to shorten the accountancy interval (Reference 6). The full implementation of that technique would require additional IAEA inspectors and analyses that would significantly strain the limited IAEA resources. In comparison, the automated technique being evaluated in this study could approach the accuracy of near-real-time accountancy measurements without the required presence of the IAEA inspector. Rather, the measurements would be considered to be estimates, to be confirmed by less frequent observed measurements and by material balances performed in the presence of an inspector. Reference 6 acknowledges the benefit of the inspector's presence for collecting "corroborative data which can be used to provide approximate verifications." The automated system can collect even more confirmatory data, depending on the degree of assurance required, to support both the estimates and accountacy measurements.

The concept being evaluated at ICPP is near-real-time material estimating as a containment-surveillance measure to complement accountancy measurements. The assurance provided by SNM solution surveillance should alleviate the near-term requirement for more frequent material balances. The potential exists for ultimately increasing the interval between material balances as confidence is gained in the method's ability to confirm SNM containment. To test this surveillance method, basic systems have been implemented at both the Tokai reprocessing plant and the ICPP. There are no technical barriers to implementing the monitoring system, collecting and analyzing the data, or maintaining transparency to plant operators or production. Yet, some political questions have been raised regarding compliance with INFCIRC 153 (Reference 1):

- the minimum amount of necessary information
- the degree of instrument verification needed
- the possible disclosure of nationally sensitive or company proprietary information

The first two reservations depend directly on the amount of assurance required by the IAEA. Additional monitoring points or additional instruments can be added to provide a system increasingly more difficult to compromise or mislead. The question of disclosing sensitive or proprietary information would usually only apply for analyses of chemical compositions. To resolve this potential difficulty, it is possible to retain process data within the monitoring system installed in the specific facility such that detailed process data of a proprietary or sensitive nature would not leave the facility. Generalized tests could then be performed on the data and conclusions communicated to the reviewing inspector without directly disclosing detailed data. In all cases, the specific requirements for each monitoring point and for the associated information would be negotiated in the respective Facility Attachment: this would, thereby, alleviate concerns of the host facility.



TECHNICAL REPORTS SERIES No. 213

TASTEX

Tokai Advanced Safeguards Technology Exercise

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA 1982

24

Task I
Product area monitoring system

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5. ASSESSEMENT OF RESULTS IN TERMS OF MEETING PURPOSE

The task I system was developed at the INEL and at the PNC plant and has accomplished most of the desired objectives for an effective monitoring system. These include basic data collection and data storage for the major plant sensors in the Pu storage area, real-time displays for the plant data, real-time print-outs of operational changes, and the capability to playback historical data for the preparation of data listings, graphical plots, and summary reports. The data are of immediate potential use to the plant operators, and the potential use for IAEA inspector applications is still under development.

6. CONCLUSIONS

It is believed that the task I system has considerable potential for enhancing the effectiveness of IAEA safeguards at the Tokai plant. The main elements of potential contribution to safeguards are listed below.

(a) The task I system can form a basis for improved monitoring of the Pu product area. Analytical laboratory density and isotopic measurements (verified via task G or task H instrumentation), together with task I observation of Pu solution evaporation characteristics and other task I measurements, can permit the assessment of Pu product quantities in the Pu product area on a near continuous basis (near real-time or post-analysis via historical data playback).

(b) The task I system produces an historical data base which may be used to monitor operations and prepare accountability-type summary reports relative to:

i) new product batch inputs into the Pu product area;
ii) current Pu product inventory at any specified time; and
iii) Pu product load-outs from the Pu product area.

(c) The recorded plant digital state changes, together with the recorded analogue signal changes, can be used for operations surveillance monitoring to verify that specified operations are performed in a satisfactory and expected manner. This surveillance activity can be performed initially via manual analysis of the data with the potential for adding future capabilities for computer aided analysis.

Excerpt from *The Tokai Works Annual Progress Report*, PNCT NB31–82–01, September 1982.

V. Product Area Monitoring System (TASK-I)

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Shigeru IHARA, Shigeru OHTAKE
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The product area monitoring system consists of a desktop computer located in the plant operations control room, four instrumentation cabinets located behind the plant control panel, and two instrumentation boxes located in the plant access area. Approximately 200 sensor signals for the tank levels, densities, temperatures, and transfer operations in the plutonium product storage area are input for the Task-I system, which includes high precision electronic manometer measurements for the plutonium product accountability tank and the seven product storage areas. The system monitors the material entering and leaving the product area, transfer operations within this area, and the amount of material currently in storage. The computer is provided with real-time displays and print-outs which present the product area status, and historical data files are maintained from which an operator may prepare summary report listings and graphical plots of selected data via data playback. A general block diagram of this system is illustrated in Figure 8.

The functions of this system are listed below.

(1) Monitoring the tank volume

i) Liquid level and density on the plutonium product accountability tank and seven plutonium product storage areas, which are the most important for accountability, are measured by Digiquartz high-precision pressure transducers. A typical example of the product solution level data for accountability tank 266V23 is presented in Figure 9. The error is estimated at ±0.026% of effective measurement range.

ii) Liquid level and density in almost all tanks are measured by the 64-channel scanivalve multiplexer subsystem.

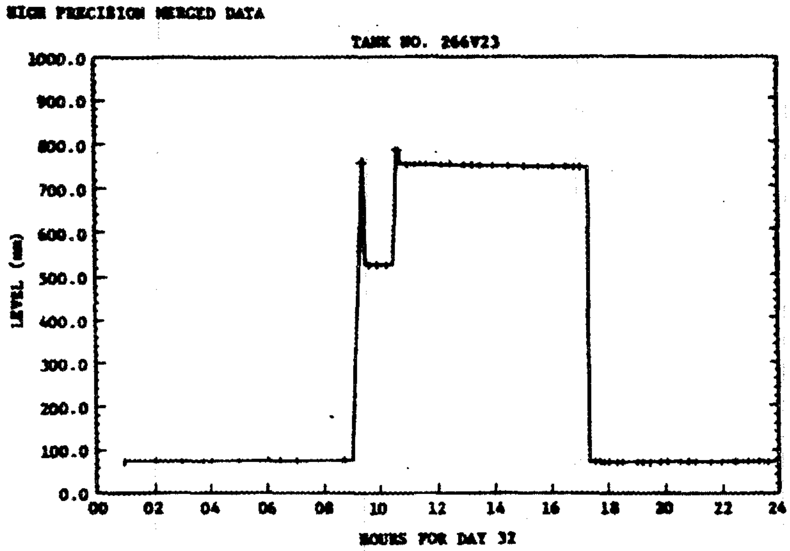

Fig.9 266V23 Level Data Plot for a Typical Product Batch

These data were compared with the plant control panel chart recording data. The error of the dp transmitters is within ±1% FS with chart recording compensation adjustment, and the error of 64-channel scanivalve is within ±0.1% FS at calibration temperature. A typical example is presented in Figure 10.

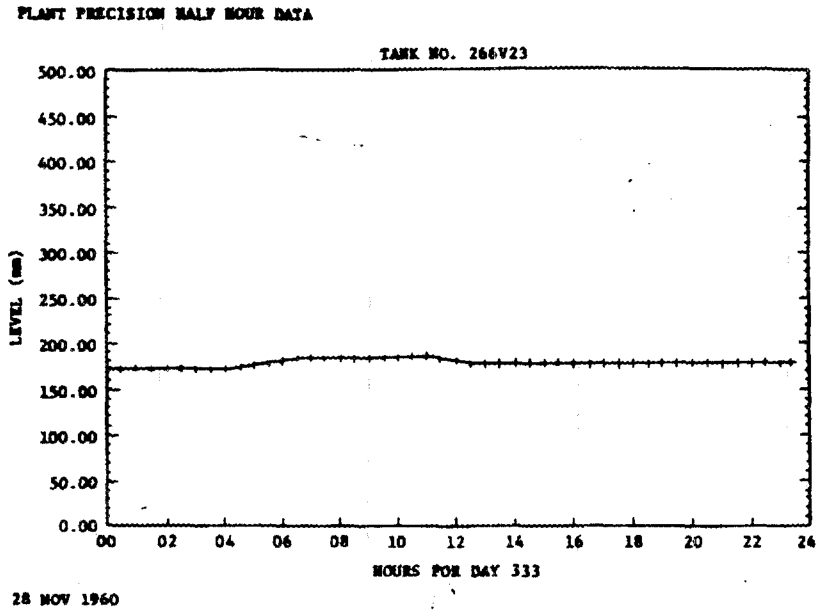

Fig.10 266V23 Level Data Plot

(2) Another anolog signals measurements (temperature).

(3) Plant digital signals are monitored for all major transfer valves, pumps, sample transmission sensors, electrical power status sensors and so on. A typical example is presented in Figure 11.

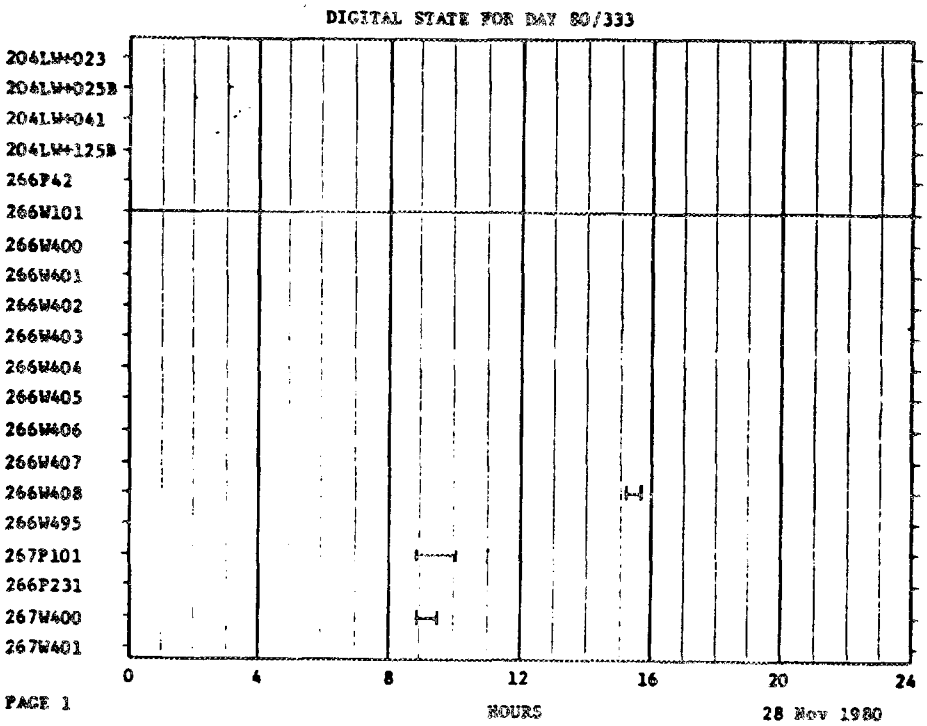

Fig.11 Digital State for Day 80/333

(4) Verification and Calibration features — In addition to the plant sensor signals, there are instrumentation sensor input signals which provide certain temper indicating and calibration features.

Field tests of the Task-I system are continuing, and most of desired objectives for an effective monitoring system are being accomplished. Futher development is required to expand the software to provide a summary report capability for all major operations within the Pu product storage area, including temper indications.

JASPAS
1983/84

JAPAN SUPPORT PROGRAMME FOR AGENCY SAFEGUARDS

ANNUAL REPORT

MAY 1984

SCIENCE AND TECHNOLOGY AGENCY
JAPAN

Project JA-3

Title: PLUTONIUM PRODUCT AREA MONITORING SYSTEM

Executing Institution:

Power Reactor and Nuclear Fuel Development Corporation (PNC)

Objective:

The purpose of this project is to develop computer-aided real-time Containment/Surveillance system of the Plutonium Product Area in Tokai Reprocessing Plant to be applied to the routine inspection work.

Activities and Results:

(1) General

This system had been developed under the TASTEX Program (Task-I), and included to JASPAS Program in July, 1982. Efforts to improve the hardware functions of prototype JA-3 system, had been made until March, 1983. After April 1983, efforts to develope the design and to establish the technical specification for the system adequate for inspector's use, including the modification of existing system, have been endeavoured.

(2) Progress of the design and specification of inspection usable system

The outline of the final inspection usable system was decided and examination on some detail specification of this system was advanced.

1) Inspector's terminal

It was adopted as a principle of design that the installation of inspector's terminal which is not directly connected to the existing on-line terminal but allows the inspector to analyze hand-carried data.

Only selected fraction of the whole data collected at the on-line terminal is transferred to this terminal via magnetic media.

2) Selection of the inspection data

Selection of the minimally required data for inspection purpose among the whole data of on-line terminal was performed.

Reduction of the number of data to be provided for inspector from the prototype JA-3 system was necessary to make efficient and for the simplification of the system.

3) Improvements of the existing hardware system

Some modification for design, especially for scanivalve system were examined to enhance the reliability of the hardware functions, because of the experience obtained through the operation of the existing system and the results of the test of new valves.

(3) Continuous test operation of the existing system

Long term operation to check the reliability of the existing system has been carried out for one year. Some malfunctions related on the scanivalve functions were observed, which were not so significant and were improved.

(4) Other technical examination

Density estimation model which enables the estimation of the density of evaporation Pu solution was examined.

(5) Others

Joint meeting between PNC, IAEA and INEL (under joint task of JASPAS and POTAS) were held in September and December, 1983, to examine the detail of the development.

<u>Funding</u>:

FY 1983 - ¥18,646,000

¥ 1,809,697 (for the cost of invitation of IAEA personnels)

<u>Schedule (for FY 1984)</u>:

(1) Decision of the final design and specification of the inspection use system

(2) Decision of modification of the existing system

(3) Restructure of the existing equipments and software program

(4) Other developments on density estimation model, etc.

International Atomic Energy Agency

Department of Safeguards STR-140

AN ADVANCED SAFEGUARDS APPROACH FOR A MODEL 200 T/A REPROCESSING FACILITY

Part I: Description and Discussion

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October, 1983

EXECUTIVE SUMMARY

The study of near-real-time materials accountancy as a potential advanced safeguards concept for the PNC-Tokai reprocessing facility began in 1978, under the TASTEX programme. Initial studies were based on computer modelling, but actual field test data were collected during 1980 and 1981. These studies clearly demonstrated that n.r.t. accountancy was feasible, and that it would produce meaningful safeguards accountancy data.

N.r.t. accountancy alone is not a complete safeguards approach, first because it is based on operator-generated measurement data, which data must be verified if it is to be used in IAEA safeguards, and second because it is generally applicable only in the process MBA, where bulk processing operations occur. This report describes an advanced safeguards approach which has been developed for a model 200 t/a reprocessing plant, using n.r.t. accountancy in the process MBA, and borrowing advanced ideas from TASTEX, the IWG-RPS, or the authors own invention for the spent fuel storage and plutonium nitrate storage MBAs. Chapters 2 through 6 discuss the basic diversion scenarios, describe the advanced approach and discuss the various ideas which have been incorporated into it. The authors acknowledge that not everything described has been constructed and tested in the specific form recommended, but they also argue that everything proposed has been developed and tested in sufficient detail to justify an assumption that the extrapolations required will also work as desired.

In the spent fuel storage MBA primary reliance is placed on 100% inspector observation and verification of all spent fuel receipts, and on surveillance measures to ensure that the inspector is aware of all receipts or shipments in the spent fuel cask receiving bay. Spent fuel assemblies, or pins removed from spent fuel assemblies, cannot be diverted except through the use of shielded casks which must move through the receiving bay. Thus control of this critical strategic point effectively assures a high detection probability for a wide variety of diversion scenarios involving spent fuel assemblies or pins.

The advanced safeguards approach gives more detailed consideration to the mechanical or chop-leach cell than most conventional approaches. If both dissolvers (or all dissolvers in a more general model) are operating more or less in accordance with design, there are only limited diversion possibilities. If one or more dissolvers are declared to be temporarily out of service, however, then there are additional possibilities related to the unreported dissolution of fuel pins or assemblies diverted from the storage MBA, or to the unreported dissolution of chopped pieces accumulated from reported dissolutions. In all cases the intent of the unreported dissolution would be to transfer plutonium to the process MBA without the knowledge of the IAEA, in order to conceal a subsequent diversion of plutonium nitrate solution from the process MBA. To protect against these possibilities, the advanced approach suggests, among other things, the use of remotely verifiable electronic seals on dissolvers declared to be out of service.

Safeguards in the process MBA are based, as noted, on near-real-time materials accountancy. The n.r.t. accountancy model used assumes weekly in-process physical inventories of solution in four buffer storage tanks and one recycle tank. Inventories are timed to coincide with emptying of the product evaporator, eliminating the need to measure plutonium in the evaporator, and solvent extraction system inventory quantities are estimated based on a simplified model which assumes that a steady-state equilibrium exists.

Isotope correlations and other data comparisons are described which would detect any attempted gross data falsifications; conventional independent analysis of verification samples is used for the detection of small measurement biases. Data thus far available are not sufficient to permit a precise definition of detection sensitivity, but the simulation and field testing studies clearly indicate that the IAEA's goals of 8 kg Pu in 1-3 weeks (abrupt), or 8 kg Pu in one year (protracted) would be met or exceeded.

A reference system of conventional materials accountancy based on cleanout physical inventories at six month intervals is also included.

The safeguards approach suggested for the plutonium nitrate storage MBA is not significantly different from conventional approaches. Conventional materials accountancy based on six month physical inventories is used as a reference system, and a variety of seals, on-line volume monitoring systems, and occasional verification samples are used to ensure detection sensitivity and timeliness.

Safeguards for uranium are briefly discussed, largely because of the corroborative information such safeguards measures can provide.

Chapter 7 describes a summary estimate of inspection effort likely to be needed to implement the advanced safeguards approach, based on two alternative assumptions, one being full capacity operation, the other being operation for 200 days at 0.4 t/d, an approximation to 50% capacity operation. For full scale operation the estimate is 3594 man-hours per year, which the report translates into 599 man-days. For 50% capacity operation the comparable figures are 2126 man-hours, or 354 man-days. These estimates are generally comparable to current actual inspection practice at the PNC Tokai reprocessing plant, but the advanced safeguards approach is claimed to provide significantly increased detection sensitivity and timeliness.

Chapter 7 ends with a caveat which deserves repetition here. Many of the verification procedures depend significantly on "continuous inspector knowledge". It is doubtful if this continuous inspector knowledge can be satisfactorily achieved if inspection effort is rotated among a group of 20-30 inspectors, none of whom ever remains at the facility for longer than a week or so at one time.

The use of sequential statistical techniques for the analysis of n.r.t. accountancy data requires a significantly different philosophical approach to anomalies and anomaly resolution. Specifically, tests are first used in a manner which has a significant probability of responding not only to diversion but also to measurement biases and other "innocent" effects. If tests applied in this manner detect no anomalies, then a high degree of assurance can be given that diversion has not occurred. The converse, that anomaly detection suggests a high probability that diversion has occurred, cannot be accepted. Instead, procedures are described for the evaluation and resolution of anomalies, in particular those resulting from measurement biases. As these biases are identified and corrected the probability of their continuing to affect the statistics decreases, and the degree of assurance of non-diversion increases. Chapter 8 summarizes anomaly resolution procedures, at least through the earlier stages. Since anomaly resolution is highly dependent on the exact nature of the observed anomaly(ies), only general procedures can be given.

A companion report, STR-141 [17], assessing the effectiveness of the proposed advanced safeguards approach using the Safeguards Effectiveness Assessment Methodology described in STR-122 [18], is in preparation.

The authors are pleased to note that the report is being published jointly in Vienna, identified as IAEA report STR-140, and in Japan, identified as JAERI-M 83-160 or PNCT N141 83-02.

D R A F T

STR-151
Wang No. 0192r
1984-07-20

NUCLEAR MATERIAL SAFEGUARDS
FOR
REPROCESSING

Current Status and Problems

System Studies Section
Department of Safeguards
International Atomic Energy Agency
Vienna, Austria

(final report date)

D R A F T

13. PROCESS MONITORING

Process, or operations, monitoring is an expression which means many different things to many different people, and which frequently brings forth immediate objections to any consideration whatsoever. Most versions, while conceptually offering safeguards advantages, require extensive inspector access to process information, and for that reason are unlikely to gain Member State acceptance. Failure to recognize that the falsification of process information in a meaningful manner is a complex problem, coupled with a corresponding insistence that all process data used for safeguards must be extensively tamper-protected and verified, also tends to cause process monitoring proposals to appear highly intrusive and not necessarily highly effective.

In the studies leading to the advanced safeguards approach a much more modest goal was considered. Specifically, it was noted that plutonium cannot be diverted from the process area of a reprocessing plant without diverting a volume of solution, and the question was asked whether it might be possible to define a carefully limited number of monitoring points which would be capable of providing redundant confirmation that solution volume was or was not disappearing in an unexplained manner. A significant positive MUF associated with an apparent disappearance of solution would constitute a serious anomaly requiring immediate and careful investigation; a significant positive MUF not associated with missing solution would be less serious. Missing solution not associated with a positive MUF would not constitute an anomaly at all and would be investigated only in terms of its potential effect on the detection capabilities of safeguards.

This work is far from complete. However, in the reference PNC-Tokai facility it was possible to define some fifteen process points which it would be useful to monitor. These points relate primarily to volume (level) recorders for all buffer storage tanks, flow meters on lines leading into and out of these tanks, and the level recorder on the product evaporator. The suggestion in STR-140 was that data from these process points would feed directly into an IAEA-controlled micro or mini computer which would compute and maintain solution balances for the major buffer tanks. These tanks are affected to some extent by additions of acid or other chemicals which would not be monitored. However, the volumes which must be removed as part of a diversion attempt are large compared to normal process variations, especially if the assumption is abrupt or semi-abrupt diversion. Observations related to solution volume probably would not be meaningful in terms of the limiting protracted diversion of 200 grams Pu per week or so; the corresponding solution volumes would be in the range of 50-100 litres and process instrumentation is not expected to be sufficiently accurate. Nevertheless, the absence of any discernible trend should be useful corroborative evidence that diversion is not occurring.

SAND79-0484

Specified Distribution Only

Operations Monitoring

August E. Binder

Sandia Laboratories

SF 2900-Q(7-73)

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Specified Distribution Only
Printed February 1980

OPERATIONS MONITORING

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Sandia Laboratories

ABSTRACT

Systems of operations monitoring (OM) are examined for application to future international safeguards activities. Operations monitoring is defined as the monitoring of process functions (i.e., valve position, pneumatic pressure, control voltages, glove port access), but not including NDA measurement of materials. Operations monitoring is related to but contrasts with the "closed-loop" controls proposed for domestic safeguards applications, which are integrated into the management of a plant. For international safeguards, operations monitoring is an "open-loop" function that does not apply immediate or physical control to nuclear material. The relationship of OM to systems of timely monitoring of nuclear material by NDA techniques is also described.

Different operating modes and other factors affecting the potential use of OM by the IAEA are described. Several levels of techniques for verification and limits to verification imposed by the design and operation of the facility are discussed. The need to initiate testing of an OM system at a pilot plant is identified.

ORNL/TM-7848
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Consolidated Fuel Reprocessing Program

EXPERIMENTAL DEMONSTRATION OF MICROSCOPIC PROCESS MONITORING

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Date Published: January 1982

NOTICE This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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UNION CARBIDE CORPORATION
for
DEPARTMENT OF ENERGY

ABSTRACT

Microscopic process monitoring (MPM) is a material control strategy designed to use standard process control data to provide expanded safeguards protection of nuclear fuel cycle facilities. The MPM methodology identifies process events by recognizing significant patterns of changes in on-line measurements. The goals of MPM are to detect diversions of nuclear material and to provide information on process status useful to other facility safeguards operations.

SUMMARY

Measurement technologies for process control and other operational applications have improved considerably in the last several years, especially in the degree to which data from process instrumentation is accessible by computer. The potential safeguards applications of this type of process instrument data have been widely recognized. A safeguards strategy, based primarily on the data from process control instrumentation called microscopic process monitoring (MPM), has been developed for reprocessing plant applications at the Oak Ridge National Laboratory.

A broadly based microscopic process monitoring system would provide maximum flexibility in detecting diversions by helping to identify anomalous process conditions and events that would indicate a diversion. A large quantity and variety of measurement information would also maximize the tamper-indicating capabilities of the system if suitable relationships between the measured parameters could be found. The MPM procedure provides a means for direct inclusion of all types of process data in the decision-making process. To make use of such data, a process monitoring methodology must exploit correlations between various measured parameters and the status of the nuclear material in the process. As the name "microscopic" implies, the MPM methodology is based on local correlations between a small number of process variables over a short period of time, thus avoiding the complexity of modeling wide-range or long-term correlations. Microscopic process monitoring is not a material accounting strategy and does not depend on material balance concepts over large areas of the plant.

The first step of the MPM technique is to predict a future value for each measured variable. Linear extrapolations and volume conservation equations are used for most MPM predictions. Even with frequent updating, the individual models used in MPM are not usually versatile enough to accurately predict future values. Fortunately, it is possible to assemble a set of simple models such that some of them will generate reasonable predictions at any particular time.

Each process variable measurement is then compared with one or more corresponding predictions. Specifically, the measured value is subtracted from the predicted value, and the difference is divided by an uncertainty factor. The uncertainty factor reflects the combined effect of the uncertainty of the measurement and the uncertainty of the prediction.

For each comparison between measurement and prediction, a unitless discrepancy statistic, denoted Z, is calculated with the following formula:

$$Z = \frac{X - Y}{(s_x^2 + s_y^2)^{1/2}} ,$$

where

X = the predicted value of a variable,
Y = the measured value of a variable,
s_x = the uncertainty of the prediction,
s_y = the uncertainty of the measurement.

This statistic is a fair measure of the significance of the difference between observation and expectation.

The MPM methodology bases safeguards decisions not on the values of the individual z statistics, but on the value of an event statistic called r. When a particular event occurs, that is, a diversion or a batch transfer, it tends to generate a distinct pattern of nonzero z statistics which are combined into a unique value of r corresponding to that event. Hence, the MPM methodology permits identification of normal process events; other events are interpreted as possible diversions.

During FY 1980 and FY 1981, the MPM concept was tested at the Barnwell Nuclear Fuel Plant (BNFP) in Barnwell, South Carolina. The plant has not yet been licensed to process spent nuclear fuel; however, cold operation with natural uranium is permissible. For the MPM experiments, the plutonium extraction and purification cycles of the BNFP were operated with natural uranium feed solution for six 7-day periods, and data from 52 on-line process measurements were analyzed and recorded. Controlled diversion experiments were conducted during the periods to test the abrupt diversion detection sensitivity of MPM. Volumes of 1, 2, 5, 10, and 20 L were removed from some of the tanks used in the demonstration. In all cases, the solution was removed from the tanks as rapidly as possible.

The BNFP experiments clearly demonstrated that MPM can be implemented in a large reprocessing plant on a standard minicomputer system. No fundamental problems were encountered in accomplishing the rapid and frequent data acquisition required for MPM. The experiments concentrated on the detection and identification of abrupt process phenomena, that is, those that cause a measurable change in process parameters within 8 min. No attempt was made to address protracted diversions. Data were compiled on the sensitivities and false alarm rates associated with these types of identification. In general, the detection sensitivity was found to be dependent on the mode of operation of the tank (i.e., static or constantly filling or emptying) and the accuracy of the instrumentation. The MPM technique proved successful in identifying abrupt diversion and batch transfers.

The feasibility of applying the MPM concept in an operating plant has been demonstrated. Future demonstrations will use binary valve and pump sensors to assist in the identification of batch transfers. Further work on slow-event monitoring (protracted diversions, instrument drift, and pulse column events) using MPM is planned. After an optimum MPM software package has been developed, current plans call for integration of the MPM with dynamic accounting and physical protection to form a comprehensive safeguards system.

AGNS-35900-CONF-131

Distribution
Category UC-83 Special

IN-PROCESS INVENTORY ESTIMATION IN A REPROCESSING FACILITY FOR NEAR-REAL-TIME ACCOUNTING

M. H. Ehinger
J. E. Ellis
K. E. Plummer

July 1981

For Presentation at the 22nd Annual Meet INMM
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IN-PROCESS INVENTORY ESTIMATION IN A REPROCESSING FACILITY FOR NEAR-REAL-TIME ACCOUNTING

M. H. Ehinger, J. E. Ellis, and K. E. Plummer

Allied-General Nuclear Services

Barnwell, South Carolina

Abstract

A modern large scale reprocessing facility (1500 MTU/yr) presents a unique challenge to meet current safeguards objectives for timely detection of material losses. For material accounting to be responsive at these throughput rates, frequent material balance closures are required. The limiting factors have been physical costs, downtime and operability constraints of inventories for frequent material balance closures.

An In-Process Inventory Technique (IPI) has been developed and tested at the Barnwell Nuclear Fuel Plant (BNFP) to provide frequent inventories without cost or instrusiveness to plant operability. A computerized measurement system makes available process measurements and process control analytical information. These data are processed to determine the process inventory. The calculation routines use routinely available process control measurements and sample results. The technique requires no shutdown, no special preparations, and no special measurements, or samples. With this technique, hourly inventory frequencies and material balance closures have been achieved during demonstration runs in the 1500 MTU/yr at BNFP. Results show sensitivities of 2 to 5% of the normal process inventory are achievable during normal operations. Recent improvements in data handling routines indicate the technique can be sensitive during transient process conditions as well.

INTRODUCTION

The role of accountancy in nuclear material safeguards in a bulk handling facility is to detect loss or diversion of material balance measurement data. For a spent fuel reprocessing plant, the effectiveness of accountancy in this role has been limited by the necessity to perform a flushout and physical inventory to close the material balance. Economics and plant operability limit the frequency of these inventories to something on the order of twice per year which complies with national regulations but cannot meet international goals for timeliness of detection.

Timeliness goals can be met when material balance intervals can be closed on a more frequent basis. However, this requires an accounting system to provide "near-real-time" accounting reports and a method of measuring plant inventory without the traditional plant shutdown and flushout.

Near-real-time accounting has been accomplished at a number of facilities. At the BNFP, the installed and operable accounting system features computerization of material balance measurement routines and data logging. These routines incorporate direct computer readout of measurement instruments and on-line computer access to analytical laboratory measurement data. The real-time material balance accounting portion has been thoroughly demonstrated.

Development of inventory taking capabilities without shutdown and flushout has been the recent goal at the BNFP to fulfill the timeliness requirements for material balance closures. The technique has become known as "In-Process Inventory."

At the BNFP, the installed computer system includes direct interface to almost 500 process instruments and on-line monitors. Current analytical laboratory measurement data are also available for all process control and accountability sample points. These data are combined for in-process inventory estimation. Demonstrations with the plant operating in a test mode using natural uranium indicate inventory sensitivities in the range of 2 to 5% of normal process hold-up are achievable during routine operations. During test periods process inventory determinations have been conducted as often as once per hour allowing frequent material balance closures for safeguards evaluations.

This has been accomplished under the constraint that only routine process control information is used. There have been no requirements for special inventory preparations, special samples, or special measurements. The procedure is a "snapshot" of current plant activities with no cost or instrusiveness to plant operability.

JOPAG 11.84-PRG-101

Joint Programme

on the

Technical Development and Further Improvement of IAEA Safeguards

between the Government of the Federal Republic of Germany and the International Atomic Energy Agency

TASK A.1

A SAFEGUARDS STRATEGY FOR AN INDUSTRIAL SCALE REPROCESSING PLANT

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Summary

In order to discuss safeguards elements which could form a workable safguards system, an industrial scale reprocessing plant of medium to large throughput is described. The main feature with regard to safeguards is an advanced technology in terms of measurement, control instrumentation and remote maintenance.

The proposed safeguards strategy is carefully adapted to the facility design and supposes conventional material accountancy as a basic measure. It is complemented by containment/surveillance in the headend material balance area taking advantage of the material's properties. To avoid a second shut-down inventory taking per year (which would be totally unacceptable both for operational as well as for commercial reasons) and to provide some assurance of timely detection of diversion, in-process inventory taking during plant operation is foreseen in the process area.

Attention is given to termination of safeguards to wastes which should occur as early as possible in the process.

The proper combination of safeguards elements as described leads to a workable approach which remains flexible with regard to adaption to varying technical boundary conditions of the plant.

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Using Advanced Process Monitoring to Improve Material Control

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ABSTRACT

This report details the work performed by NUSAC, Inc. for the U.S. Nuclear Regulatory Commission under Contract No. NRC-02-79-043-2. The NRC commissioned this work because earlier studies had indicated that material control and accounting could be enhanced by using process monitoring techniques. The purpose of this contract was to perform an in-depth study of process monitoring techniques at different levels of sophistication, each examining the potential use of process monitoring data to improve material control in a high enriched uranium scrap recovery facility. These four levels were:

- Expansion of currently used process monitoring techniques and currently generated data.
- Development of new process monitoring techniques and expanded use of existing techniques, but with no equipment modification, new equipment or process modifications.
- Expansion of currently used process monitoring techniques, development of new techniques, and minor modification of existing equipment.
- Development of new techniques, major modifications to process, and installation of new equipment.

The cost effectiveness for each system was determined by:

- Developing a yearly operating cost.
- Measuring system effectiveness as determined by its ability to meet a set of performance parameters.
- Comparing the incremental cost with the improved effectiveness.

Based on this effort, NUSAC took the most cost effective system and developed it fully, providing complete operating abilities and parameters.

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EVALUATION OF THE IMPACT OF THE MC&A REFORM AMENDMENTS ON A REPROCESSING FACILITY

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ABSTRACT

An assessment was completed on the potential for large reprocessing plants to meet the requirements of the Nuclear Regulatory Commission's proposed Category I Material Control and Accounting (MC&A) Reform Amendment. The requirements on which this assessment was based are given in the working draft revision to the rule dated December 30, 1982. The Barnwell Nuclear Fuel Plant (BNFP) was chosen as a reference design for the assessment, but most considerations would be relevant to any large Purex reprocessing facility. Spent light water reactor (LWR) fuels containing 1% Pu were the presumed feed to the plant; the design feed rate is 5 MTU/d.

The approach taken for the assessment was to characterize the process equipment and the nuclear material distribution throughout the plant, to identify quantities of material that must be removed consistent with loss-detection goals, and to determine if any MC&A techniques could detect the removal. Most of the proposed MC&A techniques had previously been tested, and stated loss-detection capabilities were based on these test results. No attempt was made to construct detailed removal scenarios or integrated MC&A systems throughout the plant.

The assessment addressed three general types of material removals or losses:

1. single space, single time (abrupt),
2. multiple space, single time (abrupt with collaboration), and
3. single space, multiple time (recurring).

With few exceptions, the abrupt loss-detection requirements of the Reform Amendment will be achievable with existing or slightly improved capabilities. Some equipment designs and/or measurement technology improvements will be needed. Recurring loss-detection capabilities will be somewhat poorer than capabilities for abrupt loss detection.

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