32.1
2-8-83

1

Dr. 1167
RFP 3256

I-1748

**DEFENSE TRANSURANIC
WASTE PROGRAM**

DO NOT MICROFILM
COVER

**Nondestructive Radioassay for
Waste Management — An Assessment**

June 1981

MASTER

Rockwell International
ENERGY SYSTEMS GROUP
ROCKY FLATS PLANT

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

RFP--3256

RFP-3256
UC-70

DE83 006081

NONDESTRUCTIVE RADIOASSAY FOR
WASTE MANAGEMENT - AN ASSESSMENT

George D. Lehmkuhl

Rockwell International
Energy Systems Group
Rocky Flats Plant
Golden, Colorado 80401

June 1981

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It has been reproduced from the best available copy to permit the broadest possible availability.

Prepared by
Transuranic Waste Systems Office
for
DEFENSE TRANSURANIC WASTE PROGRAM
UNITED STATES DEPARTMENT OF ENERGY
Under contract DE-AC04-76DP03533

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

CONTENTS

<u>Item</u>	<u>Page</u>
ABSTRACT.....	1
INTRODUCTION.....	3
NEED.....	6
REVIEW OF PRESENTLY USED INSTRUMENTS.....	11
Hanford Engineering Development Laboratory (HEDL).....	12
Idaho National Engineering Laboratory (INEL).....	13
Los Alamos National Laboratory (LANL).....	16
Mound Facility (MF).....	17
Oak Ridge National Laboratory (ORNL).....	19
Pacific Northwest Laboratory (PNL).....	20
Rockwell Hanford Operations (RHO).....	22
Rocky Flats Plant (RFP).....	26
Savannah River Plant (SRP).....	30
TRU WASTE MANAGEMENT PROGRAM NONDESTRUCTIVE ASSAY (NDA) INSTRUMENTATION TASKS.....	33
Status.....	33
Specific Projects.....	34
MEGAS Counter.....	34
Passive Neutron Crate Counter.....	37
Active Interrogation Using Neutron Sources.....	40
Differential Die-away Technique (DDT) for Active Neutron Interrogation.....	41
Cf-252 Based Shuffler System for Active Neutron Interrogation.....	43
ORNL Drum Counter Prototype.....	45

ACKNOWLEDGEMENTS

I thank R. A. Harlan of the Rocky Flats Plant for his valuable assistance in collecting information and in reviewing this report. I also thank all those people at the various sites who supplied information for this report.

	<u>Page</u>
RHO Drum Counter Prototype.....	46
LINAC Interrogation Systems.....	48
Isotope and Matrix Identification/Correction.....	50
DISCUSSION.....	53
RECOMMENDATIONS.....	62
REFERENCES.....	65

TABLES

	<u>Page</u>
A. Waste Stored at INEL.....	7
B. Areas of Need for TRU Waste NDA Instrumentation.....	8
I. Instruments in Use at INEL.....	15
II. Radiometric Instrumentation Utilized in Waste Processing at Rocky Flats.....	29
III. Savannah River Plant - Summary of Waste Assay.....	31
IV. Counters in Use for TRU Isotope Bearing Materials in Smaller Containers.....	57
V. Counters in Use for TRU Isotope Bearing Materials in Drums.....	59
VI. Counters in Use for TRU Isotope Bearing Materials in Large Boxes or Crates.....	61
VII. Program Actions Dictated by Possible Administrative Decisions.....	64

ERRATA
FOR RFP 3256
NONDESTRUCTIVE RADIOASSAY FOR WASTE MANAGEMENT - AN ASSESSMENT
June 1981

Page 7, line 6 -- change "(matricies)" to "(matrices)"

Page 12, paragraph 1 -- delete last sentence "The laboratory ... product."

Page 12, paragraph 4, line 5 -- change "g/cm², using a 1000-second" to "g/cm³, using a 200-600 second"

Page 19, paragraph 4, line 2 -- change "2220" to "2220-B"

Page 20, paragraph 3, line 3 -- change "geranium" to "germanium"

Page 23, line 7 -- change "Crop" to "Corp"

Page 24, paragraph 3, line 3 -- change "millimeter" to "square millimeter"

Page 24, paragraph 3, line 6 -- change "extimated" to "estimated"

Page 25, paragraph 2, line 1 -- change "borenole" to "borehole"

Page 26, paragraph 1, line 11 -- change "reitred" to "retired"

Page 43, paragraph 2, lines 5 & 6 -- change "ranges from 0.3 to 30 nCi/g depending" to "is about 50 nCi/g and depends"

Page 43, paragraph 2, line 7 -- change "10" to "50"

Page 44, line 5 -- change "5" to "10"

Page 45, paragraph 3, line 2 -- change "durms" to "drums"

Page 47, line 9 -- change "Cf-242" to "Cf-252"

Page 48, paragraph 2, line 5 -- change "electron linac" to "linac electron"

Page 50, paragraph 1, line 4 -- change "matix" to "matrix"

Page 55, paragraph 2, line 8 -- change "contaners" to "containers"

ABSTRACT

Nondestructive Assay (NDA) for Transuranic Waste Management is used to mean "determining the amount of transuranic (TRU) isotopes in crates, drums, boxes, cans, or other containers without having to open the container." It also means determining the amount of TRU in soil, bore holes, and other environmental testing areas without having to go through extensive laboratory "wet chemistry" analyses. It refers to radioassay techniques used to check for contamination on objects after decontamination and to determine amounts of TRU in waste processing streams without taking samples to a laboratory. Generally, NDA instrumentation in this context refers to all use of radioassay which does not involve taking samples and using "wet chemistry" techniques.

NDA instruments have been used for waste assay at some sites for over 10 years and other sites are just beginning to consider assay of wastes. The instrumentation used at several sites is discussed in this report. Almost all these instruments in use today were developed for special nuclear materials "safeguards" purposes and assay TRU wastes down to the 500 nCi/g range.

The need for instruments to assay alpha particle emitters at 10 nCi/g or less has risen from the wish to distinguish between Low Level Waste (LLW) and TRU Waste at the defined interface of 10 nCi/g. Wastes have historically been handled as TRU wastes if they were just suspected to be transuranically contaminated but their exact status was unknown. Economic and political considerations make this practice undesirable since it is easier and less costly to handle LLW. This prompted waste generators to want better instrumentation and led the Transuranic Waste Management Program to develop and test instrumentation capable of assaying many types of waste at the 10 nCi/g level. These instruments are discussed in this report.

The need to monitor waste burial sites and TRU waste temporary storage sites has led to development of other instrumentation discussed in this report.

The possible need to process previously buried or stored wastes has led to research on other instrumentation methods not yet developed and tested.

The status and direction of present instrumentation development efforts are discussed in this report and recommendations for the direction of future development work are given.

INTRODUCTION

The development of instrumentation for radiation measurement has been an ongoing process for more than half a century. In recent years, the development of new detectors, electronic equipment, and computer process technologies have revolutionized the field of nuclear instrumentation. However, the development of technologies for the assay of α emitters and spontaneously fissioning nuclides have been of limited interest and continue to offer considerable challenges. In particular, the assay of nuclear wastes containing extremely low levels of transuranics is probably the most challenging area in the nuclear instrumentation area. Because of the limited applications of these instruments, there have been limited commercial efforts to develop instrumentation suitable for this application. The needs of the TRU Waste Management Program are rather unique; therefore, a special program initiative is necessary.

All low radiation level solid nuclear waste was lumped together and placed in shallow land burial prior to 1970. There was no perceived need to segregate transuranic wastes from LLW. With the introduction of a requirement to segregate transuranic wastes and place them in retrievable storage came the need to distinguish these wastes from the LLW, which could still be buried. The defined break point is 10 nCi/g of transuranics averaged over each container of waste. Initially all segregation was done by "place of origin". At many sites this meant any waste suspected of containing greater than 10 nCi/g of transuranic isotopes (because of the place of origin of the waste) was labeled as transuranic waste. This method is still used in many instances. As costs for special handling and final disposal of transuranic wastes have grown, waste generators and storage sites have felt increasing need to assay all wastes to separate out LLW and send it to less costly waste burial.

It was the recognition of this need for TRU waste assay that prompted the initiation of an assay instrumentation program for the TRU Waste Management Program. It is important to recognize that the assay of the TRU

contents of nonhomogeneous matrices are indeed difficult, but satisfactory methods with good precision (not necessarily good accuracy) can be designed from the present state of knowledge. These designs must be proven and tested, however; and this does not mean that additional advances in technology are unnecessary or unwanted.

The development of assay instrumentation for TRU waste monitoring is a challenging problem and there are well-known limitations to the existing instrumentation that are currently available to users. An important point to be recognized is that the accuracy of nondestructive assays does not have to compete with destructive radiochemical analyses. It would be a waste of resources to attempt to achieve such accuracies in nondestructive assay instrumentation. The main purpose of assay instrumentation is for classifying wastes to determine the subsequent handling and to keep a reasonably reliable inventory. These objectives can be attained through (a) adaptation of existing technologies, and (b) judicious combination of well-known principles to design and build newer instrumentation.

For routine personnel monitoring and health physics survey, nondestructive assay techniques have been developed by many of the national laboratories and there are commercially available units which can adequately meet this need. The assay of low-density, low level wastes routinely generated in research laboratories and production facilities can be accomplished by segregation into a few categories by administrative controls and then by the subsequent gross assay of the TRU contents. These assays can be reliably performed using well-developed technologies already available.^{32,33,34} For the dense waste forms and waste forms intermixed with activation and fission products, the assay techniques are less readily available. The main principles of these assay techniques are scintillation spectrometry, high-resolution γ -ray spectrometry, neutron coincidence counting, passive singles neutron counting, and active interrogation using nuclear particle sources and the monitoring of nuclear particles formed and/or activation products. Various forms of instrumentation using these

principles are in use at several of the waste generating sites, although their present applications are controlled by site-specific practices.

Through significant resource investments over the past two decades, the nuclear materials safeguards programs have extensively investigated the scientific principles behind almost all the suggested methods for TRU assay. Although the long-term requirements of the TRU programs are quite different from the requirements of nuclear materials safeguards programs, the differences are primarily in engineering parameters, rather than in principles. In other areas of TRU instrumentation needs, technology developed by health physics programs is similarly applicable. Examining the present state of the art in assay instrumentation for transuranics, it is seen that most of the assay instrumentation needs of the TRU program can be met by the adaptation of technologies developed under the nuclear materials safeguards and health physics programs.

NEED

TRU waste is material contaminated or suspected of being contaminated with alpha-emitting radionuclides of long half-life to a level greater than 10 nCi/g. The TRU waste classification includes all transuranic nuclides except Pu-238 and includes the U-233 isotope and its daughter products. Transuranic wastes result primarily from irradiated fuel reprocessing, fabrication of plutonium, discarding failed equipment, and in decommissioning nuclear generating and processing facilities. Generally, little or no radiation shielding is required, but some TRU nuclides have energetic gamma and neutron emissions that require shielding.

Prior to 1970 the TRU waste, along with most of the other radioactive wastes, was disposed of by shallow land burial. In 1970, the Atomic Energy Commission (now DOE) initiated a policy directing that newly-generated waste be segregated and the TRU waste (as defined above) be stored in a manner that would allow retrieval in an uncontaminated condition for 20 years. This interim storage generally involves storage in special vaults or placement on specially constructed concrete or asphalt pads with a plywood, plastic, and earth covering over the waste containers. The intended subsequent step is to place these wastes in a permanent, deep geologic repository. Processing of some wastes may be required before placement in a repository. The buried wastes could also be exhumed, processed, and placed in a deep geologic repository if any, or all, of these steps are found to be desirable from environmental and risk viewpoints. The segregation of TRU wastes, processing of wastes, and emplacement of wastes put requirements on nondestructive assay instrumentation to define the transuranic content of the wastes. Monitoring for transuranics in the soil and subsurface layers around waste burial and waste storage areas requires field instruments.

TRU wastes are stored and buried at six major sites in the U.S. The wastes at these sites include:¹

$\approx 61,000 \text{ m}^3$ retrievable stored waste
 $\approx 273,000 \text{ m}^3$ buried waste
 $\approx 2-7 \times 10^6 \text{ m}^3$ TRU contaminated soil

In addition to the present inventory of TRU waste, a projected waste generation rate of $\approx 4,800 \text{ m}^3/\text{year}$ has been estimated for 1980 through 2000.

These wastes have widely varied compositions (matrices). A precise breakdown of the types of materials in the buried waste is unknown; but through records and retrieval studies, the percentages and approximate plutonium concentration for stored waste has been fairly well established. The stored waste at the Idaho National Engineering Laboratory (INEL) is characterized in Table A.

TABLE A. Waste Stored at INEL

<u>Waste Form</u>	<u>% of Total Volume</u>	<u>Density lbs/ft³</u>	<u>Pu nCi/g</u>	<u>Pu Content g/ft³</u>
Metal Scrap	36	26	518	0.090
Paper and Rags-dry	9	22	255	0.037
Paper and Rags-wet	7	27	228	0.041
Filters-CWS	7	17	966	0.105
Second Stage Sludge	6	71	61	0.031
LSA metal, glass, etc.	5	24	15	0.0018
First Stage Sludge	5	67	1587	0.69
Organic Setups (solidified oils)	3	65	152	0.067
Unknown	3	19	46	0.15
Concrete, asphalt	2	48	46	0.021

The needs for NDA instrumentation are listed in Table B below.

TABLE B. Areas of Need for TRU Waste NDA Instrumentation

A. Waste Container Assay

1. Sizes
 - i. Small packages
 - ii. Drums
 - iii. Crates
 - iv. Very large items (e.g., caissons, rail cars, oversized crates)
2. Variables
 - i. Isotopic composition
 - ii. Matrix identification
 - iii. Density, low and high
 - iv. Shielding, contact handled and remote handled

B. Detection of Transuranics in the Ground

1. Soil
2. Water
3. Core samples
4. Down hole

C. Waste Processing

1. Sorting
2. Inventory
3. Waste process monitor
4. Continuous soil monitor
5. Criticality control

Assay of so many different sizes of containers is necessary to accommodate the many different sizes used by the various sites in processing, transporting, and storing the wastes. In addition, certain techniques favor larger or smaller containers.

Techniques for measuring x-rays or lower energy gamma rays can be quite accurate and provide isotopic information but require small containers because the matrix materials absorb the energy (rays) preventing the true signal from reaching the detectors. Since certain materials are better absorbers of this energy than others, matrix identification studies are needed so that corrections can be made for the varied nature of container contents. It is impractical (costly and a possible health risk) to open all the containers to inspect the contents before counting. Other techniques, measuring neutron emissions are not affected as much by absorption; but they do not distinguish well between isotopes and thus there is a need to identify isotopes and isotopic ratios when using these neutron counting systems. Here larger containers are favored since larger containers mean more transuranic is available to provide signal for any given concentration. The detectors are sensitive to amount of material, not concentration.

The reason for developing certain instruments for low-density wastes and others for high-density wastes is mainly one of cost. It is generally less expensive to build instruments for low-density wastes than for high-density wastes because of the absorption and isotope identification problems mentioned above. Therefore, if low-density wastes can be segregated from higher-density wastes or are the only wastes of interest, the lower-cost instrument is preferred. If higher-density wastes must be assayed, then the more expensive assay systems are required.

The instruments for detection of transuranics in the ground are needed for estimating the amount and extent of transuranics in and near old burial or disposal sites and to detect any movement of these isotopes.

Processing facilities need to measure the transuranic content in effluent process streams to determine whether wastes are TRU or low level and to maintain inventory control. The container assay systems indicated above can be used here, but special assay may be necessary, such as for soils where special lower limits apply. Assay may also be needed to sort wastes as they enter the process to divert low-level wastes which do not need to go through the expensive process or to segregate certain wastes for special processing. Although such wastes contain smaller amounts of plutonium than do plutonium processing operations, instrumentation for criticality control is necessary to help ensure that certain isotopes do not accumulate in the processes and cause excessive radiation or criticality problems.

REVIEW OF PRESENTLY USED INSTRUMENTS

Each DOE site presently has some form of NDA instrumentation for measuring part or all of the wastes generated at that site. Some of the sites have extensive instrumentation while others use very little. The instruments in use at the various sites are indicated in the following sections on a site-by-site basis. The information on each site includes the types of instruments used, how the instruments are used, the nominal counting times, normal range of operation, and how much of the site wastes are put through some type of counting system. Future plans are also indicated. Tables comparing all these instruments and some discussion of the presently used instruments is also given in the discussion section of this report.

HANFORD ENGINEERING DEVELOPMENT LABORATORY (HEDL)²

The HEDL is operated by Westinghouse to develop test fuels for the Fast Flux Test Facility and breeder reactor programs in general. TRU waste can be generated in two current operations. One operation is in the test fuel fabrication area and the other is in a wet scrap development laboratory. The laboratory dissolves mixed oxide fuel scrap, purifies it in a PUREX process, and blends to desired U/Pu ratios in the product.

Materials are assayed for accountability and waste throw away decisions in two counters for 55-gallon drums. One is a Canberra Instruments segmented gamma scanner (SGS) that can be adapted to smaller packages of three gallons or less. This instrument is suitable for low-density wastes that do not have lumped plutonium. If lumping is detected or suspected, then an active interrogation system manufactured by National Nuclear Corporation is used. The interrogating particles use fast neutrons from a Pu-238/lithium source. Fast coincidence rates of fission event gamma rays and neutrons are related to plutonium and uranium content. With long counting times, the users estimate that 10 mg of plutonium can be detected in the SGS. This would translate to about 20 nCi/g in a 30 kilogram (kg) matrix. The SGS is normally used in the 1 g to 5 g range. The NNC fission multiplicity detector is typically used for 5 g to 20 g of fissile material. Both counters could operate at higher levels, although higher levels are not expected.

A package counter, used by HEDL in a RHO plutonium facility, is used to assay low density research related wastes in 1 ft x 1 ft x 2 ft cardboard containers. This is a MEGAS unit of LANL design. The unit has a detection limit below 10 nCi/g for wastes with a maximum bulk density of 0.14 g/cm², using a 1000-second counting time. Containers can be assayed at a rate of about one every 10 minutes.

HEDL is designing a fuel and material examination facility for irradiated fuels. Waste from that hot-cell facility would contain fission products in addition to TRU contamination. They are currently contacting vendors about counters for TRU, but expect to specify whatever may be commercial vendor state-of-the-art-assay systems at a later time.

IDAHO NATIONAL ENGINEERING LABORATORY (INEL)^{3,4}

There are four main contractors that generate radioactive waste at this site although other contractors may generate small amounts. EG&G Idaho, Exxon Nuclear Idaho Company, Inc., Argonne National Laboratory (ANL), and Westinghouse Corporation generate wastes. Other than health physics measurements, the generators do not perform much routine nondestructive assay on packaged wastes. Most of those wastes are largely beta ray and gamma ray emitters with very little TRU material.

The Idaho Chemical Processing Plant (ICPP) is operated by Exxon Nuclear Idaho Company, Inc. and is the main on-site handler of large quantities of high level radioactive materials and is the main on-site waste generator. ICPP processes reactor fuel to recover U and Pu. EG&G Idaho, Westinghouse, and Argonne National Laboratory operate reactors. The reactors make radioactive material in the form of used reactor fuel that is stored or processed elsewhere, sometimes at ICPP. EG&G Idaho and ANL have hot cell facilities that are used during examination of research quantities of material. Wastes from ICPP and the hot cells are largely contaminated with fission product beta and gamma-ray emitters. The TRU content is low in the wastes and not considered assayable. The wastes are discarded in the Subsurface Disposal Area at the Radioactive Waste Management Complex (RWMC).

Accounting for TRU materials in waste generated at the Idaho site is accomplished in various ways. The ICPP assays solutions and calciner products by wet chemistry. Materials for burial are assayed by a "swipe" method. Hot cell nuclear materials accounting is frequently done by calculating differences between quantities weighed in and out of hot cells. For scrap from decontamination and decommissioning of facilities, accounting is attempted from "swipe" samples after cleanup. Some attempt is made to relate those "swipe" results in D & D operations to total remaining contamination on a piece of equipment. Health physics dosimetry measurements are also made with "cutie pie" meters at times. However, dosimetry cannot be used generally for accurate TRU estimates.

The Radioactive Waste Management Complex (RWMC) operated by EG&G Idaho has a counter to verify that received drums have under 200 g Pu content. This commercial drum verification counter was specified by the EG&G Idaho instrument research organization and has been in operation since 1975. The counter was originally purchased to support retrieval test operations, to perform rough screening of retrieved waste drums. It has since been used to assay a selected, small percentage of "as-received" waste. The main throughput in this counter consists of 55-gallon drums, but sizes up to 83 gallons can be accepted. It operates on the principle of counting multiple coincidences following spontaneous fission, usually of Pu-240. The counter is not operated in an active interrogation mode; therefore, it does not respond to U-233, U-235, or other fissile species that do not have a significant spontaneous fission rate.

Periodic grab samples of surface and subsurface soils are taken. Wet chemistry may be performed by Exxon's analytical laboratories after preliminary screening by EG&G's counting laboratory. The Am-241 60 kilo-electron volt (keV) gamma ray is used as an indicator of possible plutonium in the screening. Chemical assay is not performed unless there are indications of activity in the preliminary screening.

The above remarks are summarized in Table I.

There are plans for future assay of existing waste. These plans involve disposition of accumulated buried and stored wastes. The processes to exhume and treat these wastes have not been determined and instrument needs will not be specified until plans for the waste management projects are more definite. However, an inspection station is planned using nondestructive testing with nondestructive assay by the best available technology. Equipment specifications are planned for FY 1983. A need was expressed for accurate measures on the beta and gamma-ray wastes as well as for large boxes of TRU waste.

TABLE I. Instruments in use at INEL

<u>Waste Type</u>	<u>Size Sample</u>	<u>Measuring Principle</u>	<u>Sensitivity</u>	<u>Range for Pu(g)</u>	<u>First Used (Yr)</u>
Offsite Plutonium wastes	55 & 83 gallon drums	Count n & γ in fast spontaneous fission	$\approx 1g$	1-200g	ca.1975
Miscel-(a) laneous	Any non-standard geometry	γ -ray, Germanium, neutron	(a)	(a)	(a)
Product fuel plates, etc.		Commercial fuel-plates scanner	$\approx 1g$	Up to kilograms	ca.1976
Decontaminated Scrap Equipment	Miscellaneous	Swipes & count α	<10 pico Ci on a swipe	N/A	ca.1950
Soils surface & subsurface Waste Management site	Small	Wet chemistry, but screened before chemistry by low energy γ . Process if Am-241 observed	pico Ci/g	0-100,000 dpm/g	ca.1950

(a) Such measurements may be made by an R&D group upon special request. Special studies of isolated individual drums and crates have been made during the 1970's. Because each experiment can be a special case, the experimenters may set up measurements differently.

LOS ALAMOS NATIONAL LABORATORY (LANL)⁵

The three main sources of TRU waste at Los Alamos are the TA-55 Plutonium Processing Facility, the Chemistry and Metallurgical Research (CMR) building, and the Liquid Waste Treatment Facility. Transuranic wastes from these facilities are packaged primarily in 55-gallon drums and 4 ft x 4 ft x 7 ft fiberglass coated boxes (crates). The wastes from CMR are administratively separated into containers designated as TRU or non-TRU waste. At all sites TRU waste is segregated into combustible and noncombustible. Non-TRU wastes from CMR presently are sent to low-level on-site burial without any specific container assay. Large waste items from all sources are surveyed with various hand-held instruments prior to packaging to determine if they are TRU. Filled crates may also be surveyed in this manner. Solidified wastes from the Liquid Waste Treatment Facility are analyzed radiochemically to determine proper disposition.

Except for large waste items, all room wastes from the Plutonium Facility pass through a multi-energy gamma assay system (MEGAS), and all drums of TRU waste from the Plutonium Facility and CMR are assayed with a drum counter. The Plutonium Facility MEGAS unit is of the original design. An updated MEGAS II presently is constructed for installation in CMR. These systems, described elsewhere in this report, use multi-energy gamma scans to assay 1 ft x 1 ft x 2 ft cardboard boxes of low-density solid wastes at the 10 nCi/g level. Boxes identified as TRU are subsequently repackaged in drums, or are opened and sorted, with the TRU items repackaged in drums. Transuranic waste drums are counted by a barrel counter which uses gamma and neutron counting techniques to measure 1/2 g to 200 g of plutonium content. Drums measuring too high in plutonium content are repackaged and those measuring below 1 g are designated as less than 1 g.

MOUND FACILITY (MF)⁶

The Mound Facility has very little actual TRU waste. The main trans-uranic element handled at Mound is Pu-238 which is specifically excluded from the TRU waste category unless associated transuranic elements give greater than 10 nCi/g of alpha activity. The use of gamma ray counting of waste containers at Mound Facility is, however, related to TRU waste assay. Mound Facility has used nondestructive assay on Pu-238 waste since the late 1960's.

All waste containers at the Mound Facility are presently scanned with FIDLER³⁵ or other hand-held instruments before being shipped for interim waste storage. If radiation levels warrant, the containers are sent to package counting systems.

There were four Pu-238 passive gamma ray systems at Mound Facility. Two of these used high resolution Ge(Li) detectors while the other two used NaI(Tl) detectors as gamma ray measuring devices. Recent changes have combined the two NaI(Tl) systems and one of the Ge(Li) detectors has been replaced by an intrinsic Ge detector. The form of the waste container determines which assay system is used. A Ge(Li) detector is used to assay four liter cardboard cartons, fibreglassed crates are assayed using NaI(Tl) detectors, and 55-gallon drums are measured using a segmented drum assay system.

An intrinsic Ge detector is used to assay in-line waste in cardboard containers about 7 in. high and 7 in. in diameter. This is used with an associated pulse-height analyzer and minicomputer system for gamma assay. Transmission sources are used to estimate the self-attenuation correction for the matrix (box contents). This system, operating since 1974, has a throughput of about one container each six minutes with a useful range between 40 milligram (mg) and 10 grams (g) of Pu-238.

Wastes in 55-gallon drums are assayed using a commercial Canberra Segmented Drum Assay System. In this system each drum is scanned in four segments and matrix attenuation is determined using a Cs-137 source. This system, operating since 1979, takes about 30 minutes per drum assay and has a range of about 20 mg to 25 g of Pu-238. Detection limits and accuracy depend on the waste matrix.

The waste in fibreglassed crates, up to 6 ft x 7 ft x 9 ft, includes glove boxes or other large items and is assayed using passive gamma-ray detection with NaI (TI) detectors. The transmission source for these counters is Pu-238. A one hour transmission source strength count is made once a day. Each crate is counted for three hours, one hour with the transmission source and two hours without the source. This counting system has been in use since 1980 and measures 0.1 g to 20 g of Pu-238.

OAK RIDGE NATIONAL LABORATORY (ORNL)⁷

Shallow land burial of solid wastes which contain lower levels of radioactive contamination has been practiced for over 30 years, and retrievable storage of TRU wastes has occurred for almost 10 years at this site. Only approximate estimates of the amounts of radioactivity in the wastes are available in the waste records. This, however, includes estimates of quantity and types of radionuclides present in each container. Quantative assays of total packages were not attempted since these measurements were not deemed technically or economically practical.

A scanning instrument for analysis of 55-gallon drums to assay at the 10 nCi/g TRU limit was installed in 1978. This instrument was not satisfactory for assay of the wastes at the 10 nCi/g level and was not put into regular use. This instrument is a Canberra Model 2220 using a Ge (Li) gamma ray detector.

A gamma ray spectrometer is presently used in comparative gamma peak analysis to assay for U-233 in the 0.5 g to 100 g range at the U-233 radiochemical processing pilot plant. The assays take about 15 minutes per drum and assay values are determined by comparing waste drums to known archival standard drums.

Plans for instrumentation to assay 55-gallon drums of waste at the 10 nCi/g level in 1982 include using the Canberra Model 2220 already at ORNL coupled with an active neutron interrogation system developed at LANL and described in the section of this report titled "ORNL DRUM COUNTER PROTOTYPE."

PACIFIC NORTHWEST LABORATORY (PNL)^{8,9,10,11}

PNL has been developing NDA instrumentation for use on transuranic and fission products since 1976. An instrument for surface and subsurface in-situ detection of six transuranic isotopes was completed in 1980. This instrument using a hyperpure Ge detector for high resolution gamma spectroscopy is a passive gamma system which is an extension of previous work with fission product assay. This outgrowth of well-logging techniques will detect U-235, U-238, Pu-239, Pu-241, Np-237, and Am-241. Counts of about 15 seconds will give assays at the 10 nCi/g level for some isotopes.

A mobile system for NDA for Nuclear Materials Safeguards and Waste Management use contains several counting systems and computer. The mobile systems is used at the several PNL locations at Hanford and for some off-site contract projects. Applicability of this instrumentation for use on waste packages depends on the concentration and total quantity of interfering species and the nature of the waste matrix. The counters are used to measure tens of milligrams to kilogram quantities of transuranics, depending on the isotope and on the factors given above.

The instrumentation in this mobile system includes two segmented gamma scanners, two random drivers, a neutron well counter for passive or active (Am-Li source) assay, and germanium diode spectrometers. The system can measure packages 1 gallon to 55 gallons in size. The mobile van is complete with all peripheral electronic equipment including the computer for data analysis. Utilization of the equipment for waste assay requires slight changes to optimize the sensitivities of the counters depending on package contents and configuration. Calibration is accomplished by counting known standards. Counting time can vary from 100 seconds to 1/2 hour depending on the counter and nature of the waste.

An assay instrument for measuring the transuranic element content of chopped, leached fuel hulls and other materials having high concentrations of gamma-ray emitting radionuclides uses neutron counting. This is a modular instrument comprised of radiation shields internal and external to a neutron counter module containing 80 BF_3 proportional counters in two concentric rows. The central cavity will accept a five-gallon bucket. The detection limit for Pu from commercial nuclear fuel is 46 mg in a gamma ray field up to 100,000 roentgen (R)/hr. Isotopic composition as well as concentration can be determined with this counter.

A system for checking surface contamination on glove boxes, soils, pond bottoms, etc., has been developed using an intrinsic Ge planar detector for low energy x-rays. The system finds application in decontamination, decommissioning, and field work. Ten-minute counts can detect about six d/m/cm², Am-241, or 72 d/m/cm² of Pu-239.

A method for measuring transuranics in very high gamma fields using activation of copper plates has also been developed. A plate placed in a high-level waste tank over night, retrieved, and counted in the laboratory can be used to assay for transuranic content at levels less than 10 nCi/g.

No package counters are presently used at PNL to assay the few drums and crates sent to Rockwell Hanford Operations (RHO) for TRU waste storage. The TRU values are assigned by estimating the amounts in each container.

Future NDA instrumentation development plans at PNL include passive neutron counting of barrels which also contain fission products. This system will assay transuranics at or below the 10 nCi/g level. Development of a system to measure transuranics on surfaces or in plastic pipe using isotopic sources and K x-ray fluorescence is also planned. A system for looking at the photons emitted by in-situ neutron activation is also being considered. This will be coupled with standard delayed neutron analysis to determine more about the isotopic content of the waste.

ROCKWELL HANFORD OPERATIONS (RHO)^{12,13,26-31}

The majority of solid TRU waste and scrap at Rockwell is generated during the course of fuel reprocessing, scrap recovery, storage and shipping operations at the Purex and 234-5 Z-Plant facilities. A variety of instrumentation is used at various points in the process to identify TRU waste and scrap and quantify loadings to ensure proper handling procedures are observed. All the transuranic wastes generated by contractors at the Hanford site are stored in the RHO storage areas.

As waste is generated in the process hoods and glove boxes, preliminary measurements are made using fixed and portable NaI(Tl) scintillation gamma counting instruments. On the basis of these measurements, waste is segregated so as to create a minimum volume of significantly contaminated waste. All drums, both those containing high-level "hood waste" and those containing low-level "room waste" are assayed with a fixed, large detector, NaI package counter. Utilizing a two-minute count time, a minimum detection level of 1 gram of plutonium is obtained for drums up to 400 pounds in weight. Drums measured as containing 10 or more grams of plutonium and those identified as containing gamma emitting fission products are remeasured using a Canberra, Segmented Gamma Scan system. Utilizing vertical segmentation, matrix density transmission measurement, and a high resolution Ge(Li) detector, this system provides a more reliable assay value for drums weighing up to 400 pounds, containing between 5 and 200 grams of plutonium, even in the presence of low-level fission product contamination. Empty L-10, nitrate storage bottles and exhaust filters which cannot be packaged in drums for disposal are also assayed with the NaI package counter.

More concentrated waste or scrap is currently being generated in the 234-5 Z Facility as the result of product storage and shipping operations. In addition, for many years Hanford has served as the scrap repository for many other plutonium processing sites. All of this varied material must be verified periodically for safeguard purposes and before shipment or after

receipt. Due to the large variety of scrap types and loadings a variety of instrumentation is required. Low density, low-level scrap (<250 grams Pu) such as incinerator ash and crushed slag and crucible material (Mg/Ca oxide) is normally measured on a small table version of the Canberra, Segmented Gamma Scan, employing the same techniques as the drum counter. Where large numbers of items of very similar composition are to be measured, a National Nuclear Corp., dual range passive, Neutron Well Coincidence Counter is used for the assay of plutonium in loadings over the range of 20 to 2500 grams. This instrument measures the coincident neutrons produced by the spontaneous fission of the even numbered isotopes of plutonium. Computer interfacing allows corrections to be included for fissions induced in odd numbered fissile isotopes by the ambient neutron flux and for dead time. This requires a knowledge of the isotopic composition of the items being measured. Since 1974, Rockwell has routinely determined plutonium isotopic composition and relative americium content of plutonium product and scrap forms by nondestructive gamma ray spectroscopy. In addition to measurement of packaged waste and scrap, Rockwell has made widespread use of portable NDA equipment (NaI detectors with single channel analyzers) to identify Pu and measure plutonium holdup in process hoods, equipment, piping, ducting and exhaust filters.

All the transuranic waste generated by contractors at the Hanford site are stored in the RHO storage areas. While current waste disposal practices separate placement of TRU solid waste into 20-year retrievable storage and TRU liquid wastes into cribs, past practices allowed disposal of liquid wastes in near-surface disposal facilities (cribs, french drains, reverse wells) and solid wastes into underground trenches. Characterization of the distribution of TRU activity at these sites is necessary to evaluate the engineering requirements for excavation of the contaminated material for deep geological disposal. In the past, characterization of a site involved drilling wells to obtain sediment samples for laboratory analysis. Recently, a variety of down-well instruments have been developed, tested, and used in characterizing the distribution of TRU activity in sites. Such instruments offer the possibility of rapid turn

around time for analysis which aids in the placement of future wells. The same instruments also permit monitoring of the waste sites to assure protection of the environment.

Two mobile vans for assay of ground surface layer radioactivity and for borehole radioactivity assay have been developed at Rockwell. These have been designated as Mobile Radionuclide Analysis Laboratory (MRAL) I and II and are used to obtain field data on radionuclide inventory and distribution for waste management. These units were previously referred to as DEV VAN I and II. Recently, both electronic systems housed within MRAL I and II were upgraded to include microcomputer based multi-channel analyzers which provide real-time in-field plutonium-239, americium-241 and fission product analysis. Both systems are now being field tested, with results being documented and systems implemented for operational use. With these updates, laboratory spectra data reduction is no longer required. Spectra data, however, is being stored on floppy disks for filing and laboratory data reduction verification purposes.

Mobile Radionuclide Analysis Laboratory I is a mobile system for surface analysis of X-ray and gamma-ray emitting radionuclides. The MRAL I detector system inventory includes a downlooking, 200 millimeter (mm)² lithium drifted silicon, Si(Li), detector system for in situ field analysis. This system is presently being calibrated. The sensitivity is estimated to be lower than 1 μ Ci/g for plutonium-239 and 0.1 μ Ci/g for americium-241 using 500 second counts. Rockwell has also upgraded its field Ge(Li) detectors to intrinsic germanium (IG) detectors.

Rockwell's field downlooking IG and Si(Li) detectors are supported by a cone shield. The cone is fabricated from 0.317 cm aluminum, having graded-shielded inside lining consisting of .635 cm lead, .051 cm cadmium and .025 cm copper. The detector is positioned through a hole in the top of the cone shield and is held in position by support legs attached to the detector cryostat. The detector is approximately 14 cm above the soil, viewing approximately 2000 cm² of soil surface established by the area of the shield cone base.

With the upgraded electronic system configuration, MRAL I is able to support up to three detector systems and perform simultaneously spectra acquisition, spectra reduction and report generation. Under ideal field conditions, i.e., level terrain with minimal vegetation growth, a technician should be able to analyze a combination of 12-16 in situ and sample to detector samples per hour.

Mobile Radionuclide Analysis Laboratory II is a mobile borehole gamma-ray spectrometer designed to gather data on gamma-ray emitting fission or activation radionuclides to a depth of 230 m (750 ft). The gamma-ray spectrometers include IG detectors of different detector configurations, i.e., planar and closed ended coax, and different efficiencies such that gamma-ray fields of low and high energies at various activity levels can be effectively logged.

Mobile Radionuclide Analysis Laboratory II with the upgraded electronic system configuration is able to monitor the depth of the gamma-ray spectrometer sonde, and the direction of a lead shielded collimated sonde held in position by a gyroscope system, to perform spectra acquisition, spectra reduction and report generation.

New equipment acquisitions for the near future include an additional Segmented Gamma Scan system for closer support of processing activities. A high-level neutron coincidence counter will supplement the assay of "problem" 55 gallon drums and other waste packages where lumps of plutonium are suspected. Portable germanium detectors and portable multi-channel analysers are currently on order to aid portable assay in the Purex plant where the detector's high resolution and the analyser's spectral analysis capabilities will greatly reduce the problems caused by the presence of fission products.

Future instrumentation needs will be met with commercial systems or systems developed by other DOE contractors.

ROCKY FLATS PLANT (RFP)¹⁴

Counters for radioassay of waste containers have been used at the Rocky Flats Plant since about 1964. Simple passive gamma-ray and neutron counting were used to assay 55-gallon drums from 1964 to 1973. That system was capable of plutonium assay between 0.1 g and 200 g per drum. Two other drum counters, which utilized NaI detectors for passive gamma-ray assay, were used from 1971 to 1973. Those systems had useful assay lower limits from 0.3 g to 1.6 g Pu, which varied according to the kinds of waste. Can counters for assay of 1 to 4 liter bottles and cans were used in process areas for waste and nuclear materials assay in the 1965 to 1972 era. One of those counters was the Helix Counter, a transmission corrected counter. The other Geiger and neutron tube counter was retired about 1972. Several new drum and can counters were constructed to replace the older counters in 1972 and 1973.

One new drum counter used a NaI dual window passive gamma-ray counter and BF₃ neutron detection. The gamma-ray counting provided primary information with neutron counting used for diagnostic information to make corrections for matrix or other effects and to detect any nonstandard contents. This drum counter is still in service and is used for plutonium analysis only. It assays about 0.5 g to 350 g depending on the matrix category. The matrix categories include paper and rags, filters, metals, and most other Rocky Flats wastes for a total of nine categories. Raw data from a 100 second count per drum is transmitted to a computer for data reduction and correlation. Maximum throughput rate is about five minutes per drum.

A second drum counter used a Ge gamma-ray spectrometer with a multi-channel analyzer to assay U, Pu, Am, and other special materials. The usable assay range of about 0.5 g to 350 g of material depended on waste matrix and isotopic content. Normal counting was for 600 to 1200 seconds per drum. Due to the varied nature of the wastes in these drums both computer and manual techniques were used in data analysis. The system was

calibrated for four general categories of waste; other categories of waste matrix and/or isotopic content required manual analysis. This counter was retired in 1981.

Another Ge detector counter replaced the retired Ge counter. This newest drum counter at the RFP is a commercially available, transmission corrected, segmented scan counter. In a total 800 seconds count of eight segments, this counter has a sensitivity of about 4 g Pu, operating in a changeable, high background. All waste drums pass through this counter or the NaI dual window counter, the latter being preferred for low activity drums.

A can counter installed in 1972 uses the same type of NaI and BF_3 detectors as described above for the Pu drum counter. This system is used for Pu assay (0.5 g to about 200 g) of 1 to 4 liter bottles and cans. The old Helix counter mentioned above continues in use for quantities up to 700 g.

A passive counting system for 4 ft x 4 ft x 7 ft crates of waste is also used at Rocky Flats. This system uses passive singles neutron counting and Ge gamma spectroscopy to assay the fiberglass-reinforced plywood boxes containing one of three waste categories. The three waste categories are combustibles, CWS filters, and miscellaneous metals. The system will assay for Pu, Am, and U in the range 0.6 g to 350 g with exact limits depending on isotope and matrix. Assay time is about 50 minutes per box with a 25-minute crate count, 20-minute background count, and 5 minutes between crates.

Field instruments at Rocky Flats include commercial FIDLER and Phoswich instruments. Grab samples of soil are analyzed by gamma spectroscopy and also by wet chemistry concentration and pulse-height analysis. Counting times of 16 or more hours are used to achieve the low levels of detection required.

Table II lists some of the instruments presently used by Rocky Flats Waste Management.

New systems planned for waste instrumentation to be installed and used in the next five years include:

- 1) a MEGAS system for nonline-generated waste in a plutonium processing building,
- 2) a newly designed crate counter,
- 3) a continuous monitor for incinerator ash on a conveyor belt,
- 4) a neutron coincidence based drum counter for certain high density matrices (possible active assay options are being considered),
- 5) two segmented gamma-ray scanning drum counters, and
- 6) at least one neutron coincidence package counter.

TABLE II

RADIOMETRIC INSTRUMENTATION UTILIZED IN
WASTE PROCESSING AT ROCKY FLATS

<u>NAME</u>	<u>TYPE</u>	<u>USE</u>
LUDLUM MODEL 12	ALPHA SURVEY INSTRUMENT	SURFACE ALPHA CONTAMINATION
VICTOREEN MODEL 440	GAMMA SURVEY INSTRUMENT	PENETRATING GAMMA RADIATION
CDV-700	GAMMA SURVEY INSTRUMENT (G-M)	GAMMA RADIATION GO/NO GO
COMBO	ALPHA SURVEY INSTRUMENT	PERSONNEL MONITORING ALPHA CONTAMINATION
SCINTILLATION COUNTER	ALPHA COUNTING INSTRUMENT	ALPHA REMOVABLE CONTAMINATION
LUDLUM MODEL 111	NEUTRON COUNTER	FIELD INSTRUMENT FOR NEUTRON DOSE RATES
LUDLUM MODEL 16 (NaI DETECTION)	GAMA ASSAY INSTRUMENT	PORTABLE ASSAY INSTRUMENT
FIDLER (FIELD INSTRUMENT FOR DETECTION OF LOW ENERGY RADIATION)	GAMMA ASSAY SYSTEM	PORTABLE FIELD GAMMA ASSAY INSTRUMENT
NaI DRUM ASSAY	GAMMA ASSAY SYSTEM	Pu ASSAY OF DRUMS
Ge DRUM ASSAY	SEGMENTED GAMMA ASSAY	Pu AND OTHER RADIOACTIVE ISOTOPES, ASSAY OF DRUMS
CRATE ASSAY	GAMMA ASSAY SYSTEM	Pu ASSAY OF CRATE
HELIX & CAN COUNTER	GAMMA ASSAY SYSTEM	Pu ASSAY OF CAN

SAVANNAH RIVER PLANT (SRP)¹⁵

The SRP has used nondestructive assay instruments since about 1959. Two drum counters and a smaller package counter were installed by 1962. These were updated as new technology became available between 1968 and 1976. Most of SRP's counters (there are now 10) use high resolution germanium spectroscopy to assay enriched uranium, plutonium-238 and 239, neptunium, curium, and americum. The SRP has many waste containers including large boxes and crates up to 8 feet in one or more dimensions. Large polyethylene slabs are movable to surround these large boxes and a portable germanium spectrometer is also used. Assay of these huge crates cannot be very accurate as a rule because of nonstandard geometries and unknown matrix attenuation effects. Quantitative soils assays are performed using tridirectional wet chemical separations followed by counting. Qualitative field survey instruments, usually of the "cutie pie" air-ionization chamber type are used for beta and gamma-ray assessments. Alpha particle monitors are not typically used in the field measurements. The SRP counters are summarized in Table III.

TABLE III

SAVANNAH RIVER PLANT - SUMMARY OF WASTE ASSAY

<u>Material</u>	<u>Package Size</u>	<u>Measurement Basis/Detector Matrix Correction</u>	<u>Sensitivity</u>	<u>Usual Range</u>	<u>Installed (year if known)</u>	<u>Presently used</u>	<u>Retired (Year)</u>
Process Scrap & Waste Mixed TRU	55 gal	γ/Ge single transmission	10 n Ci/g in several hrs	0.5-500 g Pu	ca.1959 updated 1967	Yes	--
Process Scrap & Waste Mixed TRU	55 gal	γ/Ge single transmission	10 n Ci/g in several hrs	0.5-500 g Pu various other	ca.1962 NaI (Tl) updated	Yes	Original NaI (Tl) retired & replaced with Ge
Process Scrap & Waste Pu-239, Pu-238, Np, U-235	5 gal	γ/Ge single transmission	10 n Ci/g in several hrs	2-250 g Pu-238 various other	ca.1964 updated '70 & '79	Yes	Original NaI retired & replaced with Ge
3 1 Process Scrap & Waste mixed TRU & Some Product	5 gal	γ/Ge segmented transmission	10 n Ci/g	2-250 g Pu various other	ca.1978	Yes	Replaced earlier NaI
Waste Mixed TRU	Miscellaneous "all purpose"	$\gamma/\text{NaI (Tl)}$ rotate only	10 n Ci/g	0.1-5.0 g Pu various other	ca.1968	Yes	--
Process Scrap & Waste U-235	1 gal Activated	active induced neutron/ ^3He empirical	unknown	unknown U-235	ca.1976	Under T&E	--
Process Waste & Incoming Scrap	Misc. to 8-ft lengths	Neutron/ BF_3 none-estimator	1 g of Pu F_4 >1 g impure Pu	$\approx$ 5 g to 2500 g Pu	ca.1979	Yes	--
Scrap	$\approx$ 1.0 gal	Active induced neutron/ ^3He empirical	10 nCi/g in certain matrixes	Under evaluation	1980	Not routine yet	--

TABLE III (Cont.)
SAVANNAH RIVER PLANT - SUMMARY OF WASTE ASSAY

<u>Material</u>	<u>Package Size</u>	<u>Measurement Basis/Detector Matrix Correction</u>	<u>Sensitivity</u>	<u>Usual Range</u>	<u>Installed (year if known)</u>	<u>Presently used</u>	<u>Retired (Year)</u>
Incoming Pu Metal Feed	2 qt	Passive neutron coincidence/ ³ He multiplication formula	Not tested	1500-2500 g Pu	1977	Yes	--
Soils, surface grab samples & subsurface		Wet chemistry	<10 n Ci/g	<1 mg	1954	Yes	--
Soil	Surface	γ/air ionization	Not quantitative	--	1954	Yes	--
Grates, Process Scrap & Waste	36-in. cubes	γ/Ge and/or γ/Nal (TI)	10 n Ci/g	0.1 to 3 grams	ca.1965 update 1976	Yes	--

TRU WASTE MANAGEMENT PROGRAM NONDESTRUCTIVE ASSAY (NDA) INSTRUMENTATION TASKS

The goal of TRU waste instrumentation development is to provide instruments for application to TRU wastes generated by DOE facilities and by commercial industry. Needs for instrumentation are quite varied since knowledge of transuranic content is required in all phases of waste management. Instruments are needed for measurement of TRU isotopes in containers of many sizes. Ideally the instrumentation systems should assay both high and low-density wastes, with and without additional beta-gamma fission product contamination, and should not depend on prior knowledge of matrix or isotopic content. Waste processing facilities require measurements for sorting, inventory, and criticality control. Surface contamination must be measured in the field and in decontamination processing. Detection of transuranic content in the ground is necessary for determining contamination associated with burial grounds and storage or disposal areas. Migration of TRU elements in the ground must also be monitored.

Once the assay instrumentation is developed in the laboratory, prototype systems are constructed and installed at actual generators for a period of field testing.

STATUS

A MEGAS has been developed for assay of low-density TRU defense wastes at or below the 10 nCi/g level. Neutron and photon interrogation are being studied for incorporation into systems which will allow assay of wastes in the presence of high beta-gamma activity and/or high density wastes. Active and passive neutron interrogation experiments are being conducted to determine design parameters and capabilities of these methods. Some measurement techniques for sorting wastes, monitoring decontaminated surfaces, monitoring specific processes, and conducting in situ measurements at waste burial sites have been developed and demonstrated. However, these are specific instruments and new instruments must be designed each

time a different site needs a similar instrument. Much more development is required before generic instruments will be available for all of these applications.

SPECIFIC PROJECTS

MEGAS COUNTER^{16,17}

A MEGAS has been developed and tested for use on low-density solid wastes (e.g., combustibles including paper, cloth, and plastics). This system is used for sorting and characterization of transuranic wastes at sub 10 nCi/g levels. The original system used a hybrid gamma-ray detection scheme coupled with x-ray detection. This system allows monitoring of the x-ray region for sub 10 nCi/g wastes, subsequently crossing over to progressively higher-energy gamma rays as the activity level increases. Such a hybrid system combines the high sensitivity (and relatively poor accuracy) of x-ray detection at the 10 nCi/g level with the lower sensitivity, but improved accuracy, of gamma-ray detection at higher activity levels. Assay accuracy of this package scanner is approximately $\pm 50\%$ at 10 nCi/g, but can be 200% or higher, depending on source location and relative particulate size of the transuranic material in the standards and the unknown. Above ~ 70 nCi/g (in 4000 g of waste) the accuracy improves to about $\pm 30\%$. The dynamic range of the system extends from a few micrograms of plutonium to gram quantities (a factor of $\sim 10^6$).

This instrument uses a single large NaI detector for viewing a rotating and translating (using a table rotated on a central screw) cardboard carton. A complete pulse-height spectrum, corrected for room background, is collected for each carton and photon yields are computed and compared to a calibration curve to give the net plutonium and americium assay.

An enhancement to the original system (designated as MEGAS II) adds neutron detectors. These neutron detectors count the spontaneous fission neutrons and other related source neutrons. Since the detectors used are

relatively insensitive to photons, this part of the system can detect all source-related neutrons in a container in the presence of high fission backgrounds which will render the NaI photon detectors ineffective.

The MEGAS of original design has been in use at several locations for three years or more. The MEGAS II has been developed and tests at LANL DP Site showed the system worked satisfactorily. Further testing is scheduled at a LANL plutonium research facility in FY1981. Delays in the construction of the assay room have caused a slip in this testing schedule. This testing will complete the present MEGAS development program.

MEGAS II COUNTER

Accomplishment	FY79				FY80				FY81				FY82				FY83				FY84				FY85			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
System ready for field tests	X																											
Field tests completed																												
First set					X																							
All tests										X																		

PASSIVE NEUTRON CRATE COUNTER^{19,20}

An assay system using modular neutron detector sections is being developed to allow 4π solid angle passive neutron counting of large waste packages. The detector sections are 8 ft by 4 ft rectangular panels 0.6 ft thick and these sections are used to build up the walls, top, and floor of the large 4π detection system. Containers to be assayed in this system include 4 ft by 4 ft by 7 ft crates and "six packs" which are six 55 gallon drums banded together with steel straps. Containers of other sizes also exist and the modular design allows for building up larger counters as required.

The principal isotope producing neutrons in common TRU waste is Pu^{240} , although, depending on the chemical form, all alpha-emitting isotopes in the waste contribute to the neutron output of the package. In this system two types of passive neutron measurements are carried out simultaneously, total neutron output and coincidence neutron rate. The latter is a direct measure of the spontaneous fission rate of all fissioning materials in the waste package, whereas the former depends, in addition, on all alpha-emitting material in the package and on the chemical form of the waste.

The basic module in the system is a polyethylene (CH_2) box in which several 2 in. diameter by 6 ft long He-3 filled (2 atm) proportional counters are placed. This "neutron chamber" approach makes very effective use of He-3 proportional counters as compared to the usual practice of imbedding proportional counters in a solid CH_2 matrix and also results in reasonably portable modules. The measured intrinsic neutron detection efficiency for this module for a bare Cf-252 spontaneous fission source is 16% when six of the proportional counters are placed with equidistance spacings within the CH_2 neutron chamber. The same module displays a 15% intrinsic detection efficiency for a Cf-252 source moderated by 3 cm of CH_2 . Efficiency of 20% has been achieved with a newer two-chambered module. An added feature of this two-chambered approach is that the count

rate ratio between the two chambers is spectrally sensitive and may be used to correct for waste matrix generated efficiency modifications.

A large increase in detectability can be attained by shielding out cosmic ray generated backgrounds. This could be achieved economically using compacted dirt shielding. A 15 ft dirt shield would result in a factor of 10 improvement in detectability as compared to the unshielded case.

A feasibility study was completed in early FY80 to determine the usefulness of passive neutron assay for drums and crates at the 10 nCi/g level. The study indicated a detectability limit of about 50 nCi/g for 55 gallon drums in the unshielded case. However, assay of crates at the 10 nCi/g level was considered possible with minimal cosmic ray shielding because of the increased signal from the large amount of material involved.

This counter design, as with all other counter designs, will not measure all wastes accurately. In fact, much care must be given to design and calibration of the system for the specific uses planned.

The schedule for design, laboratory testing, prototype construction, and prototype testing of this assay system are shown in the chart below.

PASSIVE NEUTRON CRATE COUNTER

Accomplishment	FY79				FY80				FY81				FY82				FY83				FY84				FY85			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Complete Feasibility Study at 10 nCi/g					X																							
Complete Design for Crate Counter							X																					
Complete Construction of Test Unit									X																			
Complete Accuracy and Sensitivity Tests										X																		
Complete Design and Construction of Prototype														X														
Install, Test, and Operate Prototype																												

Schedule to be determined

ACTIVE INTERROGATION USING NEUTRON SOURCES

The purpose of tasks in this area is to provide reliable assay at the 10 nCi/g level in 55-gallon barrels of waste containing dense materials such as metals and concrete in the waste matrix. These tasks include development of instruments capable of the required measurements, selection of the best instrument or instruments for demonstration, and testing of prototype instruments in actual waste management operations. This area of instrument development includes several tasks as described below. These include Differential Die-away Technique (DDT) for Active Neutron Interrogation, Cf-252 Based Shuffler System for Active Neutron Interrogation, ORNL Prototype Drum Counter, and RHO Prototype Drum Counter.

DIFFERENTIAL DIE-AWAY TECHNIQUE (DDT) FOR ACTIVE NEUTRON INTERROGATION²¹

The DDT is a pulsed thermal-neutron interrogation system useable for assay of low or high density wastes. This technique measures the fissile content of the waste with a demonstrated sensitivity of 1 mg Pu-239 in a 55-gallon drum.

The source of interrogating neutrons is a small, 3.8 cm diameter by 10.7 cm long, sealed tube, pulsed deuterium-tritium (D-T) generator placed in the assay chamber with the drum. The chamber is a specially designed graphite and polyethylene structure used to rapidly moderate the 14-MeV neutrons from the D-T source. The resulting (moderated) thermal neutrons used to interrogate the sample have a characteristic lifetime within the chamber of about 1 msec.

Only the induced fission neutrons are recorded by the system. The detectors are cadmium-shielded fast neutron detectors located outside the assay chamber but within the graphite and polyethylene moderating layer. These detectors recover from the 14 MeV fast neutron interrogating pulse overload in about 0.4 msec and are insensitive to the interrogating thermal neutrons. Therefore, the detectors are ready to record the induced fission neutrons (prompt and delayed) which they detect with high probability. The interrogating flux of thermal neutrons is measured with a low-efficiency, bare ^3He proportional counter placed inside the chamber with the drum.

The ratio of prompt-fission neutron detector counts to interrogating flux monitor counts is proportional to the amount of fissile material present. The use of pulsed, prompt singles neutron counting provides a factor of 100 to 1000 greater sensitivity than comparable techniques counting delayed neutrons or coincident prompt neutrons. This accounts for the sensitivity to 1 mg of fissile material placed anywhere within the drum.

A DDT System has been developed and tested in the laboratory and also in one field test. A prototype system for use on ORNL waste drums will be in operation in FY 82 as discussed elsewhere in this report.

Cf-252 BASED SHUFFLER SYSTEM FOR ACTIVE NEUTRON INTERROGATION^{18,20,22,23}

This technique has been used for special nuclear materials accountability measurements for several years at higher TRU levels and recent studies have indicated its capability for assay/screening of high density, 200 liter waste packages near the 10nCi/g level. The Cf-252 shuffler system combines active and passive neutron assay techniques to measure plutonium contaminated wastes. The system includes an assay chamber large enough to accommodate standard 55 gallon drums surrounded by He-3 filled proportional gas detectors for efficient neutron counting. A Cf-252 isotopic neutron source can be extended (shuffled) to interrogate the drum or retracted into a shielded position for storage while induced neutrons are counted.

A typical 1000-S assay begins with a passive neutron measurement with the source in the storage position. The passive count measures the total neutron emission rate and the coincidence rate arising from spontaneous fission of even plutonium isotopes. The detectability limit for total neutron passive counting of 55 gallon drums of high density waste ranges from 0.3 to 30 nCi/g depending on the matrix chemical composition. The coincidence technique can provide a detection limit near 10 nCi/g if no lead shielding is required or if lead shielding is used and adequate cosmic ray shielding is also provided.

The active portion of the assay involves cycles of alternate irradiation and counting periods. One active cycle consists of a 16 second neutron interrogation and an 8 second delayed neutron count with the source withdrawn. The source transfer requires 0.5 second in each direction for a total cycle time of 25 seconds. A maximum of 30 cycles is used in the active portion of the assay.

This system can be used to assay high-level, beta-gamma contaminated wastes (up to 1000 R/hr) if 15 cm thick lead shielding is placed between the barrel and the neutron detectors. With a 1 meter thick concrete cosmic ray shield around the instrument the calculated 3σ detectability limit is about 5 nCi/g. Combining the coincidence and integral passive counting data with the active assay results yields the fertile and fissile plutonium components as well as the probable average chemical composition.

The feasibility study to determine whether this system, originally developed for safeguards assay, could be used for waste assay at the 10 nCi/g level was completed in the 4th quarter of FY79 as shown in the chart below. The results indicated that assay near 10 nCi/g was feasible as discussed above.

ORNL DRUM COUNTER PROTOTYPE

The purposes of this task are: (1) to measure/verify the amount of transuranics in 55 gallon drums stored in the ORNL transuranic waste storage area, (2) to sort out any low level waste, and (3) to field test the DDT active neutron interrogation system developed at LANL.

A two-tier system will be used for examination of the ORNL TRU waste. The first tier of the system will consist of a beta/gamma drum scanner presently at ORNL and the second tier will be a DDT system which is being built at LANL (and was described above in this report). The equipment will be located in ORNL building 7824 which is immediately adjacent to the retrievable TRU waste drum storage area and is available for the indefinite period of time required for this task. Present equipment used for storing and transporting the waste will be used for retrieving the waste and moving it to the assay facility. The assay facility will have shielded storage capacity for approximately 1-1/2 weeks of operation, after which time the assayed drums will be either returned to TRU waste retrievable storage or sent to burial as ordinary solid low level waste if below 10 nCi/g.

Once the system is tested and fully operational, ORNL intends to examine all presently stored drums plus newly generated wastes by the end of FY85. The system will assay only the newly generated ORNL wastes after that time. The testing period includes system calibration and verification checks in which selected drums are opened and sampled and the samples are assayed on a separate gamma spectrometer system.

Several TRU radionuclides are present in the ORNL wastes which also include significant beta/gamma emitters. The principal TRU component is U-233 but Pu, Am, Cm, and Np are also present. One purpose of this demonstration is to show that the DDT system can assay for the TRU content at the 10 nCi/g level in the presence of the beta/gamma emitters.

The schedule for this prototype demonstration is given in a chart below.

RHO DRUM COUNTER PROTOTYPE

The purpose of this task is to design and test a prototype counter for 55 gallon drums, allowing the capability to assay waste generated and stored at Rockwell. This counter will assay waste for separation of low level from TRU at the 10 nCi/g level. A large volume of this waste is high density, contaminated with a variety of fissile materials and fission products. Due to this high density and varied isotopic content, these drums cannot be measured accurately with the instruments presently utilized. This prototype will be able to measure this high density waste.

The instrument will be housed in a separate facility which will handle 500 drums a month. This facility will be located adjacent to the solid waste burial ground.

An estimated 20-50% of the 3000 drums classified as TRU yearly are actually low-level wastes. Separation of these drums for shallow land burial, as opposed to interim TRU pad and final repository, will provide a cost savings for Rockwell.

The TRU wastes at the Hanford site are mostly plutonium contaminated wastes, but some U-233, Np-237, and Am-241 contamination is also present in certain wastes.

The instrumentation system for this prototype test will be designed and built at LANL. The facility design and instrument testing will be done at RHO. After the test period, the instrument will be turned over to Hanford waste management for continuous operations use. The schedule for this task is included in the chart below.

ACTIVE INTERROGATION USING NEUTRON SOURCES

Accomplishment	FY79				FY80				FY81				FY82				FY83				FY84				FY85			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Select System(s) for development to assay high density wastes				X																								
Complete construction of DDT test system									X																			
Complete Cf-242 feasibility study				X																								
<u>ORNL Drum Counter Prototype</u>																												
Complete simulated waste drum testing at LANL										X																		
Installed at ORNL														X														
15 Drums assayed															X													
System release to operations																		X										
<u>RHO Drum Counter Prototype</u>																												
System selected													X															
Construction complete at LANL																			X									
Calibration and testing complete at LANL																								X				
Installed at RHO																												X
Fully operational - - - FY86																												
Released to operations - - -FY 86																												

LINAC INTERROGATION SYSTEMS^{24,25}

Linear accelerator based photon and neutron interrogation systems provide the best promise for rapid assay of large containers without significant matrix effects and for rapid assay of streams for solid waste processing. This is another area where technology is being developed from earlier safeguards instrumentation work. Work supported by the TRU Waste Management program has included both photon (photofission) and neutron interrogation methods.

Work completed by LANL in FY80 using neutron interrogation showed that measurements could be made that were independent of matrix and that a sensitivity of about 1nCi/g could be achieved for 55 gallon drums. Experiments were conducted using Be (γ, n) neutrons produced by pulsed high energy electron bremsstrahlung. An electron linac beam was directed onto a Be target replacing part of the graphite cavity wall housing 55 gallon drums containing high density matrices ($>0.8\text{g/cm}^3$) such as sand, vermiculite, aluminum scrap, polyethylene, or borated glass beads. The interrogating flux was measured separately from the assay signal by using a flux monitor in the assay chamber. These flux measurements were used to normalize the assay signal and even though the interrogating flux varied by a factor of four the assay accuracy was about $\pm 20\%$ for the matrices tested. For a 200-s linac interrogation run the 3σ detection limits ranged from 0.4 to 0.7 mCi Pu, depending on the matrix in the barrel. This corresponds to a detection limit well under 1nCi/g for all matrices tested.

A milestone chart for activities in this area is given below.

LINAC INTERROGATION SYSTEMS

Accomplishment	FY79				FY80				FY81				FY82				FY83				FY84				FY85			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Photon Interrogation of small and large samples							X																					
Neutron Interrogation of small and large samples							X																					
Complete drum counter test station												X																
Assess applications of LINAC based assay												X																

ISOTOPE AND MATRIX IDENTIFICATION/CORRECTION²¹

Many of the instrumentation techniques are sensitive only to groups of isotopes, such as fissile isotopes, and also have different sensitivities to different isotopes. In addition, all techniques are affected by the matrix composition in which the transuranics are distributed. It is therefore necessary to conduct studies to define ways to compensate for the isotopic and matrix affects. The compensation can be achieved by knowing the isotopes and matrices present in the waste containers from careful waste records; but this is usually impractical. It is desirable to be able to include additional instrument measurements in the total instrument system that will allow calculation of the proper correction factors without prior knowledge of the container contents.

In passive x-ray and gamma counting systems, the principal sources of matrix generated assay errors are gross gamma-ray scattering and/or attenuation and, for some high TRU wastes, self-attenuation. For most practical screening/low precision assay applications, matrix effects are adequately taken into account with calibrations based on standards placed in typical matrix geometries. A more sophisticated compensation is based on an adjunct external gamma source transmission measurement of the waste container from which an average gamma-ray attenuation factor may be derived. In any event, the accuracy of passive gamma-ray counting is generally quite good for low density wastes (density $< 0.2 \text{ g/cm}^3$), but is poor for higher density wastes.

In high density TRU waste assay systems involving neutron counting, the principal matrix associated errors are caused by hydrogen scattering/attenuation and thermal neutron absorption. A well designed counter can achieve a considerable degree of intrinsic matrix compensation. For example, He-3 proportional counters with about 2.5 cm of polyethylene moderator in front and ≥ 2.5 cm of polyethylene in back exhibit essential flatness of response for matrix hydrogen densities ranging from zero to the equivalent of about 3-cm thickness of water moderator.

Another matrix hydrogen density compensation technique used the so-called "ring-ratio" or "slab-ratio" method. Here the detector is constructed so as to provide neutron spectral information. This spectral information can then be interpreted in terms of equivalent hydrogen density in the waste matrix and appropriate corrections can be made in the assay analysis.

In the pulsed active neutron techniques matrix compensation can be achieved using thermal neutron interrogation cavity flux monitors. Interrogating flux reductions or increases produced by matrix constituents are measured by the flux monitor. In addition, interrogation cavity thermal neutron lifetimes have been measured with this system and a strong correlation between average neutron lifetime and the amount of neutron absorbing materials in the matrix has been found. Another approach under investigation uses the measurement of matrix capture gamma-ray spectra to determine matrix composition. This measurement is done simultaneously with the induced fission neutron measurement.

Isotopic identification can often be accomplished by using a crude gamma ray spectral analysis prior to the more sensitive 10 nCi/g assay. The gamma ray analysis is then used to compensate for the isotopic affects.

A milestone schedule for this task area is included below.

ISOTOPE AND MATRIX IDENTIFICATION STUDIES

Accomplishment	FY79				FY80				FY81				FY82				FY83				FY84				FY85			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
General isotope and matrix identification studies					ongoing																							
Complete studies for ORNL System and incorporate in system													X															

DISCUSSION

All of the DOE contractor sites generating TRU waste have some form(s) of NDA instrumentation. The instrumentation at each site is presented in the section "Review of Presently Used Instruments" and is summarized for comparison in the tables below.

The instruments are split into three groupings in Tables IV, V, and VI. Table IV shows the counters used for containers smaller than 55-gallon drums while Tables V and VI cover 55-gallon drum counters and larger container counters, respectively. These tables list only instruments for past, present, or near future production use. Systems that are still under development or are in the early test and evaluation phases are not listed. Passive interrogations systems are listed first in each table, followed by the active interrogation systems. The columns are similar in each of the tables.

The first four columns give: (1) brief descriptions of the scrap or waste with "miscellaneous" applied to counters accepting several kinds of wastes, (2) container sizes typically used, (3) indication of passive or active bases for the measurements, and (4) an abbreviation for the contractor or the site. The fifth column gives an indication of the kinds of radiation that are detected by a given counter. In the fifth column the phrase "gamma-ray segmented scan" has a special meaning in these tables that includes a density correction based on a measured transmission using an external radioactive source. Other kinds of sample self attenuation corrections are noted, if known. The sixth column gives the amount of material normally counted, which is plutonium unless otherwise noted. Minimum detectable amounts of plutonium cannot always be inferred from this column, although ranges with a lower end in the microgram (μg) range are near the minimum detectable amounts attainable with the users normal counting period. The term "unk" means unknown or not available. Some counters could detect less than the values listed in the tables depending on length of counting time, presence or absence of interfering radiation, background radiation levels, and so forth. For example, the Savannah River

Plant occasionally uses its counters to assay near the 10 nCi/g level by using extended counting periods of many hours per sample. Such use is, however, not practical for continuous production use where many containers must be counted each day. The seventh column gives a brief description of the density or other physical characteristics of waste or scrap counted. The eighth, and final, column includes short comment that may be of interest to some readers and notes detectors (other than germanium spectrometers) that are presently used or were used in the past.

Several observations can be made from these tables. It is obvious that some form of NDA instrumentation is used at each site. However, very few of these counters routinely assay at the 10 nCi/g level. Almost all of these counting systems were installed for special nuclear materials accountability purposes and are used to separate recoverable scrap from wastes at levels near 1 g of transuranic content. As seen from the information in the section "Review of presently used instruments", much of the waste is judged only administratively to determine whether it is LLW or TRU waste and is never assayed.

There are several reasons, economically based, that there are not more low level counters in use today. First, any waste disposal cost savings at the time of original counter installation did not justify low level counting; second, the time, manpower, and logistics to separate the wastes into uniform waste classes (matricies) for assay was considered to be too troublesome; third, cost of recovery of the nuclear materials did not justify counting low levels; and fourth, money is not readily available for system upgrades or for new systems. Several sites have recently determined that separation of LLW from TRU wastes has economic advantages that make low level assay and waste segregation advisable. LANL presently has two systems for assay of low density combustible wastes and the Rocky Flats Plant has found that some changes in operation to certify that combustible waste is below 10 nCi/g could result in disposal cost reductions that would pay back the instrumentation costs within a few years.

There are very few active assay systems in use at these facilities today and none are used to routinely assay wastes at the 10 nCi/g level. Economic considerations in waste disposal are, however, also making these active systems attractive for assay of higher density wastes in the larger containers. The two prototype demonstration tasks of the TRU Waste Management Program are designed to show that these systems are available and reliable on a production-use basis. It is also hoped that some of the active systems can be developed so that their costs are competitive with the more sophisticated, accurate passive assay systems (i.e., passive systems at the high end of the cost range). The advantage of active assay counters is that inspection times should be shorter than inspection times needed for passive systems, when assaying at 10 nCi/g. This is an important consideration for production facilities. Passive assay signals can be completely concealed by high radiation fields and active systems must be used in these cases.

Package size has a direct bearing on the choice of active or passive assay. In small containers, acceptable detectivity can usually be achieved in short times with passive systems. In 55 gallon drums, however, the loss of abundant low energy x-rays to matrix and container attenuation greatly increases required assay times or may render passive assay completely unusable. Appropriate active systems become the choice in these cases because they can generate usable net signal in less time. In very large containers there is enough absolute amount of nuclear material present at the 10 nCi/g level to produce neutron signal acceptable for passive assay in 10 to 15 minute counts (if a high efficiency detection system is used and excellent background shielding is available). Active systems for these very large containers usually require scanning in segments because delivering a uniform interrogating flux to the whole container is not practical. Therefore, both passive and active systems are being studied and developed for the large containers by the TRU Waste Management Program.

Another factor, besides equipment costs and time per assay, that affects choice of an assay system is the ability to deal with variable wastes. It is desirable to assay waste containers without the necessity for extensive prior knowledge of the isotopic content and matrix content in the waste container. Both active and passive interrogation methods are affected by the isotopic content and matrix attenuation. Development tasks supported by the TRU Waste Management Program include studies on isotopic identification, matrix identification, and correction for these factors.

TABLE IV. Counters In Use for TRU Isotope Bearing Materials in Smaller Containers

<u>USE</u>	<u>SIZE (gallons)</u>	<u>METHOD</u>	<u>SITE</u>	<u>SIGNAL OR^(a) PRINCIPLE</u>	<u>NORMAL RANGE</u>	<u>MATRIX</u>	<u>COMMENTS^(b)</u>
Leached hulls	< 5	Passive	PNL	Neutron	Unk	Metals with fission products	100 to 1800 seconds MDA = 46 mg of Pu isotopic distribution inferred
Miscellaneous laboratory waste	1	Passive	PNL	Gamma ray segmented	Unk	Low density waste	100 seconds or more, est. MDA < 10 mg. Mobile in van
Miscellaneous production waste	15	Passive	LANL	X-ray & gamma ray segmented	5 µg - 5.0 g	Very low density paper, rags, etc. in cardboard box	1000 seconds, MEGAS design
Miscellaneous production waste	1	Passive	MF	Gamma ray			300 sec., used for Pu-238, in principle, TRU can be counted
Miscellaneous production waste	1	Passive	RHO	X-ray & gamma ray segmented	10 µg - 10 g	Very low density paper, rags, etc.	200 seconds, MEGAS design
Miscellaneous production wastes	1	Passive	RFP	Gamma ray, weight correction	0.5 - 200 g	Low density to medium density	100 sec/assay, NaI,
Miscellaneous production wastes, esp. incinerator ash	1	Passive	RFP	Gamma ray, single scan	0.5 - 700 g	Low to medium density	300 sec/assay, NaI, single average transmission
Pyrochemical salts	0.5	Passive	RFP	Gamma ray, segmented	0.5 - 500 g	Medium density	300 sec/assay
Laboratory waste	5	Passive	SRL	X-ray & gamma ray	0 to 0.5	Very low density	300 sec, Ge detector, not segmented

TABLE IV. Counters in Use for TRU Isotope Bearing Materials in Smaller Containers (continued)

USE	SIZE (gallons)	METHOD	SITE	SIGNAL OR (a) PRINCIPLE	NORMAL RANGE	MATRIX	COMMENTS
Miscellaneous scrap & waste with mixed TRU & non TRU fissile; also some product	5	Passive	SRP	Gamma ray segmented	2 - 250 g	Low & medium density	Ge replaced NaI, 10 nCi/g achieved only with several hours count
Process scrap & waste mixed TRU & other fissile	5	Passive	SRP	Gamma ray single scan	2 - 250 g	Low & medium density	Same as above entry, but has single average transmission
Product feed	0.5	Passive	SRP	Neutron, slow coincidence	1500 - 2500 g	High density	HLNCC design(c)
Miscellaneous	ca. 5-55	Active	PNL	Neutron and gamma ray fast coincidences after induced fission	0.5-200	Low to high density	2 each - random driver designs in mobile system
Miscellaneous laboratory waste or scrap	ca. 1	Active or passive	PNL	Neutron, slow coincidence	0.1-500	Low to high density	Neutron well counter design operable in two modes
Miscellaneous scrap	1	Active	SRP	Neutron	Not Avail- able	Low to high density	Under test & evaluation; pro- duction use soon

(a) "Gamma ray, segmented" means counters with gamma ray spectrometers that are germanium diodes. Transmission per segment is measured except as noted in the table.

(b) "NaI means a thallium activated sodium iodide detector.

(c) "HLNCC" means high level neutron coincidence counter, which is a neutron coincidence well counter adapted for higher levels of plutonium.

TABLE V. Counters in Use for TRU Isotope Bearing Materials in Drums

USE	SIZE (gallons)	METHOD	SITE	SIGNAL OR ^(a) PRINCIPLE	NORMAL RANGE	MATRIX	COMMENTS
Miscellaneous waste	55	Passive	PNL	Gamma ray segmented	< 200 g	Low density	≈ 300 second assay, mobile in van
Miscellaneous waste	55	Passive	HEDL	Gamma ray segmented	1-5 g	Low density	Could be used on smaller packages
Miscellaneous waste	55	Active	HEDL	Neutron and gamma ray, coincidence	5-20 g	Low to medium density	Could be used on smaller packages
Miscellaneous waste	55	Passive	INEL	Neutron and gamma ray, n-fold coincidence	0.5-200 g	Low & medium density	Can handle 83-gallon drum, ≈ 200 sec/count, not for accountability
Miscellaneous waste	55	Passive	LANL	Neutron, slow coincidence	0.5-200 g	Low & medium density	100 sec assay, 4 π counter
59 Miscellaneous waste	55	Passive	ORNL	Gamma ray, segmented	0.5-100 g	Low & medium density	15 min/assay, longer for 10 nCi/g, not normally used at lowest levels
Miscellaneous waste	55	Passive	MF	Gamma ray, segmented	20 mg - 25 g	Low & medium density	1800 sec, used for Pu-238 and could assay TRU
Miscellaneous waste	55	Passive	RHO	Gamma ray segmented	20 mg - 100 g	Low & medium density	Few minutes/assay, Ge upgraded from NaI
Miscellaneous scrap & waste	55	Passive	RFP	Gamma ray, average density correction	0.5 - 200 g	Low & medium density	100 sec. assay. Once demonstrated to detect 10 mg on longer count
Miscellaneous scrap & waste	55	Passive	RFP	Gamma ray, intensity ratio correction	0.5 - 200 g	Low & medium density	600-1200 sec assay, not tested on small amounts, to be retired
Miscellaneous scrap & waste	55	Passive	RFP	Gamma ray, segmented	0.5 - 200 g (est)	Low & medium density	Onsite. In production by Sept. 1981

TABLE V. Counters in Use for TRU Isotope Bearing Materials in Drums (continued)

<u>USE</u>	<u>SIZE (gallons)</u>	<u>METHOD</u>	<u>SITE</u>	<u>SIGNAL OR (a) PRINCIPLE</u>	<u>NORMAL RANGE</u>	<u>MATRIX</u>	<u>COMMENTS</u>
Miscellaneous scrap & waste mixed TRU	55	Passive	SRP	Gamma ray aver- age transmission	0.5 - 500	Low & medium density	Ge spectrometer
Miscellaneous scrap & waste mixed TRU	55	Passive	SRP	Gamma ray, aver- age transmission	2 - 250	Low & medium density	Ge spectrometer replaced a NaI system
Miscellaneous waste	55 + misc. other	Passive	SRP	Gamma ray no transmission	0.1 - 5	Low & medium density	NaI, "all purpose"
Miscellaneous U-238 + TRU	55	Active	PNL	Neutron & gamma ray fast coinci- dence	0.5 - 100	Low to high density	Random driver concept (NNC) ^(b)

(a) Segmented scanning systems have measured transmission matrix corrections except as noted. Most segmented high resolution systems might detect 10 nCi/g given long assay times.

(b) NNC = National Nuclear Corporation

TABLE VI. Counters In Use for TRU Isotopic Bearing Materials in Large Boxes or Crates

<u>USE</u>	<u>SIZE (gallons)</u>	<u>METHOD</u>	<u>SITE</u>	<u>SIGNAL OR PRINCIPLE</u>	<u>NORMAL RANGE</u>	<u>MATRIX</u>	<u>COMMENTS</u>
Miscellaneous	<u>< 6x7x9 ft</u>	Passive	MF	Gamma ray, segmented transmission correction	0.1 to 20 g	Metal, glove boxes, & other large items	Three hours average per crate, used for Pu-238. Presume could use for some TRU
Miscellaneous production waste and size reduced	4x4x7 ft	Passive	RFP	Neutron singles and gamma ray, ratio correction	1 to 350 g	Low density, low atomic numbers or misc. metal	45 min. average per crate, used for test of summed drum results and estimates of metals
Miscellaneous size reduced scrap	Variable	Passive	RFP	Gamma ray	1 to 50 g	Cut up metal scrap, misc. other	Some scrap pieces estimated before placement in crates
Miscellaneous waste and scrap	to 8-ft lengths	Passive	SRP	Neutron singles	5 to 2500	Mostly metals	Estimator only

RECOMMENDATIONS

The continued development of assay instruments capable of achieving 10 nCi/g sensitivities for TRU waste containers is recommended. As the future directions of the national program for nuclear wastes become more specific, future instrumentation needs will become clearer. A simplified summary of possible future actions is presented in Table VII. The studies and actions are discussed below.

The needs for nondestructive assay instrumentation depend on the outcome of several studies presently in progress within DOE. Results of these studies could eliminate the need for further assay instrumentation development by the TRU Waste Management Program or could require continued development with increased emphasis on instrumentation used in waste processing or for certification of wastes to WIPP criteria. The studies involve WIPP certification, economic evaluation of alternatives, decisions on whether to exhume buried waste, and studies to redefine the 10 nCi/g definition of TRU waste to higher and more easily measured TRU concentrations. If the concentration of transuranics differentiating between low level and TRU waste were redefined to 100 nCi/g rather than the present 10 nCi/g, this could relax the need for new assay techniques. Assay times could be shortened and in some cases the need would be eliminated for active systems presently considered necessary to reliably meet the 10 nCi/g limit. The WIPP certification studies will define the need for assay of containers going to that facility and define the need for processing stored wastes. This will in turn affect the requirement for instrumentation related to the need for processing.

The economic studies will have a large effect on instrumentation needs since much of the present reason for NDA instrumentation development is based on the perceived economic benefit for separating low level and TRU wastes. By proper administrative separation of wastes (known to be low level at the source of generation from those known or suspected of being

TRU waste) much of the waste segregation can be accomplished without instrumentation. The economic advantage for instrumentation then comes from separating out low level waste included in the TRU waste from the "suspect TRU" category. Economic studies to date show that storage, transportation, and incremental disposal costs favor this instrumental separation even with good administrative preseparation.

The outcome of several environmental and risk studies will determine the need for processing buried wastes and will have a major effect on the need for assay instrumentation development for processing. The exact course of action for instrumentation development will be determined after these studies have been completed.

TRU Waste Management Program action will be to continue development of new instrumentation for waste container assay through FY84. Implementation of these instruments at waste handling sites will depend on the requirements defined by economic and use studies now in progress. A low level of effort will be continued to maintain program continuity for instrumentation related to waste processing until exact needs are fully defined.

TABLE VII. Program Actions Dictated by Possible Administrative Decisions

<u>WIPP Criterion SAME*1</u>	<u>Processing Required*3</u>	<u>Economics*4 Favor Separation of LLW & TRU</u>	<u>Program Action</u>
Yes	Yes	Yes	Continue to develop for containers & Processing
Yes	Yes	No	Reduce development
Yes	No	Yes	Continue container assay development
Yes	No	No	Stop development, present systems good enough
No*2	Yes	Yes	Continue development
No	Yes	No	Restructure development
No	No	Yes	Continue container assay development
No	No	No	Develop only to new WIPP criteria

*1 - Present criterion on TRU assay is not tight, special instruments not required.

*2 - This assumes more restrictive assay criteria are assigned.

*3 - Includes processing of stored wastes or exhumation and processing of buried wastes if either is found necessary.

*4 - This depends on the outcome of present transportation, storage, and processing cost studies.

REFERENCES

1. "Spent Fuel and Waste Inventories and Projections as of December 31, 1980," Oak Ridge National Laboratory, ORNL/NFW-81/9, to be published, (updates Oak Ridge National Laboratory report ORO 778).
2. Goris, Paul, Hanford Engineering Development Laboratory, Personal Communications.
3. Randolph, P.D., Wells, J.D., and Anderson, B. C., EG&G Idaho, Personal Communications.
4. Alexander, D. R. and Motes, B. G., Exxon Nuclear Idaho Company, Personal Communications.
5. Warren, J. L., and Umbarger, C. J., Los Alamos National Laboratory, Personal Communications.
6. Campbell, A. R., Mound Facility, Personal Communication.
7. Haff, K. W., and Krichinsky, A. M., Oak Ridge National Laboratory, Personal Communications.
8. Brodzinski, R. L. and Fager, Jon, Pacific Northwest Laboratories (Battelle), Personal Communications.
9. Brodzinski, R. L., and Wogman, N. A., "In-Situ Quantitative Determination of Transuranic Elements in Areas of High-Level Gamma Radiation," Analytical Methods for Safeguards and Accountability Measurements of Special Nuclear Materials, NBS Special Publication 528, 1978, p. 253.
10. Nielson, K. K., Brodzinski, R. L., and Wogman, N. A., "In-Situ Transuranium Element Measurement Technique for Wastes Associated with Power Reactor Fuels," Analytical Methods for Safeguards and Accountability Measurements of Special Nuclear Materials, NBS Special Publication 528, 1978, p. 201.
11. Wogman, N. A., Brodzinski, R. L., and Brown, D. P., "An Instrument for Monitoring the Transuranic Content of Chopped Leached Hulls from Spent Nuclear Fuel Elements," Analytical Methods for Safeguards and Accountability Measurements of Special Nuclear Materials, NBS Special Publication 528, 1978, p. 284.
12. Manry, C. W., Rockwell Hanford Operations, Personal Communications.
13. Kay, Michael A., In-Site Determination of Transuranic and Fission Product Radionuclides, Proceedings of the Fourth International Conference on Nuclear Methods in Environmental and Engineering Research, University of Missouri, Columbia, Missouri, April 1980.

REFERENCES (continued)

14. Harlan, R. A., and Wickland, C. E., Rocky Flats Plant, Personal Communications.
15. Gibbs, Ann, Savannah River Laboratory, Personal Communications.
16. C. J. Umbarger and L. R. Cowder, "Measurement of Transuranic Solid Wastes at the 10 nCi/g Activity Level," Nucl. Tech. 27,500 (1975).
17. C. J. Umbarger, R. B. Walton, J. E. Foley, and L. R. Cowder, "NDA Measurement of Low-Level U and Pu Waste," J. Inst. Nucl. Materials Management, Proc. 15th Ann. Mtg., 3, 3 (Fall 1974).
18. Caldwell, J. T., et al., "Recent Developments at Los Alamos for the Measurement of Alpha Contaminated Wastes," International Symposium on the Management of Alpha Contaminated Waste, IAEA-SM-246/67, Vienna, Austria, June 2-4, 1980.
19. J. T. Caldwell, H. F. Atwater, W. Bernard, J. M. Bieri, and E. R. Shunk, "A Large Vehicle Portal Monitor for Perimeter Safeguards Applications," Proceedings of the 1st ESARDA Symposium on Safeguards and Nuclear Materials Management, Brussels, Belgium, April 25-26, 1979, p. 122.
20. T. W. Crane, "Measurement of Uranium and Plutonium in Solid Waste by Passive Photon or Neutron Counting and Isotopic Neutron Source Interrogation," LA-8294-MS (March 1980).
21. Kunz, W. E., et al., "A 1-mg-Sensitivity Fissile Assay System," Proceedings of the 3rd Annual ESARDA Symposium on Safeguards and Nuclear Materials Management, Karlsruhe, W. Germany (1981).
22. H. O. Menlove and T. W. Crane, "A ^{252}Cf Based Nondestructive Assay System for Fissile Material," Nucl. Instr. and Meth. 152, 549-557 (1978).
23. T. W. Crane, "Measurement of Pu Contamination at the 10-nCi/g Level in 55-Gallon Barrels of Solid Waste with a ^{252}Cf Assay System," in Proceedings of the International Meeting on Monitoring of Pu-Contaminated Waste, Sponsored by the Commission of the European Communities Joint Research Centre, Ispra, Italy, September 25-28, 1979 (EUR 6629 EN), 217-226.
24. Kunz, W. E., Atencio, J. D., Caldwell, J. T., "A 1-nCi/g Sensitivity TRU Waste Assay System Using Pulsed Neutron Interrogation," submitted to the 21st Annual Meeting of the INMM, Palm Beach, FL, June 1980.
25. Cates, M. R., et al., "Low-Level Transuranic Waste Assay by Photon Interrogation and Moderated Neutron Counting," Los Alamos Scientific Laboratory report LA-7857, October 1979.

REFERENCES (continued)

26. Hamilton, R. A., Evaluation of the Mound Facility Calorimeter Equilibrium Prediction Program," RHO-SA-114, (July 1979).
27. Hamilton, R. A., "Operating Experience with a Large Sample, High Throughput, Plutonium Assay Calorimeter System," RHO-SA-231, (December 1981).
28. Kindle, C. H., "In Situ Measurement of Residual Plutonium," ARH-SA-238, (June 1976).
29. Westsik, G. A., "Field Nondestructive Assay Measurements as Applied to Process Inventories," RHO-SA-96, (August 1979).
30. Fischer, D. D., Rockwell Hanford Operations, Personal Communications.
31. Hall, V. E., Rockwell Hanford Operations, Personal Communications.
32. Sher, R. and Untermeyer, II, S., The Detection of Fissionable materials by Nondestructive Means, American Nuclear Society, 1980.
33. Gozani, T., Active Nondestructive Assay of Nuclear Materials, Principles and Applications, NUREG/CR-0602, SAI-MLM-2585, U.S. Nuclear Regulatory Commission (1981).
34. Rogers, D. R., Editor, Handbook of Nuclear Safeguards Measurement Methods, NUREG/CR-2078, MLM-2855, U.S. Nuclear Regulatory Commission, to be published.
35. Tinney, J. F. and Koch, "An X-ray Survey Meter for Plutonium Contamination," Hazards Control Progress Report No. 29, University of California, Lawrence Radiation Laboratory, UCRL-50007-67-3, 1967, p. 150.