LA-UR -88-102

CONF-871110--20

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

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LA-UR--88-102

DE88 005381

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SUBMITTED TO ANS Topical Conference, The 3rd International Conference on Facility Operations Safeguards Interface, San Diego, November 29-December 4, 1987

THE USE OF SAFEGUARDS DATA FOR PROCESS MONITORING

IN THE ADVANCED TEST LINE FOR ACTINIDE SEPARATIONS

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ABSTRACT

Los Alamos is constructing an integrated process monitoring/materials control and accounting (PM/MC&A) system in the Advanced Testing Line for Actinide Separations (ATLAS) at the Los Alamos Plutonium Facility. The ATLAS will test and demonstrate new methods for aqueous processing of plutonium. The ATLAS will also develop, test, and demonstrate the concepts for integrated process monitoring/materials control and accounting. We describe how this integrated PM/MC&A system will function and provide benefits to both process research and materials accounting personnel.

I. SUMMARY

Nuclear materials accounting is an important part of nuclear fuel cycle operations. It provides assurance that nuclear material is present and at its proper location. The materials accounting system can also supply information that is useful to Operations. A modern materials accounting and control system can monitor process and equipment performance, material accumulation, and operational safety. This paper shows how a modern MC&A system can provide useful information on process systems and describes a Los Alamos plan to demonstrate an integrated process monitoring/materials accounting and control (PM/MC&A) system.

The operational benefits of an integrated process control/near-real-time materials accounting system are many. Computerized MC&A systems available in modern process plants allow closure of materials balances on individual material movements or process operations. Frequent closures on materials balance areas (MBAs) or individual process vessels can localize and identify process problems quickly. The Advanced Testing Line for Actinide Separations (ATLAS) PM/MC&A system will monitor process performance and assist the operator and experimenter by accumulating and analyzing experimental data.

Los Alamos is planning development and demonstration of an integrated PM/MC&A system in the ATLAS at the Los Alamos Plutonium Facility. The ATLAS will test and demonstrate new methods for aqueous processing of actinides and also will develop, test, and demonstrate concepts for integrated process monitoring/materials control and accounting.

The ATLAS integrated PM/MC&A system will use personal computers located at the line to aid the technician and research scientist. The PC-based system is designed to be modular, transportable, and to allow future growth. This approach will permit future expansion of the system to include additional process units and modification to fit the peculiarities of specific unit operations.

The initial system will have the capability for progressive growth in a staged manner so that individual PM/MC&A concepts can be tested and proven, revised, or discarded. The initial Phase I system will include:

- automated generation of safeguards data for manual input to the Los Alamos Materials Accounting and Safeguards System (MASS),
- automated checking of MASS inputs for consistency and errors, and
- monitoring and authorization of material transfers to assure that special nuclear material (SNM) critical safety limits are not exceeded.

Later phases may include:

- automated capture of process and safeguards data for MASS entry,
- process sequence and parameter selection using an "expert system" to assist the operator,

- material balances closure using nonaccountability grade process data to track transactions, and

- automated collection and analysis of experimental data.

The integrated PM/MC&A system will help the operator understand and follow the performance of his plant without hindering plant operations and production. This project will develop a computer-based system for tracking the processing and movement of nuclear materials. The system will demonstrate the application of personal computers located in the operating area, at or near the process line, to facilitate both process operations and material safeguards in a timely and efficient manner. This system would unite the process control/management and materials control/accounting data collection systems into a single, integrated system in which information is exchanged between these systems for their mutual benefit. The system will be installed and tested as part of the ATLAS process development line.

II. INTRODUCTION

A modern MC&A system can follow process performance and detect nonstandard conditions. The frequent closure of materials balances on individual process units can track materials processing and equipment performance. This allows the system to provide information on process streams where measurements are impractical and identify process upsets or equipment misoperation. It can also monitor material transfers in process equipment and glove boxes to prevent the accumulation of unsafe quantities or monitor the accumulation of SNM in nonmeasurable areas.

The PM system provides additional data inputs to the MC&A system that can be used to reconcile materials balance closures when unexplained discrepancies occur. Process control data can provide information that allows frequent balance closure at the level of the individual process unit and can localize real material losses in both time and physical location.

MC&A should use process control measurements whenever feasible. Where accountability-grade measurements are not available, SNM values can be inferred from secondary correlations using process measurements (density, historical values, etc.) or other attributes (volume transferred, etc.). The MC&A system should not impair plant operation and production. A good MC&A system should enhance the operators understanding of process systems performance.

To gain a productive interaction between the MC&A and process control systems, Safeguards and Operations personnel must work together during the initial stages of process and plant design. Their goal should be to provide an effective materials accounting system that provides process monitoring, control, and other operational benefits while limiting cost impacts.

III. ADVANCED TEST LINE FOR ACTINIDE SEPARATIONS

The ATLAS facility will develop the next generation of actinide processing and analytical instrumentation. These new procedures and equipment will enhance Los Alamos' ability to process intractable scrap in support of DOE plutonium recovery efforts. The ATLAS is a complete processing line with the ability to dissolve and purify incoming material and process the resulting liquid and solid waste. The floor plan is designed in modules so that equipment can be modified or replaced without disturbing other operations. The floor plan is shown in Fig. 1. Flexibility and the capability to process a wide variety of scrap will be provided using the flow sheet shown in Fig. 2.

Each unit operation has been planned so that new processing concepts can be installed without upsetting the entire process line. The unit operation approach will facilitate the implementation of the Comprehensive Materials Accounting and Safeguards System (CAMCAS) by allowing materials balances to be drawn around individual operations or a combination of unit operations.

The ATLAS will accomplish several other objectives besides providing research and production support for the DOE. With on-line "real time" analytical capability, a better understanding of the fundamental chemistry involved in all aspects of actinide processing will be achieved. With this information, improved processing procedures will be possible. These analytical techniques will make materials accounting much easier and more accurate. The ATLAS line will become a focal point for technology exchange with other sites and also provide the technical direction for the plutonium processing facilities of the future.

IV. PROCESS MONITORING AND MATERIALS ACCOUNTING SYSTEM INTEGRATION

The feasibility of an integrated process monitoring and materials accounting system was demonstrated during a series of test runs conducted at the Barnwell Nuclear Fuels Processing plant in 1980-81.[1] These tests demonstrated both the technical feasibility and benefits of near-real-time accounting (NRTA) in an operational facility. Work currently being conducted at Oak Ridge National Laboratory is further developing and demonstrating the concept of near-real-time process monitoring.[2,3]

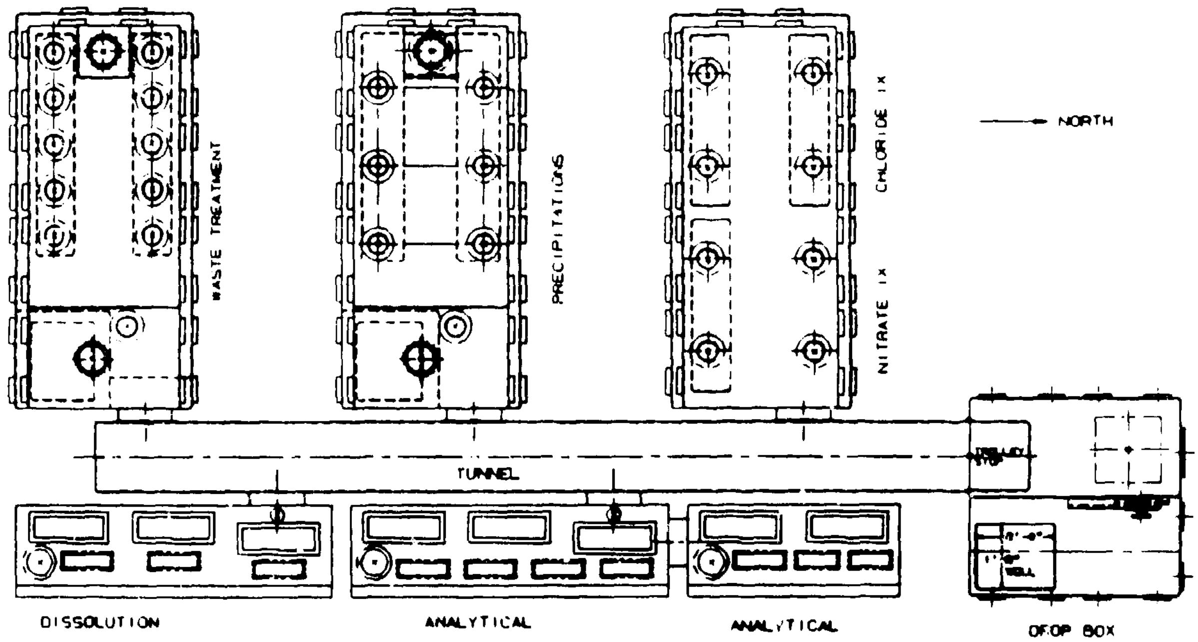

Fig. 1. ATLAS floor plan.

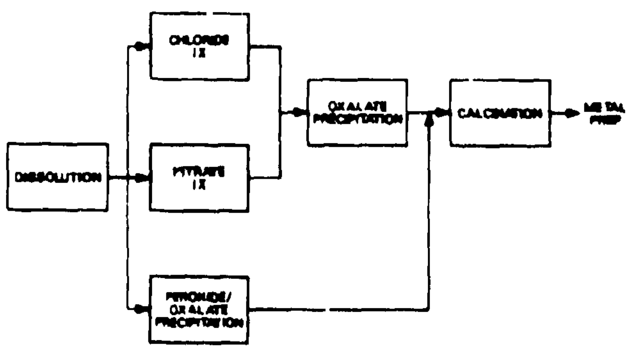

Fig. 2. ATLAS flow sheet.

Tisinger et al. have described a distributed processing system that provides both process control and materials accounting capability in nuclear facilities.[4] This system, proposed by the Los Alamos Safeguards Systems Group in 1981,[5] consists of groups of instruments and terminals in plant production and support areas connected to local minicomputers that are in turn connected to a central main computer. This system is illustrated in Fig. 3.

Each processing location has instrumentation and control requirements that are specific to that location. Computers concerned with accumulation and manipulation of data from instruments and control of the process are located at the first level.

Information pertinent to production planning, forecasting, production reporting, etc. requires accumulation of a limited subset of information from lower level computers at an intermediate level in the system. Information required for auditing and oversight of the entire plant is collected and analyzed at the top level. Access to top level data is limited to those with a need for this data (safeguards, management, and process analysts) and would be secured to prevent unauthorized access.

Testing the feasibility of a distributed processing system using interlinked minicomputers is currently underway at Los Alamos. The test system is discussed in Ref 4. This system is the basis for installation of an integrated safeguards/process control system that provides the positive features described below.

A. Process Control

Nuclear material processing operations frequently have sidestreams (typically wastes) that normally contain small to negligible amounts of product, valuable intermediates, or hazardous materials. These streams may not be monitored or sampled because they normally contain small quantities of material or because the measurement is difficult, expensive, or impractical. Undetected losses via these sidestreams can lead to a loss of valuable material and adversely impact operations by requiring the material to be recycled and reworked.

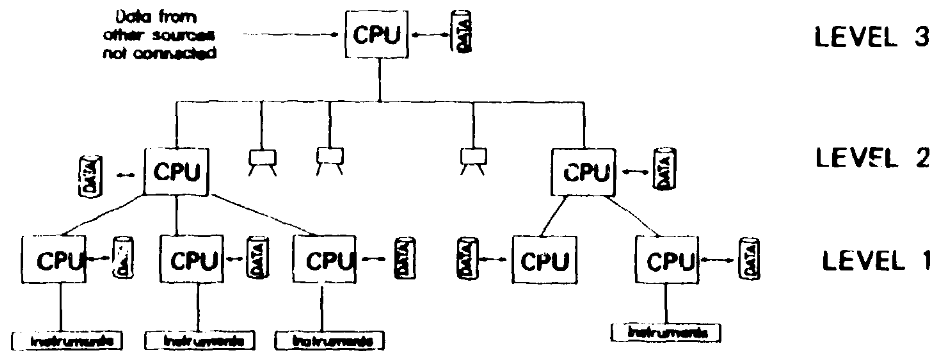

Fig. 3. A distributed process monitoring system.

Los Alamos has detected and monitored loss of nuclear material using the materials accounting system in a situation when process instruments could not detect this loss. In 1980-81, a series of tests were conducted at the Allied-General Nuclear Services, Barnwell Nuclear Fuels Plant to test the NRTA concept.[1] During these tests a series of planned diversions were made. At the completion of one test series, several diversions were detected by the NRTA system, and the point at which the material had been removed was pinpointed. However, one diversion was detected by the MC&A system that was not a part of the exercise.[6] This experience illustrates how a materials accounting system can provide timely detection and quantification of material loss where normal monitoring systems are either unavailable or their installation is impractical.

The computerized materials accounting systems available in modern process plants allow closure of balances on individual transactions (material movements or process operations). Frequent closures on sub-MBAs or individual vessels will localize discrepancies leading to timely identification of process problems. This will facilitate timely adjustment of process parameters, maximizing process efficiency and minimizing costly rework operations. This technique is being tested and demonstrated by Ehinger at Oak Ridge National Laboratory in a materials accounting application.[2]

B. Measurements Control

Process measurements must be utilized by the MC&A system to realize a comprehensive and complete materials accounting. Process instruments are typically less accurate and less well maintained than "accountability grade" instruments. Process instrumentation may be inaccurate or infrequently calibrated. Neutron monitors (provided for criticality safety) on ion exchange columns, tanks, etc. are highly inaccurate, and difficult to calibrate but can provide valuable safeguards information. An instrument of this type can be calibrated by using the MC&A system to track additions of material to individual process units. A materials accounting system that includes detailed materials tracking can monitor instrument performance, estimate measurement errors, and identify instruments that are out-of-calibration. Instrument biases can be followed and quantified as they develop, eliminating unknown errors and reducing instrument service frequency. Maintenance can then be scheduled only as needed.

Tank level measuring devices are infrequently calibrated because of the time and effort required. The MC&A system can check the calibrations. When an intertank transfer is made, the quantity shipped and received is checked to verify completion of the transfer and receipt of all material. Data required to verify this transaction can also be used to calibrate level instruments.

Figure 4 illustrates a three-tank system in which the second tank contains a level measuring device with a low bias. By comparing long-term data from these instruments, it is possible to locate this bias. A materials balance drawn around the first two tanks would indicate that a continuous bleed of material (leak, diversion, etc.) is occurring. However, if the materials balance is redrawn to include the second and third tanks, it is apparent that there is a problem with one of the measurements as there is now a net production of material that counterbalances the loss observed in the prior MBA. The amount of bias in the level measurement in the second tank can be quantified such that a software fix can be used to recalibrate the system.

The MC&A system should incorporate software that compares related data to develop relative errors, i.e., comparison of volume received vs volume sent, etc. This software can compare relevant process data to monitor and establish the magnitude of process measurement errors.

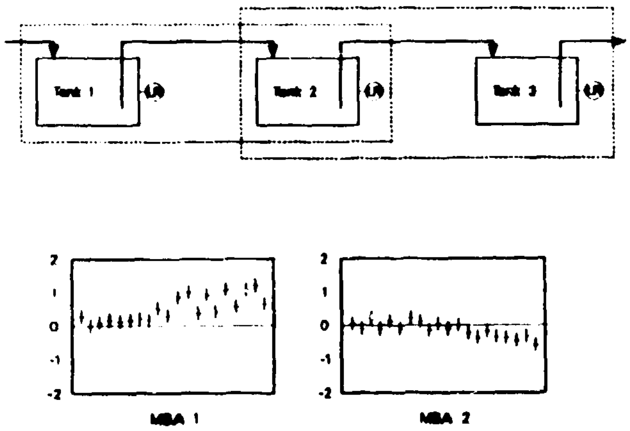

Figure 4. Three-tank system with measurement error.

Anomalies can frequently be resolved by redrawing the MBA so that the missing (or suspect) data is not a critical component in the materials balance equation. In the above example, reformulation of the tank MBA to include all three tanks would have eliminated the false conclusions that resulted from the two-tank MBA analyses. This method is frequently effective in resolving anomalies caused by false readings as the suspect instrument can be eliminated from the materials balance equation.

The MC&A system can be used as a tool to develop measurement control charts for instruments. Software updates can be made simply, quickly, and as required to maintain instrument accuracies at the highest possible levels.

C. Operations Analysis

The MC&A system collects and maintains a large database on materials flows and measurements. This database contains a large volume of information that can be useful to the analyst who wants to monitor, understand, and improve the efficiency of his operations. With this data he can ascertain the impact of minor changes on process performance. By introducing small changes in process parameters, changes in operations can be followed and quantified.

For example, the operating temperature in a process unit might be changed. The MC&A system can be used to track and quantify changes in system performance. A series of small changes can be introduced and tested under true plant conditions to validate their usefulness. This technique, known as Evolutionary Operations, can be used in conjunction with the capabilities of the MC&A system to optimize plant efficiency and performance.

D. Materials Accounting

Because unexplained inventory differences (IDs) can disrupt process operations, the job of a good safeguards officer is to maintain an MC&A system where anomalies are detected and resolved with minimum impact on production.

The ability to obtain materials balance closure is generally not limited by inaccuracies in existing measurements, but rather by unmeasured inventory or holdup. Spillage in glove boxes, heels in calciners or flourinators, deposits in vessels and pipes, etc. frequently control ID and its associated limit of error. Development of instruments to detect and quantify holdup can alleviate this problem. However, development of these instruments may be slow and possibly not cost-effective.

In handling fine solids, holdup (spillage) in glove boxes is a serious problem that is difficult to measure with any precision. The holdup term frequently becomes the major and controlling source of uncertainty in the materials balance equation. By the use of techniques similar to those used for checking instrument calibrations, it is sometimes possible to track the buildup of heels in vessels or spills in glove boxes. If supported by valid statistical methods, these data can be used to develop holdup estimators for the materials balance equation resulting in reduced IDs.

Tracking of materials accumulation in small, localized process units during plant startup, cleanout, and restart can yield statistically supported estimators of unmeasured inventory that can be incorporated into the materials balance equation. This investment of time at startup can eliminate later shutdowns for system cleanout or anomaly resolution that would hinder plant productivity. Modern materials accounting methods can produce data that pinpoints material loss to holdup and quantify the magnitude and location of these apparent "losses." These data will also show that what appears to be a significant loss is in reality the sum of many small material accumulations and measurement errors.

V. SYSTEM DESIGN

The primary goal of this project is to demonstrate the application of small, at-line computers to the control and monitoring of nuclear material processing operations. A second goal is to demonstrate that the functions of process control/management and materials control/accounting can be combined in a synergistic manner such that the benefits derived from the integrated system exceed the sum of the two separated systems.

The ATLAS PM/MC&A system will initially be small and simple with the ability for expansion as needed and as funding becomes available. The initial system will consist of several personal computers located at the process line.

A. System Functions

1. Process Monitoring and Control. The ATLAS will handle a wide range of feed materials each of which may require different processing steps and varying amounts of chemical treatment. The PM/MC&A system will provide "expert input" to the operator to assist in set-up and operation of assay and measurement systems. The "expert system " will determine sample requirements, provide instrument calibration instructions, select calibration standards, etc. on the basis of sample character.

The system will perform materials balance and stoichiometric calculations for process operations requiring addition of reagents and splitting or combining of batches. The system will calculate the proper amount of chemicals required by the process on the basis of feed type and composition.

Eventually the system will provide the primary source of procedures and operating plans for experiments carried out in the ATLAS line. The system will have the capability to record and archive all data taken during the course of an experiment or process run. Operating plans provided by request will detail material transfers between process units and processing steps that are required. The plan can also provide a listing of required sampling and measurements data.

The system will maintain a database containing measurements control data for all ATLAS line instrumentation. The measurements control software will be compatible with the existing MASS information and capabilities. Current MASS control charts and statistical tests will be run on machines located at the measurement point with monitoring and oversight performed by the MASS to assure veracity and integrity.

2. Materials Control. The movement and processing of material will be monitored by the PM/MC&A system, which will track and maintain an archival record of all material movements and processing operations. Authorization to move nuclear material between unit process areas (UPAs) shall be obtained by the operator from the system prior to movement.

The PM/MC&A system will assure that all SNM is transferred in accordance with established safety procedures and that SNM inventories in UPAs are within criticality safety limits. The system will maintain a log of material inventory within each UPA to assure that criticality safety limits are not exceeded and alarm if a request for transfer of material into a UPA could lead to inventory in excess of criticality safety limits. The system will request and record operator acknowledgement of all alarms. The system will also have the capability to list all in-line SNM inventories by location on demand.

At a future date materials movement and processing will be a two-stage process. In the first stage an operations plan will be prepared by the supervisor and entered into the system. The second or transaction stage will be carried out by a separate person (generally an operator) who will conduct the actual processing or transfer operation.

3. Materials Accounting. In its initial phase all PM/MC&A system inputs/outputs will be manual. Later phases will demonstrate electronic capture of data and automatic transfer of materials accounting data into the Los Alamos MASS.

The system will pre-process MASS data to locate errors, omissions, and anomalies so that they may be identified and reconciled in a timely and efficient manner. Some pre-processing of data for the MASS will also be performed. The system will not replace nor interfere with the Los Alamos MASS system, which is the primary materials control and accountability system for the Laboratory.

Most MASS inputs can be determined on the basis of a material type or prior processing history; this knowledge will be used to generate, for the operator, data required by MASS. At a later stage the system will automatically select and input data to the MASS. Historical data patterns and standard patterns developed by knowledgeable technical personnel would be compared with input data to identify anomalies for operator or supervisory review; preliminary material balances would be closed to locate inconsistencies and identify possible erroneous inputs.

At a future date the system will be upgraded to calculate an ID for all transactions in the ATLAS line. ID records will be of two types: a preliminary inventory difference (PID) and a final inventory difference (FID). The PID may be calculated using input obtained from indirect estimates of SNM values, best guesses, or other appropriate data. An FID may be calculated only with approved, "accountability grade" data.

All IDs shall have an associated limit of error calculated from current data contained in the measurements control database. A cumulative sum record of inventory differences and associated error limits in each UPA shall be maintained for the prior and current month. At the end of each month, materials accounting data from the prior month's accounting database will be archived to magnetic media.

The Computer Aided Process Surveillance System (CAPS) will assist in the performance of process monitoring and control, materials control, and materials accounting functions for the ATLAS line. The primary functions of the CAPS system are described below. Other operations we might provide are measurements control and bar-coded materials management and identification.

B. System Hardware

Equipment will be designed for local (at-line) operation and maintenance by Lab personnel in the plant operating area. The operating area is a regulated area subject to occasional low-level radioactive contamination.

Equipment will be selected to facilitate future system upgrades and/or expansion. System flexibility is required because the system will evolve in a continuous manner and it will be difficult to predict future directions of both the ATLAS research program and PM/MC&A development.

System design will provide capability for future direct electronic transmission of ATLAS instrumentation data to the PM/MC&A system, output of data to the MASS system, and interconnection with other at-line computers monitoring other process areas.

The system shall be designed with an "open-ended" architecture to allow future expansion by addition of other computers and terminals using the same vendor hardware.

C. System Software

The system software will be designed for simple, reliable, and easy use by an operator at the process line with minimal training. The system will allow a technically degreed, computer knowledgeable (but not proficient) supervisor without a computer science or related degree to develop operating-plans, data-sheets, calculation macros, etc.

The system will allow programming of operating-plans, data forms, and instructions by engineers/scientists having limited knowledge about computer systems and languages. The selected language shall be menu driven with simple "English language" driven programming capability. A Lotus 1-2-3 or similar, common, easy-to-use software format will be used.

Data inputs from experimental runs will be by manual input at a local terminal. Operating plans will be developed on a separate computer at a remote location and transferred to the system via floppy disk. Output from the CAPS system will be to a local monitor with option for hard-copy output to a local printer or floppy disk.

All code will be modular to facilitate independent testing of individual or linked modules and to allow future revision of existing modules or addition of new modules. The system will be designed to allow growth and evolution in step with technology improvements and a continuing research program.

VI. CONCLUSION

The primary benefit of a materials accounting system to the plant operator is that it will help him to understand and follow the operation and performance of his plant. With data from the MC&A system, he can ascertain the impact of minor changes on performance. The process can thereby be fine-tuned to give optimum performance. Any deviation from optimum performance can be detected and conditions restored to those that are optimum for the particular plant and operating environment.

The MC&A system should not hinder plant operations and production. Operations personnel should use the MC&A system to provide an enhanced understanding of process systems performance. MC&A personnel can provide assistance in the planning stages in determining where accounting will be a problem so operations can use their time productively. In summary, Operations personnel can use an MC&A system to their advantage rather than letting the MC&A system take advantage of them.

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