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Title: AN NDA SYSTEM FOR AUTOMATED, INLINE WEAPONS COMPONENT DISMANTLEMENT

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AN NDA SYSTEM FOR AUTOMATED, INLINE WEAPONS COMPONENT DISMANTLEMENT*

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ABSTRACT

The Automated Retirement and Integrated Extraction System (ARIES) is a new development and demonstration glove-box line planned for installation at TA-55. The mission of ARIES is development of advanced technologies for disassembly of retired plutonium weapons components. ARIES is subdivided into the following subsystems: Receiving (airlock to system controlled atmosphere), Disassembly (parts are separated into hemishells), Plutonium Consolidation, Americium Removal, Decontamination (removal of trace plutonium from nonplutonium parts), and Nondestructive Assay (NDA). The ARIES NDA subsystem consists of four computer-based NDA instruments (calorimeter, gamma-ray isotopic system, segmented gamma scanner, and an active/passive neutron multiplicity counter); a robot to load and unload the instruments; and a host computer to sense and control the instrument status, schedule measurements, archive the results of the assays, and direct the activities of the robot. The NDA subsystem will be fully integrated into the ARIES process line and will provide assays of nuclear material that are inherently safer and more efficient than nonautomated systems.

INTRODUCTION

Historic changes are now occurring in United States nuclear deterrence policies. As a result, the requirements placed on the United States nuclear weapons laboratories and the nuclear production complex have changed dramatically. Whereas old policies relied on deterrence by numbers (with a focus on the former Soviet Union) and on large scale production, the new Department of Energy (DOE) weapons complex will rely on deterrence by capability with a focus on nonproliferation. The future complex will focus on nuclear materials management and long-term, secure storage of nuclear material. Previously, the primary cost in the weapons complex was associated with building new weapons. Now the major costs will be associated with weapons dismantlement and decontamination and with addressing safeguards; security; and environment, safety, and health needs.

Clearly, the development of advanced dismantlement technologies will play an integral part in the changing role of the DOE. As an important component of this effort, ARIES (Automated Retirement and Integrated Extraction System) is designed to provide a test bed for the development of technology for the dismantlement of the primaries of nuclear weapons (pits). ARIES will integrate and automate the disassembly of pits, consolidation of plutonium, removal of americium from this plutonium, and in line measurement of the products and wastes by state of the art nondestructive assay (NDA) methods.

No integrated method now exists for the dismantlement and recovery of nuclear material from many weapons designs. Even those assemblies for which recovery techniques have been established require extensive manual handling (with associated personnel exposure to radiation) and result in considerable waste generation during dismantlement. The next generation nuclear materials processing facility (Complex 21) will rely on site returns to provide its feed. ARIES will provide the methods to satisfy this goal while at the same time reducing waste, lowering personnel radiation exposures, and operating to the highest standards of safety and security.

OVERVIEW OF THE ARIES PROCESS

Pits containing Plutonium will be the input for the ARIES process line and the output of the process will be americium free plutonium metal. Several integrated subsystems are necessary to accomplish this as outlined in Fig. 1.

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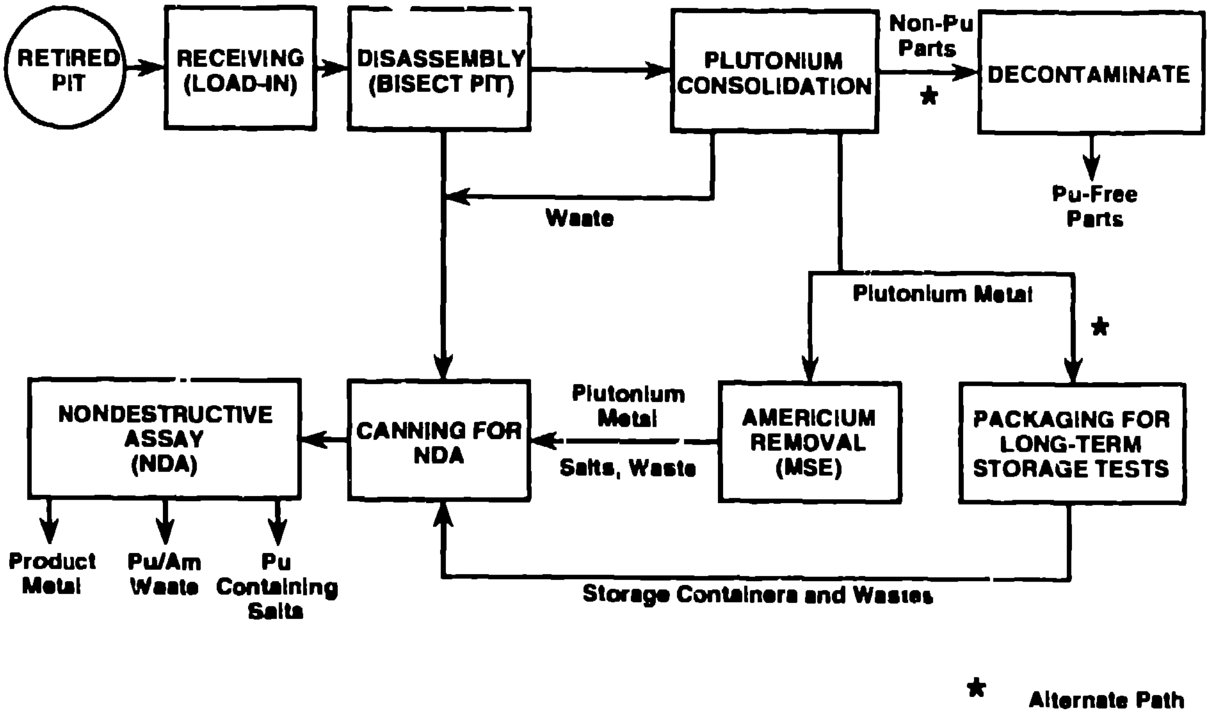

Fig. 1. Materials flow in the ARIES process.

Receiving: Pits will be introduced into the ARIES line through a contamination control enclosure.

Disassembly: A cutting lathe is used to separate the pit into two hemishells. The lathe is loaded and unloaded robotically.

Plutonium Consolidation: The hemishells are placed into the consolidation apparatus and nearly 100% of the plutonium is collected as an impure metal ready for subsequent americium removal.

Americium Removal: Highly radioactive ^{241}Am is separated from the consolidated plutonium by an automated molten salt extraction (MSE) process.

Nondestructive Assay: All products and wastes leaving the ARIES process will be assayed in-line for plutonium accountability and waste management purposes. State of the art NDA techniques (calorimetry, gamma-ray isotopics, segmented gamma scanning, and neutron counting) will be used together with a material handling robot.

Figure 2 shows the ARIES glove box line planned for installation at the Los Alamos Plutonium Facility.

ARIES NONDESTRUCTIVE ASSAY SUBSYSTEM

The ARIES NDA subsystem consists of four computer-based NDA instruments (calorimeter, gamma-ray isotopic system, segmented gamma scanner, and an active/passive neutron multiplicity counter); a robot to load and unload the instruments; and an NDA host computer that will sense and control the instrument status, schedule measurements, archive the results of the assays, and direct the activities of the robot. The flow of material in the ARIES NDA system is from the main ARIES glove-box line into a temporary material staging area, through the NDA instruments, and then out of the glove box line for final disposition to storage, process lines, or waste.

The ARIES NDA subsystem, described more fully below, is shown in block diagram form in Fig. 3. Figure 4 illustrates the interface of the instruments to the NDA glove box.

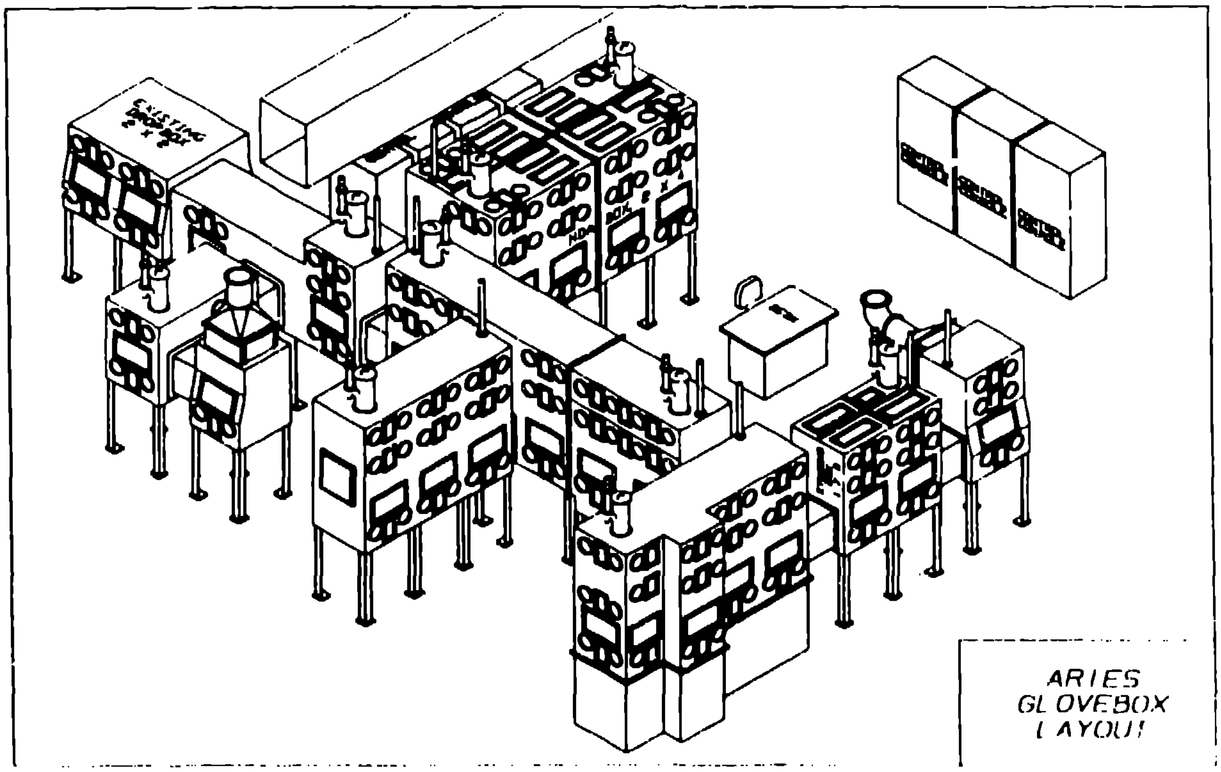

Fig. 2 The ARIES glove-box line

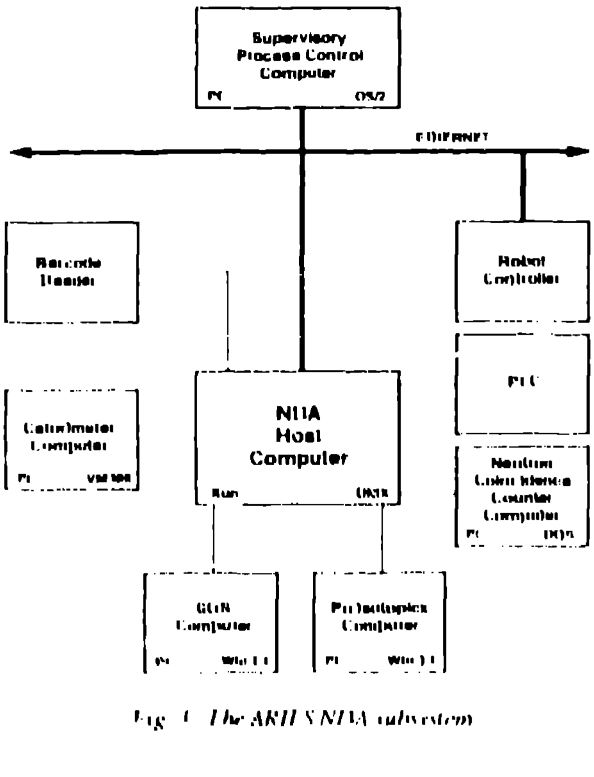

Fig. 3 The ARIES NDA subsystem

NDA Host Computer

A typical plutonium sample will be received into the sample holding area from the MSE operations. Data, such as sample identification and description and analyses requested, will be entered into the NDA host computer by the operators (manual operation) or from the ARIES process control computer. The sample identification will be verified in the NDA glove box with a bar code reader. The NDA host computer will schedule analyses, keep track of the status of the four NDA instruments, request loading and unloading of the instruments by the robot, request modification of the instrument configuration (neutron counter) by the robot, archive results, and prepare reports on the items that have been analyzed. The NDA host computer will combine the assay results from the various instruments to give a complete assay for grams of plutonium and americium. Complete assay results will be reported by the NDA host computer to the operators or to the ARIES process control computer. The NDA host computer will report complete assay results to the operators and the ARIES process control system computer.

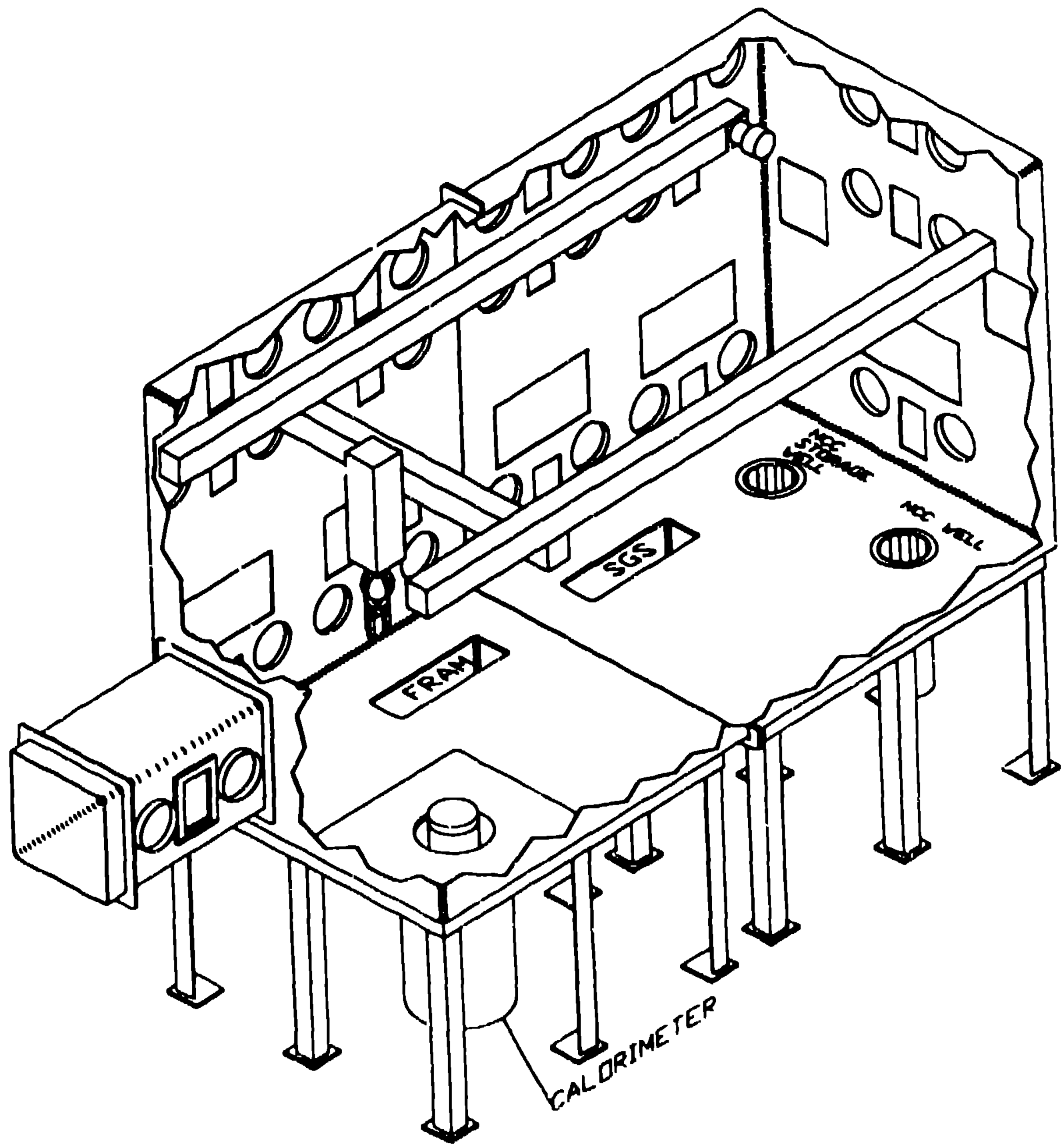

Fig. 4. Cutaway view of ARIES NDA glove box

NDA Automated Material Handling Robot

The NDA robot will load the instruments and, after analysis is complete, unload the instruments and return the items to the staging area. The robot will also be responsible for changing the configuration of the neutron counter to accommodate different methods of assay. After all of the assays requested for an item are complete, the NDA robot will load the items into the between box shuttle and they will be removed from the ARIES glove box line for further chemical processing, to storage, or as waste.

Calorimeter

The ARIES calorimeter, designed by EG&G Mound Applied Technologies, is a water-bath heat exchanger calorimeter modified for in-line glove box use. The calorimeter will be attached to the glove box through a single opening in the bottom of the box and preserve the integrity of the glove box. That is, the inner chamber of the calorimeter is also the glove box containment. The water jacket is around the outside of the calorimeter and there is no danger of leakage into the glove box enclosure.

The wattage range and measurement precisions for the instrument are specified to be

0.1 watts ± 2.0 % through 10.0 watts ± 0.1 % .

The 7-in.-diam sample well of the calorimeter will accommodate the ARIES sample can (standard food pack, #502, "2-lb coffee can") which is 5.125 in. in diameter and 6.5 in. high.

The calorimeter computer will be a PC with a VM386 operating system. The calorimeter program will use both equilibrium and prediction methods of "end-point" detection to determine if an assay is complete. Results of standard, sample, and baseline runs will be stored on disk for later use. The results of the measurement, in watts, will be passed to the NDA host computer to be combined with the gamma-ray isotopic measurement of specific power (watts/gram plutonium) to give an assay for total plutonium.

Plutonium Gamma-Ray Isotopic System

The software for the Plutonium Gamma-Ray Isotopic System will be a newly developed PC version of the FRAM (Fixed Energy, Response Function Analysis with Multiple Efficiencies) software[1] that has been used in the NMT-4 NDA Laboratory since 1989.

The FRAM software will measure the plutonium isotopic distribution and ^{241}Am fraction in all the plutonium bearing samples produced by ARIES. Typical measurement times will be 20 to 30 min for samples with a few hundred grams or more of plutonium to 1 to 2 h for samples with a gram or so (the practical lower limit for the system). The gamma-ray isotopic measurement produces values for the specific power (P_{eff} in watts/gram plutonium) and the effective ^{240}Pu fraction ($^{240}Pu_{eff}$) for the plutonium in the sample. These quantities are combined with the results of calorimetry (P_{eff}) or neutron counting ($^{240}Pu_{eff}$) to give an assay result of grams of plutonium. The individual isotopic fractions and ^{241}Am fraction are also used in the coincidence counter analysis. Typical measurement precision of P_{eff} for pure metal samples is expected to be about 0.3% (one standard deviation) for a 30 to 60 min assay time. The precision for $^{240}Pu_{eff}$ is expected to be about 2.0% for the same assay time. Measurement accuracy is expected to be <0.25% for P_{eff} and <1% for $^{240}Pu_{eff}$ for metal samples. The heterogeneous matrix of the MSE salts makes analysis of these materials more difficult. For the MSE salts, the measurement accuracy is expected to be in the 5% range for both P_{eff} and $^{240}Pu_{eff}$.

The gamma-ray spectra will be obtained with a single lead-shielded, high-purity, planar, germanium detector connected with appropriate electronics to a PC-based multichannel analyzer. The detector will be mounted on a computer-controlled, stepping-motor-driven platform and will be able to move toward or away from the sample being measured. This will allow for optimization of sample count rates. The detector, shielding, and support platform will sit on the floor under the glove box floor, outside the containment, and will view the sample through a well mounted to the floor of the glove box. The computer system will be a PC operating under Windows 3.1/DOS.

Inside the glove box, the robot will place the sample on the turntable of a scanning mechanism inserted into the glove-box well. The scanning mechanism rotates the sample and scans the sample vertically past the uncollimated detector.

Segmented Gamma Scanner (SGS)

The software for the ARIES segmented gamma scanner will be a new PC version of software already developed by Los Alamos Safeguards Assay Group N-1.

The segmented gamma scanner will measure the amount of an isotope of plutonium, usually ^{239}Pu, (or ^{235}U or ^{241}Am) by comparing the intensities of gamma rays emitted from narrow horizontal segments of a sample with the radiation emitted by a calibration standard. The measurement is corrected for matrix attenuation by using an external ^{75}Se transmission source. Because this method measures amounts of specific isotopes, the measured isotopic fraction is required to convert the results to the mass of each element. The SGS result will be combined with the measured isotopic fraction in the NDA host computer.

The glove box well and scan table will be very similar to that described for the ARIES gamma-ray isotopic system (see above). The overall hardware design for the SGS is similar to that of the gamma-ray isotopic system with the addition of a transmission-source holder and shutter mechanism for the transmission source. The detector platform will be fixed for the SGS.

ARIES Neutron Counter

The ARIES neutron counter (ARNC) will be designed to have flexible capability to handle both plutonium and uranium items. The plutonium capability of the counter will consist of passive neutron coincidence counting, passive multiplicity counting,[2] and combined active/passive coincidence counting. Passive multiplicity counting may be used to measure some materials with (α, n) contributions arising from the sample matrix (MSE salts). Neutron counting will be used primarily to measure those items that have low masses of nuclear material and therefore cannot be measured by calorimetric assay.

Active interrogation capability for the assay of high-density ^{235}U will be designed into the ARNC. This capability requires two americium-lithium isotopic sources for active irradiation of the sample. The americium-lithium sources will be contained in a separate set of end plugs for the ARNC. The robot will change end plugs when the instrument is switched from passive mode. The americium-lithium sources will each have neutron outputs of approximately 10^5 n/s.

A combined active/passive[3] capability will also be provided. This will require a third set of end plugs. The ARNC will be the first system with capability to apply four different measurement methods (passive, passive multiplicity, active, and active/passive) to a single sample. The initial implementation of the system will be used to define the best technique for each sample type. The ARNC computer will be a PC operating under DOS.

ASSAY REQUIREMENTS

The material to be analyzed in the NDA box will be mostly plutonium metal, plutonium bearing MSE residues, or waste contaminated with plutonium. Materials will be analyzed according to the level of nuclear material and the item matrix. The "amount of SNM" in the table is based on the optimum operating ranges for the indicated instrument. The assay paths of the various materials are summarized in the table below. Initially the instruments will analyze only plutonium materials. At a future date, the NDA instruments can be set up to assay uranium items generated by the ARIES processes.

CONCLUSION

The ARIES integrated system is a test bed for the development of processes that remove plutonium from site-returned pits with the greatest possible safety and consideration of the environment. These goals dictate design and installation of a fully integrated set of processes that minimize fully integrated set of processes that minimize waste, enhance worker safety through automation, and employ state-of-the-art processes and instrumentation.

Measurement Method of Choice for Material Generated by the ARIES Project

Item to be Measured	Amount of SNM	Measurement Method of Choice			
		SGS	Calorim.	g - Iso	ARNC
MSE Pu metal product	> 100 g		X	X	Possible
MSE Salt	> 50 g Pu < 50 g Pu	 X	X	X	Possible
Pu Contaminated Bisection Waste	< 10 g Pu	X		Possible	Possible
Pu Contaminated High Density Waste	< 50 g Pu			X	Passive
Pu Contaminated Low Density Waste	< 50 g Pu	X		Possible	
Enriched U Pieces	0.5 - 1 kg				Active
Depleted U Pieces	0.5 - 1 kg				Passive
Depleted U Contaminated Low Density Waste	No good assay method with this system for depleted uranium at low levels				
Enriched U Contaminated Low Density Waste	< 5 g U	X			

The ARIES NDA subsystem is an automated, in-line, complete NDA laboratory. The system has been designed to assay any of the types of material that the ARIES process will produce with the most up to date measurement methods. The automated material handling robot will reduce operator radiation exposure to radioactive material. Because all of the instruments are in-line, items will not have to be bagged out, again reducing operator exposure to radiation. Safeguards will also be enhanced because the materials will not have to be removed from the process line for measurement.

ACKNOWLEDGMENTS

The ARIES project draws on resources from the Nuclear Materials Technology (NMT), Mechanical and Electronic Engineering (MEE), Applied Theoretical Physics (X), Design Engineering (WX), and Nuclear Technology and Engineering (N) Divisions at Los Alamos as well as resources at EG&G Rocky Flats and EG&G Mound Applied Technologies. The NDA portion alone involves approximately 15 people in the Safeguards Assay group (N-1) and the Nuclear Materials and Accountability group (NMT-4) at Los Alamos and additional resources at EG&G Mound. The work of all has been instrumental in the successful development of ARIES to date.

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