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An Evaluation of the DYMAC Demonstration Program (Phase III Report)

by

The Los Alamos Safeguards Subsystems Development and Evaluation Group

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ABSTRACT

An accountancy system based on the Dynamic Materials Accountability (DYMAC) System has been in operation at the Plutonium Processing Facility at the Los Alamos National Laboratory since January 1978. This system, now designated the Plutonium Facility/Los Alamos Safeguards System (PF/LASS), has enhanced nuclear material accountability and process control at the Los Alamos facility. The nondestructive assay instruments and the central computer system are operating accurately and reliably. As anticipated, several uses of the system, notably scrap control and quality control, have developed in addition to safeguards. The successes of this experiment strongly suggest that implementation of DYMAC-based systems should be attempted at other facilities.

I. INTRODUCTION

An accountancy system based on the Dynamic Materials Accountability (DYMAC) System[1-5] began operation concurrently with processing at the new plutonium facility at the Los Alamos National Laboratory in January 1978. Its designer, the Los Alamos Safeguards Subsystems Development and Evaluation Group, began transferring responsibility for operation of the system to the Los Alamos Operational Security/Safeguards Division in late 1979. In early 1980 the system was redesignated the Plutonium Facility/Los Alamos Safeguards System (PF/LASS), and on March 3, 1980, day-to-day operation was placed under the control of the Nuclear Material Data Processing and Measurement System Group. The Los Alamos Safeguards research and development (R&D) groups continue to upgrade the system's nondestructive assay (NDA) instruments and provide maintenance support.

PF/LASS is providing near-real-time knowledge of inventory status and has demonstrated that improved safeguards can be realized by NDA instruments, a central computer, and careful process-control techniques. Two-and-one-half years of operating experience indicate that significant benefits have accrued to the plant management beyond those associated with safeguards. This report outlines the benefits of the DYMAC System to both safeguards and process control interests at the Los Alamos Plutonium Processing Facility.

II. BACKGROUND

A. Safeguards

Safeguarding special nuclear material (SNM) at domestic facilities is the responsibility of two complementary systems: the physical protection system (PPS) and the materials control and accountability (MC&A) system. The PPS consists of fences, gates, guards, and procedures for patrolling and allowing or refusing access to the facility. The PPS is responsible for limiting facility access to authorized personnel and for allowing only authorized transfer of SNM across a facility boundary; these responsibilities are exercised primarily at the facility perimeter. The MC&A system consists of measurement instruments, computers, and a set of procedures to provide timely, detailed knowledge of the whereabouts of the SNM. The MC&A system is responsible for the SNM while it is in the facility. This system (1) defines procedures for controlling movement of material, (2) monitors adherence to these procedures, and (3) provides data for detecting diversion of SNM. In case of an actual or claimed breach of the safeguards system, the MC&A system has a number of responsibilities that include (1) assessing the validity of a claim, (2) providing a description of the missing material, (3) determining the time period during which material was diverted, and (4) identifying material custodians.

Accounting of SNM at the Los Alamos National Laboratory has a long history dating back to the middle 1940s. In 1962, Christensen et al.[6] developed an automated processing system to improve SNM accounting at Los Alamos and at the same time to provide process data. They assumed that good accounting data are also good process control data. Punched cards of 80 columns were coded with information detailing each transfer of SNM between unit processes. The cards were sorted on an IBM 083 sorter and further processed on an IBM 1401 computer. This system was used at the former Los Alamos plutonium facility. Because of the 80-column limit, certain operating procedures such as round-off rules were developed; these procedures are still in effect. The high state of development of SNM accounting at the former plutonium facility contributed significantly to the success of the DYMAC application at the new facility, although some aspects of this accounting approach are more encumbering than might now be necessary.

B. Principles of DYMAC

The concepts of a DYMAC System have been espoused on many occasions (see Refs. 1-4) but have never been reported in any one document. Briefly, these concepts require adoption of the following principles.

1. The processing plant is divided geographically into nonoverlapping, contiguous materials balance areas (MBAs), each of which is divided into unit processes. No area of the plant where SNM may reside is excluded. Each unit process is completely contained within one MBA.
2. Each item of SNM is assigned a unique name. A central computer keeps track of each item by its name.
3. No material crosses a unit-process boundary or changes chemical character without a transaction being performed to update the book inventory that resides in the central computer.
4. Measurements are made in near-real-time on each item as it enters and as it leaves a unit process. All items, even waste and scrap, are measured.
5. All measurements are made nondestructively with instruments that are certified daily by comparison to standards traceable to the National Bureau of Standards.

6. All NDA instruments transmit measurements directly to the central computer without process-technician intervention.
7. Two persons are always involved in the transfer of an item from one unit process to another: one person to measure and send it, the other to receive and measure it. The sender and receiver may together perform a measurement on a single instrument to satisfy this requirement.
8. The person who makes a measurement is responsible for making the related transaction. Transactions must be made immediately upon transfer of an item or a change in its chemical character.
9. A Nuclear Materials Officer (NMO) is responsible for accountability of all the SNM in the plant. The NMO reports to an organization that does not have immediate responsibility for plant production.

   The effectiveness of a DYMAC System depends on the effectiveness of the NMO. However, the NMO cannot be effective without timely and reliable data concerning the SNM content and location of every item in the plant. A DYMAC System can and must supply this information.
10. The accounting system and associated records must be auditable in the usual sense; for example, it must be possible to develop a detailed history of the passage of an item through the facility.

C. Principles of PF/LASS

The Los Alamos plutonium facility system does not embody all of these DYMAC principles. Several compromises were necessary. Some were made in the interest of process efficiency; others were made because fulfilling all of the DYMAC precepts was not technologically possible. Thus, it is appropriate to differentiate the conceptual system (DYMAC) from its application at the plutonium facility (PF/LASS).

The main features of PF/LASS as documented in the DYMAC Phase II report[5] are listed here. PF/LASS is a system for near-real-time accountancy of SNM. The system incorporates NDA instrumentation--some on-line, some off-line--for analyzing and verifying SNM content with a set of instructions for handling and measuring SNM as it passes through the facility. Thirty-six digital electronic balances,[7,8] other NDA instruments,[9-16] and 23 terminals are located throughout the plant at key points. Additional instruments and terminals are located in the vault and in the adjacent cold support building where the computer is located. Operating procedures require that measurements be made and communicated to the central computer[17,18] whenever a change occurs in an item, such as a change in its location or physical state, or whenever an item is split or combined with another item. These measurements are either typed on a terminal or transmitted directly to the computer over communication lines that connect some of the electronic balances to the central computer. For each transaction, the computer uses the measurement data and the information supplied by the process technician to update its inventory. The inventory data base may then be queried by process technicians and supervisors to obtain up-to-date information on the location and status of any item in the plant.

PF/LASS departs from DYMAC in the following ways.

1. Not all measurements are made on certified instruments. For example, when a PF/LASS balance is out of service, a technician sometimes uses a process balance to obtain measurement data but reports to the central computer that a PF/LASS

balance was used. Although this practice is undesirable in principle, it is justifiable in terms of processing efficiency. Because process balances are calibrated and a check weight is performed before a measurement is made, no problems have resulted.

2. Many materials transfers involve only one individual who often carries the material across a unit-process boundary to continue processing. In addition, only one measurement is made as material crosses a boundary, rather than the two required by DYMAC principles. Because Department of Energy (DOE) regulations do not now require double measurement, and process efficiency would suffer if such a rule were adopted, the single measurement approach is used. No associated problems have resulted.
3. Some determinations of SNM content must be inferred rather than measured, primarily because not all residues are amenable to measurement on current instrumentation. For example, at present there are no NDA instruments in the system for assaying PuF_4, although experimental models of such instruments[13] are now undergoing trials.
4. Not all NDA instruments are tied directly to the computer. At present, only 18 balances are directly connected. Thus, most measurements are reported to the PF/LASS computer by process technicians. This procedure is a violation of DYMAC tenets, but it is allowed by DOE regulations.
5. The NMO is responsible to the plant manager. This is a violation of DYMAC precepts but is acceptable under DOE regulations.
6. Many features of the present software system are not transportable. The record structure, the packets containing the interactive dialogue, and the method of keying records are all unique. Thus, software developed for the Los Alamos plutonium facility cannot be directly useful at other installations unless exactly the same computer (a Data General Eclipse C330), the same operating system (the Advanced Operating System), and the same file structure are used.

III. SUCCESSES OF PF/LASS

Many anticipated benefits of PF/LASS have been realized. Some impact primarily on safeguards, others on process control. These benefits, and features of the system that bring them about, are outlined below. They include quick inventory, decreased error rate, timely accountability, on-line instrumentation, instrument reliability, instrument measurement accuracy, system reliability, system flexibility, improved reporting, improved process control, and process-technician satisfaction.

A. Quick Inventory

The most conspicuous success of PF/LASS has been a decrease in the amount of time required for inventory. Preparing book inventory reports with PF/LASS is so quick and easy that a book inventory report is routinely prepared on the last working day of each week for each glovebox in the reprocessing wing; the report is then confirmed by the individual responsible for the area.

According to facility staff, annual and semiannual inventories are significantly facilitated by PF/LASS. Under the old paper accounting system used at the former facility, the last afternoon and evening before the start of the inspection were always hectic because of the need to balance the books and to eliminate inventory items of negative mass. With PF/LASS, facility personnel say they are so prepared for these inventories, they do not experience last-minute confusion as before. They also state that PF/LASS saves them a day at each inventory.

In addition, because inspectors now have available the means for a more reliable inventory verification, safeguards are improved. Before PF/LASS, inspectors had to rely on weight measurements and simple survey-instrument measurements for verification. Now, NDA instruments are used to verify the presence and amount of SNM in items.

At present, facility personnel must perform a complete shutdown and cleanout before each physical inventory. This halts production for 3-4 weeks. After the inventory is complete, scrap generated during the cleanout process must itself be reprocessed before regular production can begin again. This costs another several weeks. The plant loses 1/6 to 1/4 of its production capacity because of inventory procedures. With 145 process technicians employed at the facility, the price paid for cleanout is significant.

Facility staff are currently analyzing PF/LASS data to provide justification for a request to forego shutdown and cleanout before each physical inventory; detailed knowledge of plant holdup can be obtained from a DYMAC System to obviate that need. DOE regulations give encouragement to this possibility. If facility management can demonstrate that holdup in certain processes and gloveboxes is minimal and that gloveboxes having large holdup are cleaned several times a year, then shutdown could be eliminated, at a yearly savings of ∿$1 million.

B. Decreased Error Rate

Except for the plutonium facility, Los Alamos uses a standard paper-entered accounting system. Although mistakes in entering and transcribing data on forms are infrequent, much time and effort are expended in detecting and rectifying these errors. Before PF/LASS, the production control office at the plutonium facility made about 80 corrections per month to 8000-10 000 transactions in the data base just to correct item names. Although few of the computer's potential verification procedures have been incorporated, PF/LASS has decreased the error rate dramatically. At present, little is done beyond checking whether the item identification number actually exists in the data base before allowing the transaction, but this simple check catches many errors. The production control office estimates that four additional employees would be needed to detect and rectify errors if the error rate equaled that existing before PF/LASS was initiated.

The goal of achieving an auditable accounting system can be realized. The low error rate and the timeliness of the information contained in the transaction file make possible detailed histories of each item's movement through the plant and each item's interaction with other items. These histories, called audit trails, are beginning to prove useful in quality control and accountability studies.[19,20]

In spite of decreased error rate, a small part of the information in the data base is erroneous. These errors are introduced in several ways. The most common is the typographical error made during data entry. Another is incorrect designation of the measurement instrument used during an assay. Some of these errors are caught by the present system. Many others could be recognized before acceptance of a transaction if the computer were programmed to flag impossible variables (for example, instruments that are out of service or not in the same unit process as the material being assayed) and potentially erroneous or unexpected variables (for example, unlikely changes in material weight, composition, or unit process). Any approach will require that process supervisors have authority to establish procedures for circumventing malfunctioning instruments with minimum disruption to processing efficiency. As supervisors recognize that the benefits of such approaches outweigh their difficulties, these approaches will undoubtedly be adopted. The basic structure of the computer program makes such adoption possible.

Access to the system is tightly controlled by passwords. The process technician is asked for his/her identification number and a password. If both questions are answered correctly, the technician is given access to the system at a specified level of privilege. The computer determines this level by comparing the password to a table of privileges for that password. Different individuals have different privileges on the system (for example, only supervisors can write correction transactions).

At present, transactions do not record the identity of persons making the transactions. This information would be essential should a processing anomaly or a diversion occur. The Operational Security/Safeguards Division has proposed that the computer automatically add that data to the transaction record.

C. Timely Accountability

Because of reduced errors and a more up-to-date book inventory, accountability of the plant is greatly improved over that of the previous facility. Although not all aspects of certain inventory differences are fully understood, and although not all of the NDA instruments are connected directly to the computer, the timeliness of the data base is a clear improvement over the old paper system.

Little on-line accountability is implemented, and the only alarm system available to the NMO is an "overdue in transit" alarm. Because processes in operation at the facility are varied and complex, caused by the R&D nature of the plant, accountability programs need to be developed and implemented unit process by unit process. Past emphasis has been on an accounting system. That has now been largely achieved so that accountability can be given higher priority.

When processing of an item in a unit process is complete, the product is transferred from the unit process. Material associated with sidestreams, such as waste or scrap, is also transferred either at that time or at some later time. The computer is notified of each of these transferred items by means of transactions. The difference between the SNM content of item(s) entering the unit process before processing and the SNM content of the items leaving the unit process after processing is designated as material in process (MIP). When a unit process has been cleared, the central computer determines the MIP (designated as MIPXX where XX identifies an individual unit process) and adds that amount of SNM to the account that records the MIPs produced in a particular unit process. Process technicians determine when the MIP will be calculated; if they mistakenly claim that a unit process is empty, a false value is reported.

Facility management has a need for on-line MIP graphs for each unit process. Although the PF/LASS data base contains all the information necessary for plotting these graphs, they are not produced on the PF/LASS computer. Instead, a tape is generated and sent to the Los Alamos Central Computer Facility (CCF) where the necessary graphs are produced off-line. The graphs would be more timely if produced directly by the PF/LASS computer. Because they display clearly the accountability aspects of each unit process, they are a key to an effective safeguards program. The present inability to produce these graphs on-line is a serious deficiency that should be corrected.

The system does not now readily handle items containing more than one material type. Because the item "name" is ACCOUNT/MATERIAL-TYPE/ITEM-IDENTIFICATION, items containing more than one material type have more han one name that PF/LASS will recognize, that is, one name for each material type. The process technician can report that one name has left the unit process and can forget that additional names must also have left the unit process. The computer then believes that several items are in transit when, in fact, all these names are associated with one physical item. If process technicians are not careful to recognize that they have a mixed item, they can mistakenly clear their account of one material type but not another. The system should be reworked so that a physical item can have one and only one name. For items of mixed material types, the computer should alert the process technician to make additional transactions to clear the unit process.

In spite of these minor handicaps, PF/LASS has improved safeguards at the facility. A particularly illuminating example of improved safeguards was evidenced in the lean-residue ion-exchange process. In this process, four streams feed the ion-exchange columns from which there are several outgoing streams, including effluent, eluant, and scrap. This process evidences large gains and losses in the MIP with a generally upward trend. On several occasions the process has had to be cleaned out to reduce the MIP to acceptable levels. Although detailed data from PF/LASS for each input and output stream have not yet made possible pinpointing the source of this MIP, comparisons of recent data to older data show that this MIP is due to holdup, not diversion.

D. On-Line Instrumentation

Although it has been determined that all of the NDA instruments are capable of transmitting their measurement results directly to the computer, only 18 balances have been coupled directly to the computer. For all other NDA instruments, the process technician must note the reading and then enter it as part of a transaction on a PF/LASS terminal. This not only slows processing but also increases the opportunity for error.

Another difficulty arises from failure to have the instruments on-line. Rather than take the time to certify an instrument before making a measurement, some process technicians make measurements with one instrument but report that they were made with another. To reduce the tendency of process technicians to avoid using the proper instrument, responsibility for certifying each NDA instrument each working day has been assigned to a single individual.

This approach is not a panacea, however. A few process technicians avoid using the PF/LASS instruments because of the inconvenience of moving materials back and forth from their processing area to the instruments and because they have to walk back and forth several times between a terminal and an instrument to effect a measurement.

One possible solution is to require that all measurements be authenticated by the computer as outlined above. To avoid disruptions caused by out-of-service NDA instruments, supervisors could be given the authority to modify information used by the computer for authentication. Then, if an instrument is out of service, the process technician could be assigned an alternative instrument that the computer will accept. When the original instrument is returned to service, permission to use the alternative instrument could be withdrawn. Some reprogramming would be necessary to effect these improvements.

Consideration of the problems just discussed makes it clear that from a safeguards perspective, all the measurement instruments should be on-line. Now, more than a hundred instruments and terminals need access to the main computer. As now configured, only 80 units may be directly interfaced to the computer because of hardware and software limitations. Interfacing such a large number would so degrade system response time that the system would be unusable. System response time is already barely acceptable because of the high data rate to the main computer.

This computer-access problem could be overcome by multiplexing the instruments to the main computer through minicomputers. Discussions indicate that such an approach is feasible. Care must be taken, however, to ensure that communications protocol between the instrument and the central computer is error-free.

If all instruments are brought on-line, we must also find a way for process technicians to perform all the weighing steps during one trip to a balance. We believe this could be accomplished with a microprocessor-based hand-held terminal.[10] The process technician could use this terminal to control the taring and weighing operations so that the PF/LASS computer could obtain both measurements at one time.

E. Instrument Reliability

The past year of PF/LASS operation has seen much improvement in NDA instrument reliability. Because initial failure rates with the first version of the solution assay instrument (SAI)[12] were unacceptable, that instrument was removed from the process line and reworked. The second and third instruments are refined versions of the original and are interchangeable. Reliability has improved to the point where there have been no hardware failures during the last 6 months. Software failures are fewer than one per month per instrument.

In late May 1980, an SAI was contaminated with plutonium, and the decontamination procedures apparently ruined the instrument's electronics. Because of its modular design, the instrument was repaired within 7 working days after obtaining access to the decontaminated equipment.

Thermal neutron coincidence counters (TNCs)[9] have proved to be very reliable in operation. Although the plutonium facility has 20 TNCs, only 7 are used routinely because of a lack of calibration standards. Additional standards are now being prepared for bringing more TNC units into regular use. Safeguards R&D personnel are called on to repair an average of about 1-1/2 units per month. Thus, the mean time to failure is approximately 5 months--remarkable for a device that must work in a difficult and experimental environment.

Forty electronic balances are associated with the PF/LASS installation. Other types of balances are also used for processing. Balances associated with PF/LASS are checked daily and adjusted where necessary to bring them into tolerance. In addition to routine calibration checks, a technician provides maintenance beyond routine adjustments. During a recent 3-month period, 11 balances needed repair. Most of these repairs were minor, for example, replacement of a light bulb or malfunctioning switch. Two balances, however, gave continuing trouble until they were finally replaced. Both malfunctioning units were operating in a glovebox whose temperature variations exceeded specification.

One of the two segmented gamma scanners (SGSs)[11] has operated for 5 years and has needed repair on an average of three times per year. Considering the complexity of the mechanical and electronic systems of the SGS, this is a very acceptable performance. The second SGS has been in operation for only 18 months and has given considerably more trouble.

F. Instrument Measurement Accuracy

Measurements made with the NDA instruments are accurate. For example, SAI measurements are considered so trustworthy by facility personnel that many samples, particularly more concentrated ones, are no longer routinely sent for chemical analysis. Availability of SAI measurement data not only speeds processing at decision points but obviates the need for making a second entry to the accounting system when the results of the chemical analysis are known. Before the availability of the SAI, average values were determined for each step and were carried by the accounting system until the results of chemical analysis were obtained about 2 weeks later. Then the deviations from the average for 5 or 10 samples were credited (or debited) to the appropriate MIP account. The present method is a clear improvement.

An apparent difficulty with the SAI arose at the peroxide-precipitation and peroxide-dissolution step of the Fast Flux Test Facility (FFTF) process. Here the SAI measures feed stock and output solutions as well as minor side streams. A consistent material loss of $\sim$5% of throughput was observed. Because the SAI was a relatively untried instrument, its accuracy was suspect. A set of experiments was undertaken that traced the discrepancy to the fact that two different bottles of solution that were assumed to be equivalent were not. Because one of these bottles contained the dilute wash from rinsing the filter, its average concentration of plutonium was lower than the other. Chemical measurements were being made on the solution contained in only one of the bottles, leading to an assay error of $\sim$100 g per month. Process procedures have now been modified to avoid these inhomogeneities; the average differences in the plutonium content of the two bottles are now within the expected measurement error of the SAI. This case has been discussed more thoroughly in Ref. 20.

Particularly disconcerting was the discovery that the balances sometimes gave incorrect readings with no other indication of failure. A digit in the readout display would sometimes read zero instead of the actual value measured because of malfunction of the digital readout circuit. A circuit was designed and installed[7] in each balance that allows the operation of the digital readout to be checked before each use. No further problems have occurred. Had this problem gone undetected, it could have had serious repercussions.

On the whole, most of the measurement instruments work very well. Further development is necessary to make the instruments more capable of assaying solutions with low plutonium concentrations. This goal might be accomplished through further refinement of the SAI, through installation of a K-edge densitometer,[21] or through installation of a transmission-corrected x-ray fluorescence unit.[22] This would provide additional places in the process stream where samples need not be taken for delayed chemical analysis.

The biggest measurement problems are associated with the ion-exchange columns in the lean-residue process where the MIPs rise very quickly and fluctuate significantly. Better methods are needed for measuring the contents of the horizontal receiving tanks and for making measurements on the various streams as they flow into the tanks. Also, a procedure is needed for accurately determining the flow rate and plutonium concentration as a function of time so that integration of data can give a better estimate of tank contents.

At present, solutions are being routed to a calibrated vertical tank for volume measurement. The solutions are also stirred and sampled for plutonium analysis.

One small problem concerning measurement accuracy has resulted from the natural tendency of an instrument user to expect more from the instrument or system than was designed into it. Instruments are usually designed to work with one class of materials or range of concentration. Specifications for these instruments are usually determined and agreed to in consultation with the plant management before the instruments are developed and installed. After having experience with them and gaining confidence in them, users have a natural tendency to want to use the instruments for purposes other than those intended. The average process technician is usually disappointed when an instrument is not able to perform adequately under unplanned-for circumstances. Clearly, careful and continuing attention to communication as well as to continued system development and upgrade are called for.

G. System Reliability

The computer itself has been quite reliable since it has been transferred from development to operations. During the 3-month period of April through June 1980, no software failed, although some minor problems continued to be identified and corrected in the transaction packets. This performance followed a period of frequent failures during the conversion to a new operating system. Hardware availability has averaged between 90 and 95%.

About 23 000 records are now in the on-line data base. Between 8000 and 10 000 transactions are handled each month. In addition, the computer keeps track of the details of >300 separate sets of steps to be followed in developing a transaction. These sets contain material that forms the dialogue between the process technician and the computer.

About 80% of the transactions handled by the computer each month involve in-transit transactions, which place items in transit or take them out. These transactions contribute to the overload of the system, perhaps unnecessarily, and could raise questions about system reliability. Handling in-transit activity in a manner that minimizes impact on the computer should be considered. Many items are placed in transit when they are being moved within a unit process or between adjacent unit processes. Because the computer must interact with a process technician once to place the item in transit and a second time to take it out, the number of transactions would be halved if a single transaction could be used to effect the transfer. Not all in-transit transactions can be replaced, but system performance would benefit from redesigning the transactions used within a particular unit process.

H. System Flexibility

A serendipitous feature of PF/LASS is the way it assumes responsibility of accounting for silver, gold, platinum, and other precious metals in the facility. System coding was designed to keep track of SNM using a two-digit code for material type. The 9X series of material type (user designated) has been assigned to accountable precious metals. Process technicians simply transfer and account for precious metals in the same manner that they account for SNM--by using PF/LASS transactions. This same approach is also used to account for nonfissile radioactive sources and to keep track of subaccountable amounts of SNM.

The system can also handle shipments that have peculiarities outside the range of those normally anticipated. For example, a recent shipment contained recoverable amounts of plutonium and uranium as well as significant amounts of iron and titanium. The 80-column format of the old paper system had no provision for additional information. With PF/LASS information was partially encoded through appropriate entries. To alert process technicians to the peculiarities of the item, the other constituents were listed in the remarks section of the transaction that created the inventory listing.

I. Improved Reporting

PF/LASS assists in determining and reporting shipper/receiver differences. Scrap lots are usually shipped with a receipt showing net SNM content. When these lots arrive at the facility, their contents are sorted into sublots of similar scrap type. Each sublot is assayed using the best method available for that sublot, and the total SNM content for the sublots is compared to the shipper's claim. The timely and convenient reports generated from PF/LASS data greatly simplify this complex process.

Because the amount of material in many scrap lots is small, items from several different shipments are combined for processing. PF/LASS data allow credit to be given for each shipper's share of the material being produced. These data are also used to assist in the production of the monthly scrap report for the Central Scrap Management Office (CSMO) and to help prepare a weekly FFTF oxide production report. The production control office estimates that PF/LASS saves about 1-1/2 person-days/month over the old paper system in preparing the CSMO report.

Plant management meets weekly to plan processing for the remainder of the week. Data from PF/LASS that have been analyzed at the Los Alamos CCF are heavily used during these sessions; such data would be useless if 2 weeks behind, as can easily happen with a paper system. Processing priorities are determined at this meeting by a number of factors, including the amount and kind of material in the vault and what material is available or is causing overcrowding. This key information is readily available from PF/LASS. Although a paper system could supply data that are reasonably up-to-date, extraordinary efforts at a prohibitive cost would be called for.

On July 1, 1980, a flexible new system of inventory report generation was made available. A requestor can now specify the kinds of records to be included in the report (for example, records on ^{239}Pu in the button-oxidation, oxide-dissolution, and peroxide-precipitation unit processes only). The computer assembles a subfile of all inventory items that meet specified requirements; the report is then generated from that subfile. Reports can be generated by unit process, material type, account number, etc. With this technique, more useful reports with less extraneous information can easily be generated. These reports are used by the plant NMO, by process personnel, and by groups within the safeguards R&D program for accountability studies.

J. Improved Process Control

PF/LASS also provides more timely, more effective, and easier process control. Nondestructive assay allows timely determination of solution concentrations or fissile content so that decisions may be made at branch points in a batch process. Before the installation of PF/LASS, these decisions could not be made until the results of wet-chemical analysis were known, causing a delay of almost 2 weeks. Materials had to be returned to the vault and processing had to be halted on that item. Now, because of the NDA instruments, production need not be halted.

The following example illustrates another way that NDA instrumentation benefits process control. Much of the work at the facility involves acid leaching of plutonium from indissoluble scrap. After a leaching is complete, the processor must decide whether another leaching should be done or whether the material should be sent to retrievable waste storage. Before installation of the 18 TNCs, the material had to be bagged out and transferred to a central measurement point. This process not only took significant time and posed health hazards, but it created even more waste and scrap. With the ready availability of an in-line TNC, the processor is able to determine, without bagging out, whether further leaching is necessary.

Much waste and scrap are accumulated by the process technicians, who determine the plutonium content of their collection by using the TNC. The process technicians send this scrap to reprocessing only after they have accumulated enough material to make such a transfer cost effective. By transferring relatively large amounts, the percentage uncertainty in the amount transferred is improved.

The facilities of the PF/LASS computer are being used for quality control of enrichment. In the FFTF oxide production process, the final product must meet tight specifications of isotopic enrichment, typically to within 0.5%. Because the PF/LASS transaction process automatically calculates the enrichment of a mixture from the original amounts, the process technicians have a powerful tool to assist them in obtaining the proper mixture. Process technicians sign on to the terminals, enter the data for a transaction, then wait for the net isotopic enrichment to be fed back to them. If the enrichment is within acceptable limits, they complete the transaction. If the enrichment is not within acceptable limits, they abort the transaction and select different items to be combined. In other words, they use PF/LASS to perform the mixing calculation for them.

Another advantage of PF/LASS is that personnel in the production control office can monitor activities in the processing rooms from their terminals. Because the data base is always timely, the personnel who monitor transactions occurring in various parts of the plant are able to pinpoint trouble spots so that corrections can be applied quickly before errors compound.

Process managers now access the inventory for each item of material in their area of responsibility. Because this inventory is as up-to-date as the last transaction made, managers can determine whether bottlenecks are developing in their areas. They then can move immediately to eliminate these bottlenecks, thus realizing improvement in process efficiency and, hence, cost effectiveness.

Results of NDA measurements are also useful in criticality control. Although facility design has been carefully planned to avoid criticality problems, and although conservative limits have been placed on the size of items that can be moved into each area, criticality control is still a great concern. The quick inventory feature of PF/LASS allows a process supervisor to spot potential problems and to head them off. The management of the facility plans to implement a revision of the PF/LASS computer program that will automatically check for criticality concerns and produce a signal to indicate when limits might be exceeded if a proposed transfer of material were permitted.

Another area where nondestructive assay is of significant use is in the monitoring of effluent streams from ion-exchange columns. In the lean-residue ion-exchange process, effluent to be transferred to the evaporator system is kept in a large number of holding tanks to accumulate the desired batch size. Intermediate tanks are used to collect the effluent from individual ion-exchange runs until verification is made that the plutonium concentration is below the evaporator process limits. Inadvertently adding an item of relatively high SNM content to these tanks could require that the entire tank be reprocessed, at significant expense in terms of delay in the plant. To ensure that each item is below the evaporator process limits, the effluent is monitored with the SAI, and the decision to reprocess or concentrate in the evaporator system is made from that information. Thus, even though concentrations are below those that the SAI can actually measure, its ability to determine an upper limit on SNM content saves a few days relative to radiochemical analysis. The final accountability determination must still await the results of radiochemical analysis.

K. Process-Technician Satisfaction

The majority of persons at Los Alamos who have worked on both a process line with PF/LASS and on one with the standard paper system much prefer the computer-based system. This view is doubly gratifying because, as in any undertaking of this type, problems can develop from the differences in goals for processing and safeguards. As indicated, compromises were sometimes necessary between the demands of efficient processing and the stringencies of a good safeguards program. An effective system now in place and accepted by process technicians suggests that this experiment has been successful.

Management at the facility believes that PF/LASS is easier to learn to use than the old paper system was. Although the dialogue style employed in PF/LASS may slow experienced process technicians, neophytes are carefully coached by a series of prompts specific to each process. Thus, the process technician need not become an expert in PF/LASS procedures before making process transactions.

Development of a series of generic transactions that would have almost universal application is being considered. Operations such as splitting or combining batches are common to most processes. If all such transactions were handled identically, training in PF/LASS procedures for process technicians working in one unit process would apply equally to any other unit process.

Clearly the question-and-answer procedure for data entry is slower than the faster process technicians would like. Process technicians quickly learn what will be asked and when. Because the input and output of the terminals are independent, a technician can enter several pieces of data while the terminal is still displaying questions. Unfortunately this approach has limits, and technicians are sometimes forced to wait. One solution would be to replace the present terminals with cursor-positioning terminals. Then the technician would need to fill only the blanks in the displayed array, greatly speeding data entry and improving technician satisfaction even more. Also, because this approach would look more like the paper-entry system, training time might be reduced for individuals who are familiar with the paper system.

Process-technician satisfaction would probably be enhanced by increasing the number of terminals in the plant and by changing their type. Currently, in many areas of the plant, to effect automatic weighings, technicians must walk back and forth between the terminals and gloveboxes where measurements are performed. Some technicians avoid this by recording the various measurements on a piece of paper and then reporting the final results at one sitting, clearly increasing the opportunity for error. For measurements to be made properly, all the NDA instruments should be interfaced to the computer and each should have an associated hand-held terminal. These instruments should also be capable of making measurements that need not be reported to PF/LASS.

IV. SUMMARY

This first DYMAC experiment has been a success but not necessarily in the way expected. Benefits to processors were perhaps underestimated by the developers. More discussion with the management of target processes could increase benefits derived from DYMAC and perhaps lead to concomitant increases in system safeguards.

Not enough attention appears to have been given initially to the "people" problems that, in retrospect, we know were bound to occur. Instrument design allowed for many contingencies; similarly, the dialogue process between the computer and the process technician was designed to be transparent and simple. Little was anticipated and allowed for, however, in the sociology of the interaction between the two organizations involved--processing and safeguards, organizations that have different missions, backgrounds, types of employees, and personalities. The next DYMAC experiment must pay more attention to this concern and recognize that a tight safeguards system is usually perceived as inimical to efficient processing, even if the safeguards system is optimally designed. Because this conflict is inevitable, care must be taken to minimize it and to provide benefits to the processor that outweigh the detriments. More effort must be spent by system designers, not only in understanding the needs and concerns of the customer and the peculiarities of the particular operation, but in providing a safeguards system that takes these needs, concerns, and peculiarities into account. PF/LASS has clearly shown that benefits to the processor are significant. These benefits need to be communicated effectively to other facilities.

V. RECOMMENDATIONS

The success of the first DYMAC experiment encourages its continued exploitation and implementation. Our experience indicates, however, that such exploitation must attend to more than the technological aspects of a DYMAC system. Close attention must be given to ameliorating the tensions that arise from the multiple and sometimes conflicting interests of organizations with disparate missions. Thus, a diverse program of implementation is recommended. Such a program must spell out the responsibilities of the implementing group as well as those of the eventual operator.

A. Plutonium Processing Facility Support

The safeguards R&D program should maintain an effort at the Los Alamos plutonium facility along the following lines.

1. Bring all of the NDA instrumentation on-line to the central computer. This would ensure that measurements are less likely to be falsified, either accidentally or intentionally. Before all of the instruments are brought on-line, intelligent hand-held terminals should be developed so that process technicians do not have to leave their work stations to coordinate measurements with corresponding transactions.
2. Develop more procedures for validating transaction information before it is used to update the data base. The logical constraints provided by normal processing on the information transmitted to the data-base computer could also be included in the MC&A system. For example, certain transactions are logically made from only a limited number of areas within the facility; measurements can be made on only a limited number of instruments; only a limited number of individuals should be carrying out specific process steps. Along with

such constraints, overrides must be included to avoid bottlenecks in the process stream.

3. Improve the holdup measurement capability so that nuclear material in equipment can be located and assayed.
4. Improve shipping and receiving procedures. Provide verification capability, as well as records, to individuals who authorize transfer through the facility perimeter.
5. Develop an automatic vault inventory system because, at any given time, a large fraction of the facility's nuclear material is in the vault.
6. Develop an on-line graphics capability for assessing MIP. This capability would provide rapid, visual assessment of the many unit processes and their performance history.
7. Work with facility personnel in the analysis of PF/LASS data to determine appropriate holdup patterns for each unit process. Analysis of PF/LASS data in lieu of a complete plant cleanout could provide savings of ~$1 million per year. Such a savings could inspire other plant managements to adopt DYMAC systems.
8. Establish realistic control limits that can trigger responses. This program would require improved measurement control procedures to determine the uncertainty associated with measurements, material in process, holdup measurements, or inventory differences.
9. Provide automatic closing of the materials balance and automatic determination of the interim inventory difference.
10. Improve the computerized audit-trail capability, including audit trails on individual items as well as on suspicious processes or persons.

Using data generated at the facility, some of these proposed improvements could be developed and modeled outside the facility, thus minimizing the impact on processing. After development, specific elements of hardware, software, techniques, or procedures could be further tested in the facility before possible operational implementation.

This support primarily would serve to maintain the Los Alamos Plutonium Processing Facility as a showplace for advanced safeguards technology. Secondarily, it would help ensure the availability of a test bed for new techniques and instruments at a location that is convenient to the safeguards research program at the Laboratory. Access to the facility would also provide data for continuing accountability studies to help pinpoint possible sources of diversion. Such studies would also develop detailed knowledge of how tight the present system really is.

B. Expanding DYMAC Beyond Los Alamos

To improve acceptance of DYMAC systems, we suggest that small projects at other DOE nuclear facilities be expanded. These projects are envisioned as small enough to avoid threatening the target facilities and to help them in process control. We believe, from experience gained during the first DYMAC project, that once plant managers have a chance to use good NDA instruments, even on a limited basis, they are much more willing to have them installed throughout a plant to implement a nuclear accountability system.

A supportive, nonthreatening posture will be important in approaching these installations. Developing and installing these instruments on schedule and providing good support to process technicians and maintenance personnel to instill a high degree of confidence in NDA procedures will also be important. Therefore, we will need to develop and test such systems here at Los Alamos.

C. Retrofit Project

We propose to retrofit a DYMAC System to an existing processing facility for several reasons. The DYMAC system at the present Los Alamos Plutonium Processing Facility was designed for the facility as it was being built; instruments were installed in environments that were uncontaminated at the time of installation. New challenges will arise as we attempt to retrofit a DYMAC system to an operating facility.

Because the Los Alamos facility is oriented to plutonium processing, a uranium processing facility might be an attractive choice for implementing the DYMAC System in a different kind of facility. Choosing a non-batch process facility might yield experience wh⁻re materials balances must be drawn during continuous processing.

Such systems will be possible only if close cooperation between the plant management and accountability system designers is effected. The first phase of such a program will require detailed interaction between groups but should be possible where plant managers are convinced that the benefits to their processing will outweigh the onus of processing delays caused by enhanced safeguards procedures.

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