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CONF-890736--33

DP-MS--89-22

DE89 014143

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Received by OSTI
JUL 17 1989

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A paper proposed for presentation and publication
INMM Annual Meeting--1989
Orlando, Florida
July 9-12, 1989

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*This paper was prepared in connection with work done under Contract No. DE-AC09-76SR00001 (now Contract No. DE-AC09-88SR18035) with the U.S. Department of Energy.

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ABSTRACT

One of the facilities at the Savannah River Plant includes eight high-technology microcomputer based nondestructive assay systems. These assay instruments were developed and fabricated for this facility by the N-1 group at Los Alamos National Laboratories. Thirty two additional NDA systems of three types are also used in this facility. These instruments provide valuable service for accountability and material control and in addition for nuclear criticality safety and process control. While this equipment is assembled from more mundane commercially available or simple, locally constructed mechanical assemblies plus commercially available instrumentation, some mechanical and instrument arrangements are unique and similar systems have not been seen in many SNM handling facilities. A special procedure providing traceability of calibrations to national measurement standards is used for most of this equipment. This paper will concentrate on the mechanical and instrument arrangements of these blue collar systems, their calibration and how they have been useful in this process.

INTRODUCTION

Discussions of special nuclear materials (SNM) accountability measurements concentrate, justifiably, on high technology, high performance methods and how the leading edge of the technology is being advanced. Most measurements based on older methods providing lesser performance are often deemed too routine or mundane to discuss. Many people new in the business and some more experienced have overlooked or forgotten the usefulness of these well established techniques. Some current processes no longer include many instruments of this class. Often, in older processes, such instruments have not been updated with state-of-the-art equipment and methods and have become unreliable through disuse and lack of attention. This is unfortunate since these relatively inexpensive, mundane Blue Collar measurements provide a valuable extension of material surveillance and offer additional benefits for nuclear safety, environmental protection, and production assistance.

NDA Instrumentation Classes

A complete SNM accountability system information base requires a variety of measurements. These may be divided into five basic classes: classic accountability measurements, high performance nondestructive assay (NDA) systems, data from existing process monitors, common fixed radiation monitoring systems and portable measuring instruments. Classic measurements such as weight, volume and destructive analysis of representative samples have been extensively developed to provide acceptably high accuracies, as long as adequate controls are applied and enforced. High technology NDA systems have been intensively developed. Performance can now exceed that routinely achievable with some of the classic measurements. Higher confidence in results is also possible with NDA systems due particularly to fewer variables, most notably where sample repeatability is a problem or where procedures are complex. However, each application for NDA systems seems to be unique, particularly physical arrangements and program designs. Such unique systems are generally expensive, both in cost and in time to design, fabricate, program, test and to develop the physics. These instruments are also relatively complex to operate and maintain.

The remaining three classes of measurements consist of the lower performance, Blue Collar systems. Instruments used are much less complex and costly and are usually faster allowing wider application and process coverage with more timeliness of data. Measurements of the third class of measurements are obtained mostly from existing process monitoring and control instruments. Several papers (reference 1) in the past few years have encouraged more extensive use of this data in accountability systems. Newer facilities often use computer based distributed process control and monitoring systems from which data can be easily accessed for the accountability system.

The final two measurement classes mostly include radiation monitoring instruments of more traditional design. Class four systems are primarily fixed installations, class five, portable instrumentation. These two groups are often ignored in discussions of modern accountability and NDA measurements. Unfortunately, these systems are also omitted from some facilities as being too inaccurate or unreliable for continuous use in industrial environments. Considerable improvement has been made in the past few years in equipment design, reliability and knowledge of application. Major benefits of these systems now are: relative simplicity and reliability, lower cost, compactness (especially detectors), ease of maintenance, and usually much faster "continuous" response. Most system components are available from several competitive commercial sources and system development costs, due mostly to simplicity and lack of infinite programmability, are frequently relatively low. Major limitations are usually: poor discrimination among competing data, low relative accuracy, and poor stability in under-designed or over-applied systems. Ultimate measurement sensitivity seems comparable to high performance NDA systems in many situations.

An SRS Accountability Data Base

One of the facilities at the Savannah River Site (SRS) employs all five classes of measurements to provide the information base for a near-real-time accountability system. Eight high performance NDA systems (Table 1) were developed at the Los Alamos National Laboratory (LANL), group N-1, specifically for this process. These instruments and their high performances were discussed in a previous paper (reference 2). Several of these NDA systems provide measurement precisions better than 0.2%. Standards, some with traceable accuracies better than 0.03% $\pm$ 1σ (reference 3), have been developed for them.

TABLE 1. High Performance NDA

	Precision	Standards
• GAMMA ASSAY		
- At-Line Solution Assay (ZEA)	0.12%	0.05%
- Low Density Scrap Assay	0.5	0.1
- Low Density Waste Assay	4	1
• NEUTRON ACTIVATION		
- Finished Product Shuffler	0.15%	0.03
- High Density Scrap Shuffler	0.17	0.03
- High Density Waste Shuffler	5	1
• NEUTRON SELF INTERROGATION		
- Receipts Assay Monitor	1	0.05

This facility also includes thirty instruments of the fourth class (with 15 more currently proposed) and eleven (plus 1 proposed) of the class five portable instruments. Detectors and hardware used in the fixed installations have been found reliable enough for use in limit monitoring service. These systems shut the process down if limits are exceeded and the process is not operated unless these monitors are also fully operational. Some of these instruments are also used to provide additional confirmation of nuclear criticality safety. These systems have been designed to be free from any single unannounced failure not resulting in an automatic shutdown.

Stand Alone Instruments

Three groups of instruments (Table 2), mostly gamma monitors using sodium iodide (NaI(Tl)) detectors, were developed and installed in this SRS process facility. The first group consists of three simple stand alone instruments (figure 1) used to provide approximations or limits (go/no go) tests. The first of these (figure 2), the Low Density Scrap Sorter (LDSS) allows small (two liter) low density scrap cartons to be sorted quickly (2 seconds) into relatively clean (< 4 μCi) unreclaimable items or those requiring an accurate assay. This reduces demand on a high technology segmented gamma scanner (LDSA) which requires over eight minutes to assay a carton. The second instrument called the Pot Monitor, is similar in design. It is used to confirm that a process container of specific design (pot) is free from excess SNM holdup and safe to store without prior cleaning. The third similar instrument, the In-Process Solution Assay (IPSA) system, provides a rapid (10 seconds) approximate (5%) assay of sample vials of process solutions. These approximations allow problems with unexpected sample concentrations to be quickly detected and corrective measures taken. These samples are subsequently assayed using the high performance At-Line Solution Assay (ALSA) system which can provide measurement precisions better than 0.2% but requires more than one half hour for each measurement. Commercially available stabilized assay meters including ^{241}Am seeded NaI(Tl) detectors or instruments assembled from standard NIM (nuclear instrument module) components have been used successfully for these monitors. Instrument stability and reliability have been good enough to allow calibrations to be made only semi-annually. Daily source checks are used to confirm operation and little maintenance or adjustment has been required.

TABLE 2. Blue Collar NDA Systems

- STAND ALONE NDA
  - Low Density Scrap Sorter
  - Pot Monitor
  - In-Process Solution Assay
- BREAKTHROUGH MONITORS (26 ea. + 15)
  - Saddle
  - Tank
  - Tubing
  - Strap-On
- PORTABLE MONITORS
  - Smart
  - Frisker
  - TLD

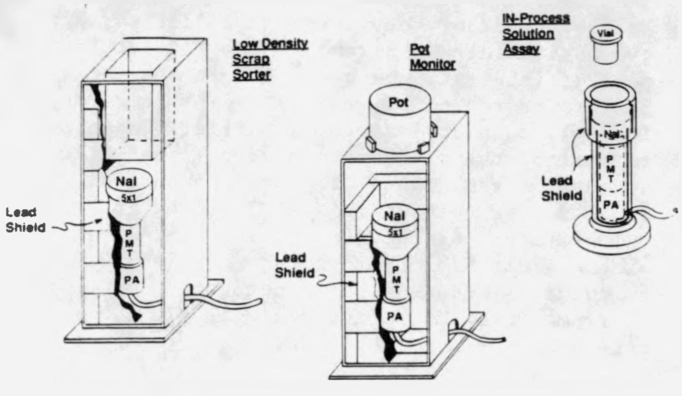

FIGURE 1. Stand Alone Blue Collar NDA

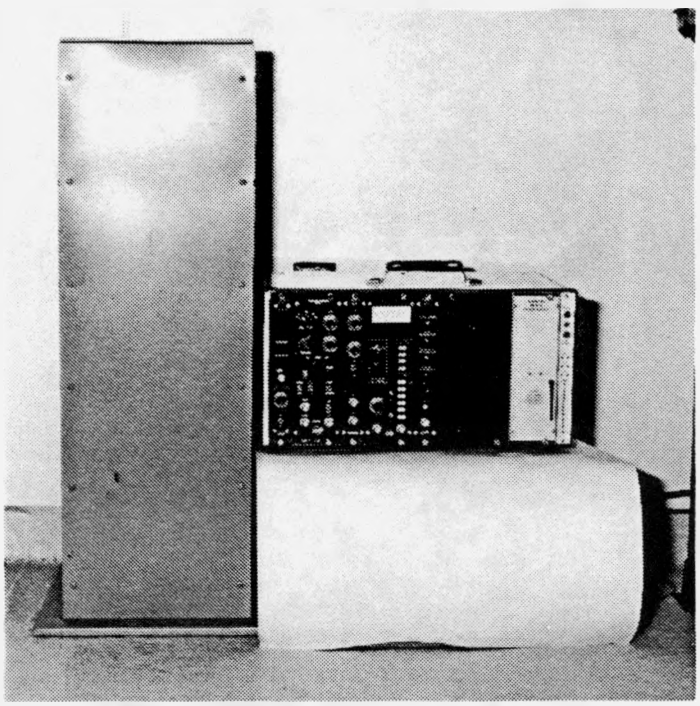

FIGURE 2. Low Density Scrap Sorter

Breakthrough Monitors

The second group of instruments, referred to as Breakthrough Monitors are used for in-line surveillance of liquid process streams. Most have alarms connected to valves to shut processes down if concentrations exceed preset limits. Twenty-six monitors currently installed include three basic styles (figure 3) of detector assemblies with differing sensitivities and flow capabilities. Fifteen additional monitors of a fourth style are currently being considered. The first style, called a saddle type, is the least sensitive (>50 µCi/l) but can accommodate any flow since detector and shield can straddle an existing process pipe. Prime limitations of this arrangement are volume of solution viewable, background and accuracy for a less than full pipe. Some models (three are used in our process) of this style are commercially available. The second style, the tank type, is commercially available. A two inch diameter NaI(Tl) detector two to six inches long is placed in a well in the center of a six liter tank. The tank inlet is designed to mix the solution by swirling. The solution outlet at the bottom of the tank is self flushing and is piped to create a fixed tank volume with a weir type trap. A gas bypass is provided from the tank to the outlet. Sensitivity is about 4 nCi/l with three inch thick lead shielding. Flow capacity is up to about 50 liters per minute but volume turnover at very low flow rates would be unpredictable. The third style breakthrough monitor, the tubing type, is designed for low intermittent flows of possibly thermally hot process solutions. More than 130 feet of half inch ID Teflon® easy to clean tubing (over 20 liters volume) is wound in rising layers to permit degassing. Flow rates up to 10 liters per minute can be accommodated. A two inch diameter by twelve inch long NaI(Tl) detector and one inch thick lead shielding can provide sensitivities as low as one nCi/l. A larger six inch hexagonal detector could be accommodated for additional sensitivity but more shielding would be required. The fourth style breakthrough monitor being considered will consist of a small NaI(Tl) (1/2 x 1/2 inch to 3/4 x 3 inch) detector assembly strapped to an existing small process pipe with relatively thin lead shielding wrapped around both. These monitors will be used in relatively clean areas to confirm continued cleanliness (freedom from backflow) in cold feed pipes.

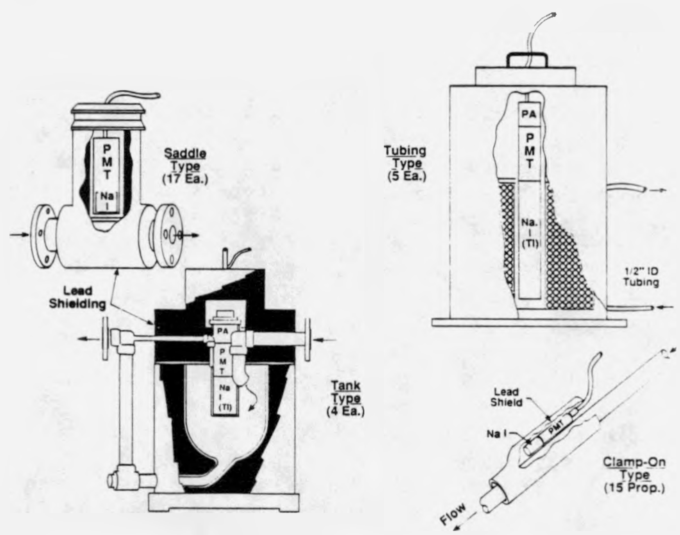

FIGURE 3. Breakthrough Monitors

Safety Qualified Instrumentation

Instrumentation used for breakthrough monitors is similar to that used for the stand-alone systems above. However, some of the breakthrough monitors are utilized for effluent lines flowing into tankage that is not geometrically favorable. Instruments for these systems have been designed to provide alarm protection that is free from unannounced single failure. For these monitors, the basic instrument (figure 4) consists of a NaI(Tl) crystal, photomultiplier and preamplifier detector assembly, a high voltage supply, linear pulse amplifier, single channel analyzer (SCA) plus an alarming ratemeter. To achieve acceptable monitoring stability, a ^{241}Am seed is added to the detector crystal and a gain stabilized amplifier with SCA is used to lock onto the reference pulse from the seed. An alarm module is added to monitor the fixed pulse rate from the ^{241}Am as well as the amplifier gain control circuit. This rate monitoring (i.e. tracer) continually confirms operability of the pulser seed, crystal, photomultiplier, high voltage supply and the amplifier circuits.

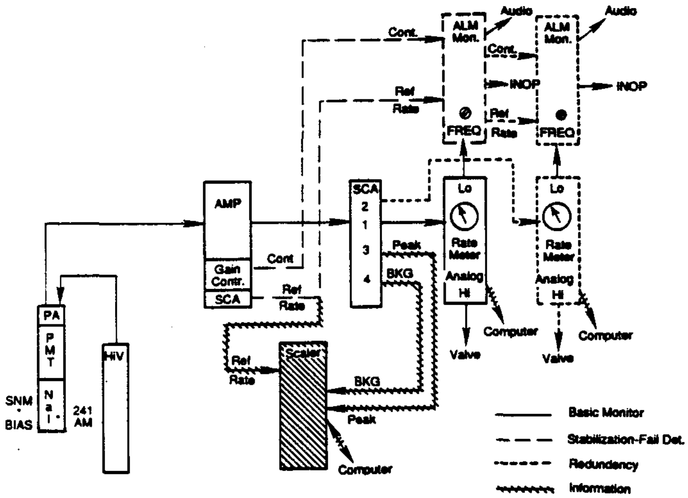

FIGURE 4. Monitor Instrumentation

To confirm operation of the SCA and ratemeter, an additional alarm is added to the ratemeter. The original ratemeter alarm is set normally as a high concentration alarm and is wired to an external valve to shut the process down (also occurs with loss of power). The additional alarm is set low to trip if the rate drops below a value just above zero. A small SNM bias source fixed to the detector crystal keeps the minimum countrate above this alarm if the ratemeter, SCA and other components remain operable. Ratemeter alarms are also connected to the alarm monitor which provides an additional alarm output to warn of inoperability and also causes a process shutdown. Since the alarm circuits could fail without warning and prevent the protective response, a second ratemeter fed from a second SCA and controlling a second process valve, plus a second alarm module have been added for redundancy.

An added feature of this instrument provides data for input to an accountability computer. A three channel scaler plus timer is remotely programmable to select the scaler channel to be read or the data collection period. Normally, long integrals are collected until an upset is detected through the ratemeter, the analog outputs of the ratemeters also being monitored by the computer. During the upset, the computer can collect short integrals and track the problem. Two inputs to the scaler are connected to the output of the linear amplifier through two additional SCA circuits, one set for the peak of interest, the other set to monitor a background region of interest. The third scaler input is connected to the amplifier SCA output to monitor the ^{241}Am reference peak and allow computer surveillance of proper operation. The local scaler readout is useful during instrument calibration. Since a four channel SCA in a single width NIM module became available at the time this system was being designed, a complete instrument will fit into a single NIM bin providing a considerable saving of cost and space.

Traceable Calibration

Current criteria for Quality Assurance require safety monitors as well as accountability data generating instruments to be calibrated traceably to national standards. A special procedure has helped to satisfy these requirements. Traceable rate, time and voltage measurements are routine. Methods to acquire SNM standards of traceable quantities, while not as simple, are also well established. However, methods to set pulse heights and SCA windows at exact traceable energies around a peak of interest have been less exact. Use of the sampled DC or SVA (slow voltage analysis) mode provided in some pulse height analyzers (PHA) greatly simplifies this task. An easily obtained certified DC voltage source can be measured at the exact values required for the peak of interest. Response of some PHAs can be calibrated as a qualified transfer standard (easily better than ±0.1 channel or 1 part in 10,000) by padding the ADC input resistors.

Portable Instruments

The fifth class of instruments includes mostly portable equipment used to measure SNM held up in process equipment and facilities. These instruments (figure 5) are typified by those used most often for health protection surveys. Recently developed, microprocessor based "smart" versions of these instruments have been particularly useful. These instruments can accept several probes with a minimum of reprogramming and can be easily switched from ratemeter to scaler response. We use these instruments in evaluation of holdup in overhead pipes and ducts (small detector on telescoping handle) and to search for potential SNM accumulation on bottoms of large tanks (tripod probe with telescoping handle). Portable PHA's are also used with these probes for some of these measurements.

Another useful instrument is the less versatile "smart" SNM "frisker" of the type developed at LANL for use by security inspectors to manually search personnel and vehicles. These portable radiation monitors are most useful in the ten second integrating mode in assessment of the SNM holdup on walls of large tanks. Special procedures have been developed for calibration and calculation of the statistical certainty of results.

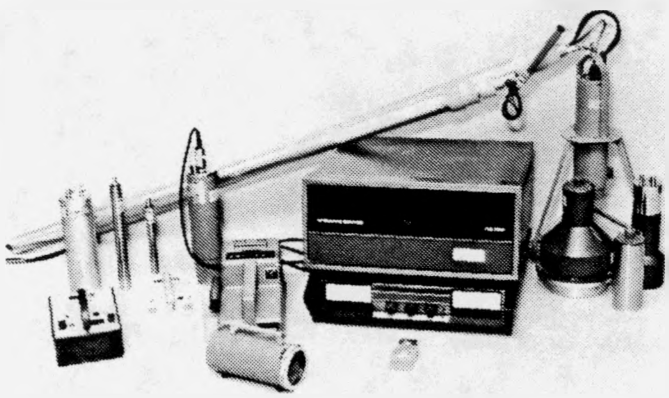

FIGURE 5. Portable NDA Instruments

An additional monitoring system not yet implemented will be used to inexpensively monitor air ducts, etc., primarily to confirm freedom from significant accumulation of SNM in large or difficult to access areas. Two thermoluminescent dosimeter (TLD) crystals are mounted in a special shielded holder designed to measure both the SNM and background. These assemblies will be placed in numerous appropriate locations on normally clean pipes, ducts and possibly tanks. Periodic checks (monthly or semi-annually) of these detectors at a base station reader would confirm most areas to be free from significant SNM contamination since the last reading. Laborious hand searches of many areas could be avoided. Areas needing additional assessment with more thorough coverage would be quickly identified. Integrals of problem areas using arrays of more closely spaced detectors would also be possible.

REFERENCES

1) Proceedings, Third International Conference on Facility Operations-Safeguards Interface, American Nuclear Society, November 29, 1987, page 209.

2) NDA for a Facility at SRP, RV Studley, Page 326, ibid.

3) A Nondestructive Assay Standards Program at SRP, INMM 28th Annual Meeting Proceedings, R. V. Studley, July 12, 1987, page 661.