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SAFEGUARDS INSTRUMENTATION A COMPUTER-BASED CATALOG Second Edition

Clemens Auerbach

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**TECHNICAL SUPPORT ORGANIZATION
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INTRODUCTION

A. General Remarks

This report, a second edition of BNL 51450 (see Reference File), was assembled at the request of the Office of Safeguards and Security, U.S. Department of Energy, under the auspices of its International Support Program. In view of the favorable reaction to BNL 51450 on the part of its users, format and orientation of the CATALOG were left basically unchanged. A deliberate effort was made to focus on the operator-inspector interface, with the following prospective users in mind: (1) inspectors (IAEA, regional and national) who will derive profit from a systematic knowledge of what is available to operators in the way of safeguards-related equipment; and (2) facility operators whose interest in implementing improved safeguards is predicated both upon operational and administrative requirements and upon the need to interact effectively with inspectors. In keeping with this orientation, the CATALOG does not include devices for physical protection; NUREG-0274 (Catalog of Physical Protection Equipment, MITRE Corporation, 1978) provides useful detailed information in the physical protection area.

This CATALOG contains entries on new developments and on items listed in BNL 51450, which have either been carried over unchanged or been updated. More than 70 entries were deleted because of either obsolescence, insufficient interest in terms of safeguards, or lack of documentable development activities in recent years. Some old listings as well as new material were consolidated into more generic entries. As in the earlier document, the emphasis is on devices and instruments that are either in field use at this time or under

active development. A few items such as NDA reference materials, instrument vans and certain shipping containers are included because they are important adjuncts to optimum utilization of safeguards instrumentation. As was the case with its predecessor, most of the material in this CATALOG originated in the U.S. and Canada; a few contributions came from member states of the European Community. It is hoped that circulation of the CATALOG will serve to promote a wider exchange of information between the U.S. and other nations engaged in safeguards technology development. The data base (see below) is not only accessible to queries but can also be expanded to receive new entries, and stripped of obsolete or redundant items. Indeed, users are invited to send appropriate material to the author and thereby contribute to keeping the data base current.

The quest for reliable cost information remains a difficult one. While capital cost figures have been obtained for most entries, information on maintenance cost, replacement cost and lifetime is still fragmentary. Apart from their tendency to fluctuate, most figures should be viewed mainly as guidelines, especially in the case of equipment under development at non-commercial sources. In some cases additional comments may be found under DESCRIPTION. Costs are given in U.S. dollars, as of the latter half of 1984.

For equipment which is commercially available, the SOURCE line identifies representative suppliers. Whenever applicable, the line is also used to identify laboratories or contractors which are involved in development work; these may therefore serve as sources of both the equipment itself and of information relating to it. The list of suppliers, commercial or otherwise, is not intended to be exhaustive. A citation in no way represents an endorsement, and

omission carries no implication that sources not listed are less qualified than those cited. Again, in some cases additional comments may be found under DESCRIPTION.

B. How to Use the CATALOG

This CATALOG was assembled from a slightly modified form of the computer data base which was developed to produce BNL 51450 and store the information contained in it. It is made up of the Equipment File (Section VII), the Reference File (Section VIII), and the Source File (Section IX). Users can access the three files for immediate queries; the USER'S GUIDE (BNL-30660, Dec. 1981) will be revised in the near future to reflect the modifications. A discussion of Sections III-IX follows, starting with the three data files.

1. Section VII

The Equipment File consists of the following lines; those which are either inapplicable or for which information is unavailable are not printed.

- a. EQUIPMENT NAME - Self-explanatory
- b. USE CATEGORY
 - (1) Materials Accountancy
 - (2) Containment-Surveillance

The term "Inspector Use" was dropped because it overlaps the others and because the USEFUL TO line effectively conveys the information in question. The "Process Monitoring" term was also eliminated; this CATALOG is dedicated to safeguards applications, regardless of additional functions which a given piece of equipment can fulfill. It is recognized that some of the flow measuring and sensing devices bear a somewhat tenuous relationship to

Materials Accountancy.

c. GENERAL TYPE - This is the key line, because the Equipment File entries are arranged by GENERAL TYPE. The categories used in this CATALOG are listed below; a degree of arbitrariness in their use is unavoidable. For example, some of the "active" NDA devices listed can also be used in the "passive" mode, i.e., in the absence of an external source.

- (1) Mass Measurement
- (2) Density Measurement
- (3) Volume Measurement
- (4) In-Process Monitor
- (5) Element Measurement
- (6) Isotope Measurement
- (7) NDA: Active Gamma
- (8) NDA: Passive Gamma
- (9) NDA: Passive L X-ray
- (10) NDA: Active Neutron
- (11) NDA: Passive Neutron
- (12) NDA: Passive N&G
- (13) NDA: Alpha
- (14) NDA: Heat
- (15) NDA: Sound
- (16) Bundle Counter
- (17) Optical Surveillance
- (18) Portal Monitor
- (19) SNM Monitor

- (20) Seal
- (21) In-Plant Monitor
- (22) Identification
- (23) Communication
- (24) Transportation
- (25) Environmental Monitor
- (26) Sealed Container

d. MATERIAL TYPE - The following descriptive or inclusive terms are used in this CATALOG for the primary material upon which the equipment operates or with which it is associated; again, some arbitrariness is unavoidable.

- (1) Containments
- (2) Fuel (Fresh)
- (3) Fuel (General)
- (4) Fuel (Spent)
- (5) Gamma Emitters
- (6) Heavy Water
- (7) In-Process Liquids or Gases
- (8) Laboratory Samples
- (9) Miscellaneous
- (10) Plutonium
- (11) SNM in Solutions
- (12) SNM in Waste
- (13) SNM (Miscellaneous)
- (14) Uranium
- (15) Uranium Hexafluoride

e. STATUS - The following four classifications used in the Program for Technical Assistance to IAEA Safeguards have been adopted as a convenient indicator of current status (see POTAS reference in Section VIII), although it is recognized that much of the equipment in this CATALOG has not been designed expressly for IAEA use. The distinction among the first three classes is somewhat arbitrary; also, in some cases inclusion in Class IV merely means that the capability for commercial production exists.

(1) CLASS I: Laboratory Device - The purpose of this equipment is to demonstrate the principle of operation and the nature of the data that will be produced, so that the IAEA can comment on the approach and future design options. In most cases the equipment will be operated by the designer.

(2) CLASS II: Development Prototype - The purpose of this equipment is to allow joint IAEA-US evaluation, including laboratory and limited field testing. Technical experts at the IAEA will be trained to use the equipment. A preliminary equipment manual will be provided and a preliminary safety analysis will be completed.

(3) CLASS III: Field Evaluation Unit - The purpose of this equipment is twofold: to permit (1) final evaluation of the device prior to developing a production capability and (2) limited use during IAEA inspections. The unit will have undergone a complete safety and reliability analysis. A complete equipment manual and development report will be provided. Where limited quantities are required to meet IAEA needs, these units could be put into full operation by the IAEA after the field evaluation is complete.

(4) CLASS IV: Production Model - Equipment developed to this point will have complete production drawings, production specifications, test

procedures, etc., such that the IAEA can obtain commercial supplier quotes on fabrication, testing and delivery of multiple quantities.

f. STATUS DETAIL - This line is a new addition; it appears only in those cases where a capsule phrase on current status could be formulated and appeared useful.

g. USEFUL TO - This line indicates whether the equipment is primarily useful to an inspector, to the plant operator, or to both.

h. FACILITIES - This line identifies the facility types in the nuclear fuel cycle for which the equipment is useful. The category "Fuel Storage" refers to either fresh or irradiated fuel.

i. CAPITAL COST (See comments in Part A above) - This is the approximate cost of purchasing and possibly installing the equipment (in late 1984 U.S. dollars). For seals, this is often the cost of the verification device. As stated earlier, additional comments may appear in the DESCRIPTION. For example, in some cases the cost of ancillary electronic packages is not included.

j. MAINTENANCE COST (See comments in Part A above) - This includes annual repair costs, film costs, battery costs, or other operating costs. For seals, this is the cost of the seal itself. Note that the commonly used rule of thumb of taking 15% of the capital cost as annual maintenance cost has not been adopted in this CATALOG.

k. REPLACEMENT COST (See comments in Part A above) - This is the cost of replacing the equipment without paying again the structural installation costs.

l. LIFETIME (See comments in Part A above) - This is the useful life-

time in years, generally limited by obsolescence or breakdown. Another factor bearing on the lifetime of certain devices is the decay of radioactive sources.

m. SOURCE 1,2 (See comments in Part A above) - This line gives one or two brief descriptive terms which identify the complete listings in the Source File, Section IX. This would be either a representative commercial supplier of the equipment or a laboratory (or contractor) developing it.

n. REFERENCE 1,2 - This line gives one or two brief descriptive terms which identify the listings in the Reference File, Section VIII.

o. REFERENCE DETAIL - This line appears only if a reference is not a dedicated report; it gives additional bibliographic information: the author(s), the number of a page, a volume or an issue, and the year of publication. Unless indicated otherwise, the detail refers to REFERENCE 1.

p. DESCRIPTION - The DESCRIPTION provides a thumbnail sketch of the background, nature and use of the item in question. In some instances it includes information on cost and availability beyond what was stated in the COST and SOURCE lines. There are also occasional references to related equipment. The DESCRIPTION should not be regarded as providing technical specifications.

2. Section VIII

The Reference File gives bibliographic data on each of the references, identified by the descriptive terms mentioned in 1.n. above.

3. Section IX

The Source File is self-explanatory; the sources are identified by the descriptive terms mentioned in 1.m. above.

4. Section III

This is in effect a conventional Table of Contents, with equipment listed by page number, and by GENERAL TYPE.

5. Section IV

0 This is an alphabetical listing of the CATALOG entries.

6. Section V

The entries under each of the two USE CATEGORIES are listed by page number.

7. Section VI

The entries under each MATERIAL TYPE are listed by page number.

C. Background and Acknowledgements

The framework and starting point for this edition was BNL 51450; the background and original references are given in the INTRODUCTION to that document. The information presented in this CATALOG was again obtained from the available literature and from a large number of persons, both by correspondence and conversations. Individuals contacted include personnel at DOE contractors, foreign national and regional laboratories, the IAEA, and a variety of commercial organizations. The author has attempted to select literature references which are easily accessible and provide a maximum breadth of coverage, including enough citations to allow further background reading. As reflected in the Reference File, proceedings of INMM and ESARDA meetings and of other topical conferences have been particularly valuable to the author as sources of recent information. Some of the most informative technical reports cited in the CATALOG represent work sponsored by the U.S. Program for Technical Assistance to IAEA Safeguards (POTAS). Finally, the author has greatly profited from in-

formation relating to IAEA resources and needs, provided in different contexts by W.A. Higinbotham and G.R. Keepin.

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It is a pleasure to acknowledge the help and patience of Dave Kirby who modified the computer data base and report procedures which he had developed earlier, Bonnie Blittner who introduced this novice to the mysteries of the data base and once again contributed to the task of producing the document, and Karen Luczak who typed all the new and revised information into the data base.

Any errors and omissions are the responsibility of the author; comments, suggestions and criticism of either contents or format of the CATALOG will be greatly welcome.

GLOSSARY

AECL	Atomic Energy of Canada Limited
AFR	Away from Reactor
ANL	Argonne National Laboratory
ARC	AECL Random Coil
Ba	Barium
Be	Beryllium
BF ₃	Boron trifluoride
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
CANDU	Canadian Deuterium Uranium (Reactor)
CCTV	Closed-Circuit Television
CdTe	Cadmium Telluride
Ci	Curie
CRT	Cathode-Ray Tube
DCM	Data Collection Module
DOT	Department of Transportation
DRM	Delta-Rate Meter
DT	Deuterium-Tritium
ESARDA	European Safeguards Res. & Dev. Assoc.
EURATOM	European Atomic Energy Community
FBR	Fast Breeder Reactor
FCA	Fast Critical Assembly
FS	Full Scale
FWHM	Full Width at Half Maximum
GCEP	Gas Centrifuge Enrichment Plant
GM	Geiger-Mueller

GLOSSARY

HEU	Highly-Enriched Uranium
HP	High Purity
HW	Heavy Water
HZ	Hertz
IAEA	International Atomic Energy Agency
ICPP	Idaho Chemical Processing Plant
IDM	Inspector Display Module
INMM	Institute of Nuclear Materials Mgt.
JRC	Joint Research Centre
k\$	\$1,000
KV	Kilovolt
LANL	Los Alamos National Laboratory
LAW	Low-Activity Waste
LEU	Low-Enriched Uranium
LLNL	Lawrence Livermore National Lab.
LWR	Light-Water Reactor
M	Mega
ma	Milliamperes
MAW	Middle-Activity Waste
MCA	Multichannel Analyzer
mCi	Millicurie
MOX	Mixed Oxide
MR	Milliroentgen
MWd	Megawatt - Day
n	neutron
nCi	Nanocurie

GLOSSARY

NBL	New Brunswick Laboratory
NBS	National Bureau of Standards
NDA	Nondestructive Assay
NRC	Nuclear Regulatory Commission
ORGP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
PE	Polyethylene
PHA	Pulse Height Analysis
PNL	Pacific Northwest Laboratories
ppm	Part per Million
PRCM	Programmable Read-Only Memory
PVM	Personnel Vehicle Monitor
PWR	Pressurized-Water Reactor
R	Roentgen
RF	Radio Frequency
RMS	Root Mean Square
RSD	Relative Standard Deviation
RTD	Resistance Temperature Detector
SAL	Safeguards Analytical Laboratory
SCA	Single Channel Analyzer
SCCM	Standard Cubic Centimeter/Minute
SLPM	Standard Liters per Minute
SRP	Savannah River Plant
SNM	Special Nuclear Material
TC	Thermocouple
TDR	Time-Domain Reflectometry

GLOSSARY

THM	Tonnes Heavy Metal
THTR	Thorium High-Temperature Reactor
TRU	Transuranium
W	Watt
WINCO	Westinghouse Idaho Nuclear Company
XRF	X-ray Fluorescence
Z	Atomic (Element) Number
ZPPR	Zero-Power Plutonium Reactor

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Sec VII

EQUIPMENT NAME

GENERAL TYPE

USE
CAT.

1 Balances (Electronic)	Mass Measurement	MCA
2 Uranium-Hexafluoride-Cylinder Weight Standards	Mass Measurement	MCA
3 Semi-Portable Cylinder Load Cell	Mass Measurement	MCA
4 Vibrating Tube (Anton-Parr) Densimeter	Density Measurement	MCA
5 High-Precision Level and Density Sensor Box	Volume Measurement	MCA
6 Quartz Bourdon-Tube Digital Pressure Gauge	Volume Measurement	MCA
7 Turbine-Flowmeter Automated Tank Calibrator	Volume Measurement	MCA
8 Pulsed Sonar Sounding Device (AQUATRAK (R))	Volume Measurement	MCA
9 Radio Frequency Resonance Level Monitor	Volume Measurement	MCA
10 Time-Domain Reflectometry	Volume Measurement	MCA
11 Electromagnetic Flowmeter	In-Process Monitor	MCA
12 Mass Flowmeter	In-Process Monitor	MCA
13 Orifice Flowmeter	In-Process Monitor	MCA
14 Thermal Flowmeter	In-Process Monitor	MCA
15 Ultrasonic Flowmeter	In-Process Monitor	MCA
16 Vortex-Shedding Flowmeter	In-Process Monitor	MCA
17 Liquid In-Line Sensing Devices	In-Process Monitor	MCA
18 Thermal Flow Sensor	In-Process Monitor	MCA
19 Ultrasonic Liquid In-Line Sensor	In-Process Monitor	MCA
20 Transfer-Jet Monitor	In-Process Monitor	MCA
21 Tubing Block	In-Process Monitor	CS
22 Controlled-Potential Coulometer	Element Measurement	MCA
23 Atomic-Emission Spectroscopy	Isotope Measurement	MCA
24 Mass Spectrometer (Gas-Phase)	Isotope Measurement	MCA
25 Mass Spectrometer (Thermal-Emission)	Isotope Measurement	MCA
26 Two-Stage Mass Spectrometer	Isotope Measurement	MCA
27 Mass Spectrometer (Transportable Quadrupole)	Isotope Measurement	MCA
28 Mass Spectrometer, Quadrupole	Isotope Measurement	MCA
29 K- or L-Edge Densitometer	NDA: Active Gamma	MCA
30 K-Edge Densitometer (Compact)	NDA: Active Gamma	MCA
31 K-Edge Densitometer (KfK)	NDA: Active Gamma	MCA
32 K-Edge/K-XRF (Hybrid) Solution Assay System	NDA: Active Gamma	MCA
33 Energy Dispersive X-Ray Fluorescence Analysis	NDA: Active Gamma	MCA
34 Segmented Gamma Scanner (SGS)	NDA: Active Gamma	MCA
35 In-Line Gas-Phase Enrichment Monitor	NDA: Active Gamma	MCA
36 Stabilized Assay Meter (SAM-II)	NDA: Passive Gamma	MCA
37 Brookhaven Survey Assay Meter (BSAM)	NDA: Passive Gamma	MCA
38 Hand-Held Assay Probe (HM-4)	NDA: Passive Gamma	MCA
39 Hand-Held Detector for UF6 Cylinder Assay	NDA: Passive Gamma	MCA
40 UF6 Sample Bottle Enrichment Meter	NDA: Passive Gamma	MCA
41 Portable Plutonium Isotopic Analysis Unit (PIAU)	NDA: Passive Gamma	MCA
42 High-Resolution Gamma-Ray Spectrometer	NDA: Passive Gamma	MCA
43 High-Resolution Gamma-Ray Spectrometer (II)	NDA: Passive Gamma	MCA
44 Rocky Flats Assay Meter (RFAM)	NDA: Passive Gamma	MCA
45 Threshold Detector for Gamma Spectrometry	NDA: Passive Gamma	MCA
46 NDA Reference Materials for Scrap and Waste	NDA: Passive Gamma	MCA
47 Autoradiography	NDA: Passive Gamma	MCA
48 Low Pu Solution Assay Instrument (LOSAI)	NDA: Passive L X-ray	MCA
49 Random Driver	NDA: Active Neutron	MCA
50 Shuffler (Cf-252)-Mod. I (Fast/Thermal Neutron)	NDA: Active Neutron	MCA
51 Sb-Be Photoneutron Interrogation System	NDA: Active Neutron	MCA
52 Active Well Coincidence Counter (AWCC)	NDA: Active Neutron	MCA
53 Uranium Neutron Coincidence Collar	NDA: Active Neutron	MCA
54 Fuel-Rod Scanner	NDA: Active Neutron	MCA

Page in Sec VII	EQUIPMENT NAME	GENERAL TYPE	USE CAT.
55	Spent Fuel Assembly Assay System	NDA: Active Neutron	MCA
56	Spent-Fuel Assembly Monitor (KfK)	NDA: Active Neutron	MCA
57	Leached Hull Monitor	NDA: Active Neutron	MCA
58	Isot'ic Source Assay System/Fissometer (ISAS/ISAF)	NDA: Active Neutron	MCA
59	Differential Die-Away System for Waste Assay	NDA: Active Neutron	MCA
60	Crated Waste Assay Monitor (CWAM)	NDA: Active Neutron	MCA
61	Dual-Range Thermal-Neutron Coincidence Counter	NDA: Passive Neutron	MCA
62	Neutron Well Coincidence Counter	NDA: Passive Neutron	MCA
63	Neutron Well Coincidence Counter (KfK)	NDA: Passive Neutron	MCA
64	High-Level Neutron Coincidence Counter (HLNCC)	NDA: Passive Neutron	MCA
65	Plutonium Neutron Coincidence Collar	NDA: Passive Neutron	MCA
66	Inventory Sample Coincidence Counter (ISCC)	NDA: Passive Neutron	MCA
67	Special Coincidence Counter Heads	NDA: Passive Neutron	MCA
68	Universal Fast Breeder Reactor Subassembly Counter	NDA: Passive Neutron	MCA
69	Solution Neutron Coincidence Counter	NDA: Passive Neutron	MCA
70	Plutonium Nitrate Bottle Counter	NDA: Passive Neutron	MCA
71	End-Crop Box Counter (ECBC)	NDA: Passive Neutron	MCA
72	Reactor Power Monitor	NDA: Passive Neutron	CS
73	Fuel-Drawer Scanner	NDA: Passive N&G	MCA
74	Nondestructive Spent Fuel Verification (IDN-1)	NDA: Passive N&G	MCA
75	Multi-Energy Gamma Assay System (MEGAS-II)	NDA: Passive N&G	MCA
76	Multichannel Analyzer (Portable)	NDA: Passive N&G	MCA
77	Multichannel Analyzer (Stationary)	NDA: Passive N&G	MCA
78	On-Line Alpha Monitor	NDA: Alpha	MCA
79	Calorimeter	NDA: Heat	MCA
80	Ultrasonic Gauge	NDA: Sound	MCA
81	Ultrasonic Heavy Water Analyzer	NDA: Sound	MCA
82	Fresh-Fuel Bundle Counter (CANDU)	Bundle Counter	MCA
83	Spent-Fuel Bundle Counter (Sandia)	Bundle Counter	MCA
84	Spent-Fuel Bundle Counter (CANDU)	Bundle Counter	MCA
85	Spent-Fuel Bundle Gamma-Ray Verifier	Bundle Counter	MCA
86	Minolta Surveillance Camera	Optical Surveillance	CS
87	Film Camera System (CANDU)	Optical Surveillance	CS
88	KfK ELMO Camera System	Optical Surveillance	CS
89	Surveillance TV and Recording System (STAR)	Optical Surveillance	CS
90	MINISTAR System	Optical Surveillance	CS
91	Psychotronic Surveillance System	Optical Surveillance	CS
92	Closed-Circuit Television System (CANDU)	Optical Surveillance	CS
93	Spent-Fuel-Bundle Cerenkov Verifier (CANDU)	Optical Surveillance	CS
94	Improved Cerenkov Viewing (Night-Vision) Device	Optical Surveillance	CS
95	Fuel Verification Periscope	Optical Surveillance	CS
96	Portal Radiation Monitor	Portal Monitor	CS
97	Safeguards Doorway Monitor	Portal Monitor	CS
98	Vehicle Portal Monitor	Portal Monitor	CS
99	Vehicle Monitor	Portal Monitor	CS
100	(Yes/No) Electronic Dosimeter	SNM Monitor	CS
101	(Yes/No) Radio-Luminescent Dosimeter	SNM Monitor	CS
102	Thermoluminescent Dosimeter (TLD)	SNM Monitor	CS
103	Hand-Held Monitor	SNM Monitor	CS
104	Shelf Monitor System (II)	SNM Monitor	CS
105	Label (Adhesive) Seal	Seal	CS
106	Cup-and-Wire Seal (Type E)	Seal	CS
107	Metallic Seals	Seal	CS
108	Optical Cap Seal	Seal	CS

Page in Sec VII	EQUIPMENT NAME	GENERAL TYPE	USE CAT.
109	Ultrasonic Cap Seal (ARC-SPAR)	Seal	CS
110	Photogr. In Situ Verifiable (PIV) Seal System	Seal	CS
111	VACOSS-3 Electronic Sealing System	Seal	CS
112	Shrink-Tubing Seal	Seal	CS
113	Integrated Monitoring System	In-Plant Monitor	CS
114	Laser Spent-Fuel Cover	In-Plant Monitor	CS
115	Bar Coding	Identification	CS
116	Seal Pattern Reader (SPAR)	Identification	CS
117	BWR Fuel Assembly Ident. Device (FAID/SPAR)	Identification	CS
118	Fuel-Assembly Ident. System (Magnetic-Inclusion)	Identification	CS
119	LDVER (Local Verification System)	Communication	CS
120	Plutonium Product-Area Monitor	Communication	MCA
121	Resin Bead Sampling	Transportation	MCA
122	Pu Air-Transportable Model 2 Package (PAT-2)	Transportation	MCA
123	Mobile Safeguards Van	Transportation	MCA
124	Passive Environmental Monitor (PASEM)	Envtl. Monitor	CS
125	ELCODRUM, Tamper-Resistant Container	Sealed Container	CS

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Passive Environmental Monitor (PASEM)	124
Photogr. In Situ Verifiable (PIV) Seal System	110
Plutonium Neutron Coincidence Collar	65
Plutonium Nitrate Bottle Counter	70
Plutonium Product-Area Monitor	120
Portable Plutonium Isotopic Analysis Unit (PIAU)	41
Portal Radiation Monitor	96
Psychotronic Surveillance System	91
Pu Air-Transportable Model 2 Package (PAT-2)	122
Pulsed Sonar Sounding Device (AQUATRAK (R))	8
Quartz Bourdon-Tube Digital Pressure Gauge	6
Radio Frequency Resonance Level Monitor	9
Random Driver	49
Reactor Power Monitor	72
Resin Bead Sampling	121
Rocky Flats Assay Meter (RFAM)	44
Safeguards Doorway Monitor	97
Sb-Be Photoneutron Interrogation System	51
Seal Pattern Reader (SPAR)	116
Segmented Gamma Scanner (SGS)	34
Semi-Portable Cylinder Load Cell	3
Shelf Monitor System (II)	104
Shrink-Tubing Seal	112
Shuffler (Cf-252)-Mod. I (Fast/Thermal Neutron)	50
Solution Neutron Coincidence Counter	69
Special Coincidence Counter Heads	67
Spent Fuel Assembly Assay System	55
Spent-Fuel Assembly Monitor (KfK)	56
Spent-Fuel Bundle Counter (LANDU)	84
Spent-Fuel Bundle Counter (Sandia)	83
Spent-Fuel Bundle Gamma-Ray Verifier	85
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Stabilized Assay Meter (SAM-II)	36
Surveillance TV and Recording System (STAR)	89
Thermal Flow Sensor	18
Thermal Flowmeter	14
Thermoluminescent Dosimeter (TLD)	102
Threshold Detector for Gamma Spectrometry	45
Time-Domain Reflectometry	10
Transfer-Jet Monitor	20

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Turbine-Flowmeter Automated Tank Calibrator	7
Two-Stage Mass Spectrometer	26
UF6 Sample Bottle Enrichment Meter	40
Ultrasonic Cap Seal (ARC-SPAR)	109
Ultrasonic Flowmeter	15
Ultrasonic Gauge	80
Ultrasonic Heavy Water Analyzer	81
Ultrasonic Liquid In-Line Sensor	19
Universal Fast Breeder Reactor Subassembly Counter	68
Uranium Neutron Coincidence Collar	53
Uranium-Hexafluoride-Cylinder Weight Standards	2
VACOSS-3 Electronic Sealing System	111
Vehicle Monitor	99
Vehicle Portal Monitor	98
Vibrating Tube (Anton-Parr) Densimeter	4
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USE CATEGORY Containment Surveillance

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Surveillance TV and Recording System (STAR)	89
MINISTAR System	90
Psychotronic Surveillance System	91
Closed-Circuit Television System (CANDU)	92
Spent-Fuel-Bundle Cerenkov Verifier (CANDU)	93
Improved Cerenkov Viewing (Night-Vision) Device	94
Fuel Verification Periscope	95
Portal Radiation Monitor	96
Safeguards Doorway Monitor	97
Vehicle Portal Monitor	98
Vehicle Monitor	99
(Yes/No) Electronic Dosimeter	100
(Yes/No) Radio-Luminescent Dosimeter	101
Thermoluminescent Dosimeter (TLD)	102
Hand-Held Monitor	103
Shelf Monitor System (II)	104
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Metallic Seals	107
Optical Cap Seal	108
Ultrasonic Cap Seal (ARC-SPAR)	109
Photogr. In Situ Verifiable (PIV) Seal System	110
VACOSS-3 Electronic Sealing System	111
Shrink-Tubing Seal	112
Integrated Monitoring System	113
Laser Spent-Fuel Cover	114
Bar Coding	115
Seal Pattern Reader (SPAR)	116
BWR Fuel Assembly Ident. Device (FAID/SPAR)	117
Fuel-Assembly Ident. System (Magnetic-Inclusion)	118
LOVER (Local Verification System)	119
Passive Environmental Monitor (PASEM)	124
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Semi-Portable Cylinder Load Cell	3
Vibrating Tube (Anton-Parr) Densimeter	4
High-Precision Level and Density Sensor Box	5
Quartz Bourdon-Tube Digital Pressure Gauge	6
Turbine-Flowmeter Automated Tank Calibrator	7
Pulsed Sonar Sounding Device (AQUATRAK (R))	8
Radio Frequency Resonance Level Monitor	9
Time-Domain Reflectometry	10
Electromagnetic Flowmeter	11
Mass Flowmeter	12
Orifice Flowmeter	13
Thermal Flowmeter	14
Ultrasonic Flowmeter	15
Vortex-Shedding Flowmeter	16
Liquid In-Line Sensing Devices	17
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Ultrasonic Liquid In-Line Sensor	19
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Atomic-Emission Spectroscopy	23
Mass Spectrometer (Gas-Phase)	24
Mass Spectrometer (Thermal-Emission)	25
Two-Stage Mass Spectrometer	26
Mass Spectrometer (Transportable Quadrupole)	27
Mass Spectrometer, Quadrupole	28
K- or L-Edge Densitometer	29
K-Edge Densitometer (Compact)	30
K-Edge Densitometer (KfK)	31
K-Edge/K-XRF (Hybrid) Solution Assay System	32
Energy Dispersive X-Ray Fluorescence Analysis	33
Segmented Gamma Scanner (SGS)	34
In-Line Gas-Phase Enrichment Monitor	35
Stabilized Assay Meter (SAM-II)	36
Brookhaven Survey Assay Meter (BSAM)	37
Hand-Held Assay Probe (HM-4)	38
Hand-Held Detector for UF ₆ Cylinder Assay	39
UF ₆ Sample Bottle Enrichment Meter	40
Portable Plutonium Isotopic Analysis Unit (PIAU)	41
High-Resolution Gamma-Ray Spectrometer	42
High-Resolution Gamma-Ray Spectrometer (II)	43
Rocky Flats Assay Meter (RFAM)	44
Threshold Detector for Gamma Spectrometry	45
NDA Reference Materials for Scrap and Waste	46
Autoradiography	47
Low Pu Solution Assay Instrument (LOSAI)	48
Random Driver	49
Shuffler (Cf-252)-Mod. I (Fast/Thermal Neutron)	50
Sb-Be Photoneutron Interrogation System	51
Active Well Coincidence Counter (AWCC)	52
Uranium Neutron Coincidence Collar	53
Fuel-Rod Scanner	54
Spent Fuel Assembly Assay System	55

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USE CATEGORY Materials Accountancy

Spent-Fuel Assembly Monitor (KfK)	56
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Differential Die-Away System for Waste Assay	59
Crated Waste Assay Monitor (CWAM)	60
Dual-Range Thermal-Neutron Coincidence Counter	61
Neutron Well Coincidence Counter	62
Neutron Well Coincidence Counter (KfK)	63
High-Level Neutron Coincidence Counter (HLNCC)	64
Plutonium Neutron Coincidence Collar	65
Inventory Sample Coincidence Counter (ISCC)	66
Special Coincidence Counter Heads	67
Universal Fast Breeder Reactor Subassembly Counter	68
Solution Neutron Coincidence Counter	69
Plutonium Nitrate Bottle Counter	70
End-Crop Box Counter (ECBC)	71
Fuel-Drawer Scanner	73
Nondestructive Spent Fuel Verification (ION-1)	74
Multi-Energy Gamma Assay System (MEGAS-II)	75
Multichannel Analyzer (Portable)	76
Multichannel Analyzer (Stationary)	77
On-Line Alpha Monitor	78
Calorimeter	79
Ultrasonic Gauge	80
Ultrasonic Heavy Water Analyzer	81
Fresh-Fuel Bundle Counter (CANDU)	82
Spent-Fuel Bundle Counter (Sandia)	83
Spent-Fuel Bundle Counter (CANDU)	84
Spent-Fuel Bundle Gamma-Ray Verifier	85
Plutonium Product-Area Monitor	120
Resin Bead Sampling	121
Pu Air-Transportable Model 2 Package (PAT-2)	122
Mobile Safeguards Van	123

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MATERIAL TYPE Containments

Label (Adhesive) Seal	105
Cup-and-Wire Seal (Type E)	106
Metallic Seals	107
Photogr. In Situ Verifiable (PIV) Seal System	110
VACOSS-3 Electronic Sealing System	111
Shrink-Tubing Seal	112
Seal Pattern Reader (SPAR)	116

MATERIAL TYPE Fuel (Fresh)

Uranium Neutron Coincidence Collar	53
Fuel-Rod Scanner	54
Plutonium Neutron Coincidence Collar	65
Universal Fast Breeder Reactor Subassembly Counter	68
Fresh-Fuel Bundle Counter (CANDU)	82
Fuel-Assembly Ident. System (Magnetic-Inclusion)	118

MATERIAL TYPE Fuel (General)

Dual-Range Thermal-Neutron Coincidence Counter	61
Fuel-Drawer Scanner	73
Fuel Verification Periscope	95
BWR Fuel Assembly Ident. Device (FAID/SPAR)	117

MATERIAL TYPE Fuel (Spent)

Threshold Detector for Gamma Spectrometry	45
Spent Fuel Assembly Assay System	55
Spent-Fuel Assembly Monitor (KfK)	56
Nondestructive Spent Fuel Verification (ION-1)	74
Spent-Fuel Bundle Counter (Sandia)	83
Spent-Fuel Bundle Counter (CANDU)	84
Spent-Fuel Bundle Gamma-Ray Verifier	85
Surveillance TV and Recording System (STAR)	89
Spent-Fuel-Bundle Cerenkov Verifier (CANDU)	93
Improved Cerenkov Viewing (Night-Vision) Device	94
(Yes/No) Radio-Luminescent Dosimeter	101
Thermoluminescent Dosimeter (TLD)	102
Optical Cap Seal	108
Ultrasonic Cap Seal (ARC-SPAR)	109
Laser Spent-Fuel Cover	114

MATERIAL TYPE Gamma Emitters

Portal Radiation Monitor	96
Vehicle Portal Monitor	98
Vehicle Monitor	99

EQUIPMENT NAME	Page in Sec VII
(Yes/No) Electronic Dosimeter	100
Hand-Held Monitor	103

MATERIAL TYPE Heavy Water (HW)

Ultrasonic Heavy Water Analyzer	81
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MATERIAL TYPE In-Process Liquids or Gases

Vibrating Tube (Anton-Parr) Densimeter	4
High-Precision Level and Density Sensor Box	5
Quartz Bourdon-Tube Digital Pressure Gauge	6
Turbine-Flowmeter Automated Tank Calibrator	7
Pulsed Sonar Sounding Device (AQUATRAK (R))	8
Radio Frequency Resonance Level Monitor	9
Time-Domain Reflectometry	10
Electromagnetic Flowmeter	11
Mass Flowmeter	12
Orifice Flowmeter	13
Thermal Flowmeter	14
Ultrasonic Flowmeter	15
Vortex-Shedding Flowmeter	16
Liquid In-Line Sensing Devices	17
Thermal Flow Sensor	18
Ultrasonic Liquid In-Line Sensor	19
Transfer-Jet Monitor	20
Tubing Block	21

MATERIAL TYPE Laboratory Samples

Controlled-Potential Coulometer	22
Mass Spectrometer (Thermal-Emission)	25
Two-Stage Mass Spectrometer	26
Mass Spectrometer (Transportable Quadrupole)	27
Mass Spectrometer, Quadrupole	28
Resin Bead Sampling	121
Pu Air-Transportable Model 2 Package (PAT-2)	122

MATERIAL TYPE Miscellaneous

Balances (Electronic)	1
Reactor Power Monitor	72
Minolta Surveillance Camera	86
Film Camera System (CANDU)	87
KfK ELMU Camera System	88
MINISTAR System	90
Psychotronic Surveillance System	91
Closed-Circuit Television System (CANDU)	92
Integrated Monitoring System	113
Bar Coding	115

EQUIPMENT NAME	Page in Sec VII
LOVER (Local Verification System)	119
Plutonium Product-Area Monitor	120
Passive Environmental Monitor (PASEM)	124

MATERIAL TYPE Plutonium

Portable Plutonium Isotopic Analysis Unit (PIAU)	41
High-Resolution Gamma-Ray Spectrometer	42
Rocky Flats Assay Meter (RFAM)	44
High-Level Neutron Coincidence Counter (HLNCC)	64
Inventory Sample Coincidence Counter (ISCC)	66
Special Coincidence Counter Heads	67
On-Line Alpha Monitor	78
Calorimeter	79

MATERIAL TYPE SNM (Miscellaneous)

Stabilized Assay Meter (SAM-II)	36
Brookhaven Survey Assay Meter (BSAM)	37
High-Resolution Gamma-Ray Spectrometer (II)	43
Autoradiography	47
Random Driver	49
Shuffler (Cf-252)-Mod. I (Fast/Thermal Neutron)	50
Sb-Be Photoneutron Interrogation System	51
Isot'ic Source Assay System/Fissometer (ISAS/ISAF)	58
Neutron Well Coincidence Counter	62
Multichannel Analyzer (Portable)	76
Multichannel Analyzer (Stationary)	77
Safeguards Doorway Monitor	97
Shelf Monitor System (II)	104
Mobile Safeguards Van	123
ELCODRUM, Tamper-Resistant Container	125

MATERIAL TYPE SNM in Solutions

Atomic-Emission Spectroscopy	23
K- or L-Edge Densitometer	29
K-Edge Densitometer (Compact)	30
K-Edge Densitometer (KfK)	31
K-Edge/K-XRF (Hybrid) Solution Assay System	32
Energy Dispersive X-Ray Fluorescence Analysis	33
Solution Neutron Coincidence Counter	69
Plutonium Nitrate Bottle Counter	70

MATERIAL TYPE SNM in Waste

Segmented Gamma Scanner (SGS)	34
Low Pu Solution Assay Instrument (LOSAI)	48
Leached Hull Monitor	57
Differential Die-Away System for Waste Assay	59

EQUIPMENT NAME	Page in Sec VII
Crated Waste Assay Monitor (CWAM)	60
Neutron Well Coincidence Counter (KfK)	63
Multi-Energy Gamma Assay System (MEGAS-II)	75

MATERIAL TYPE Uranium

Hand-Held Assay Probe (HM-4)	38
NDA Reference Materials for Scrap and Waste	46
Active Well Coincidence Counter (AWCC)	52
End-Crop Box Counter (ECBC)	71

MATERIAL TYPE Uranium Hexafluoride

Uranium-Hexafluoride-Cylinder Weight Standards	2
Semi-Portable Cylinder Load Cell	3
Mass Spectrometer (Gas-Phase)	24
In-Line Gas-Phase Enrichment Monitor	35
Hand-Held Detector for UF ₆ Cylinder Assay	39
UF ₆ Sample Bottle Enrichment Meter	40
Ultrasonic Gauge	80

EQUIPMENT NAME : Balances (Electronic)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Mass Measurement
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 4,000
SOURCE 1 : Mettler
SOURCE 2 : Sartorius
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : LA-8042
REFERENCE DETAIL : 1. Crawford, Ehinger & Ellis; 133.
2. Phillips, Foley, Menlove & Reilly; V. III, App. N.

DESCRIPTION

Very accurate mass measurements of SNM are an essential ingredient in effective process monitoring and materials-accountancy.

A precision balance can increase the precision of mass measurement needed in any such procedures from the 0.1% for standard scales to better than 0.01%. Electronic balances can be designed for microsamples (a 4 gram range with 0.1 microgram readability), for the traditional analytical role (160 gram range with 0.1 milligram readability), or for high-capacity measurements (up to 60 kilogram range with 1 gram readability).

The electronic balances are generally microprocessor-controlled and compatible with a range of remote peripheral devices such as printers and calculators. They all employ the electromagnetic-forces-compensation system for weighing.

The cost given is for a 60 kg top-loading Sartorius balance. An analytical balance of 160 gram range would cost about \$3000. Calibrated stainless-steel weight sets for such balances cost about \$1000.

EQUIPMENT NAME : Uranium-Hexafluoride-Cylinder Weight Standards
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Mass Measurement
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

In routine use at U.S. enrichment and fuel fabrication facilities.

USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
Fabrication
CAPITAL COST : 90,000
SOURCE 1 : Paducah
REFERENCE 1 : ANSI N15.18

DESCRIPTION

To calibrate scales for weighing cylinders of uranium hexafluoride, replica cylinders made of solid stainless-steel have been constructed. In the one order of this type to have been filled, two each of 2.5-ton, 10-ton, and 14-ton UF₆ cylinders were fabricated as pressure vessels. One of each size was cut open and filled with lead and concrete to mimic the weight of filled cylinders; the others were used to simulate empty cylinders. All weights were then certified by NBS.

These replica cylinders were constructed under the direction of the Paducah Plant of Union Carbide in 1975 and 1976 through an NRC contract, to be used by the nuclear industry on a borrowing basis. The cost given covers six stainless-steel cylinders, three filled, and a weight certification, with an inflation factor of two. Because these replicas were only made once, because stainless-steel cladding may be sufficient and because pressure-vessel construction may not be necessary, the cost estimate is very rough.

An ordinary stainless-steel block for weight calibration would have a rough cost of about \$8000 for a 500 kg block.

EQUIPMENT NAME : Semi-Portable Cylinder Load Cell
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Mass Measurement
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Large system undergoing further tests at ORGDP. Small system in routine use.

USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
Fabrication
CAPITAL COST : 6,000
SOURCE 1 : BLH
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : K/OA-5826
REFERENCE DETAIL : Fainberg et al.; V. II, 505.

DESCRIPTION

Two systems for weighing cylinders are under consideration, with a view to eventual use by IAEA inspectors. The first is a semi-portable load-cell-based system designed for weighing 2.5-ton (gross weight about 3000 kg) uranium hexafluoride shipping cylinders. It was developed at BNL and calibrated at NBS. The system, which includes a digital display, accurately weighs checkweights to within one-half kg. It also can be rapidly disassembled and assembled. The cost is 3/4 for the weighing system and 1/4 for a hoist. Infrequent calibration would cost about \$1000.

The second system, also transportable, will weigh up to 14-ton (gross weight about 12,000 kg) cylinders. It requires two load cells, connection to the cylinder being made by a lifting fixture suspended from the two parallel load cell chains. Tests at ORGDP with BNL collaboration indicate an accuracy of about 1 kg.

The above cost pertains to the small system, i.e. one load cell plus accessories; the large system would cost about \$20,000 to install.

The above source identifies a major manufacturer of load cells. Additional vendors supply the accessories, for example D.J. Instruments, Inc. (transducer indicator), Automatic Control Systems (standardizer), and Ormond, Inc. (flexures).

EQUIPMENT NAME : Vibrating Tube (Anton-Parr) Densimeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Density Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 9,000
SOURCE 1 : Mettler
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : AGNS35900-2.4103
REFERENCE DETAIL : Crawford, Ehinger & Ellis, 133.

DESCRIPTION

Very accurate measurements of liquid density facilitate calibration of solution characterizations in reprocessing plants, where crucial measurements of reactor Pu production are made.

The measuring principle of the densimeter is based on the change of the natural frequency of a hollow oscillator tube when filled with about one milliliter of sample. The electronic part of the instrument provides the excitation of the oscillator at constant amplitude. The built-in quartz-crystal-controlled timer performs a period measurement. This period is displayed digitally or, in the case of units with a built-in microprocessor, the period can be used to calculate density which is displayed digitally. The measuring system is calibrated by the measurement of two samples of known density (normally, air and water). The sample tube is thermostated by circulation of water or by the use of a semiconductor Peltier element (DMA-46 density meter only). Given proper calibration for the measurement range of interest, resolution at a minimum is 0.0001 g/cc for most units and is 0.00001 g/cc for the DMA-55 (\$10,665) and 0.000001 g/cc for the DMA-60 (\$7,505).

EQUIPMENT NAME : High-Precision Level and Density Sensor Box
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Installed in plant. Tests are planned.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 10,000
SOURCE 1 : WINCO
SOURCE 2 : Parosci
REFERENCE 1 : ENICO-1080

DESCRIPTION

The Sensor Box provides high-precision measurement of solution levels and densities in four process vessels using plant bubbler probe signals. The sensor box makes accountability-grade measurements of solution volume and weight in calibrated tanks and can detect very small changes in tank volumes.

The device contains two Paroscientific "Digiquartz" 0-15 psi (differential) pressure transducers and a pneumatic Multiplexer. The "Digiquartz" is a compact device which measures differential pressure and may be applied to dip tube bubbler-probe systems for the measurement of volume and pressure. The 0.15 psi model used here has a claimed resolution of .005% of full scale and a claimed accuracy of 0.015% of full scale. The device is small and weighs only 138 grams.

The box provides measurements of both level and density, even if one of the two transducers fails, as long as the probes are intact. The box was designed for remote computer operation and for use in harsh environments. On-line calibration check capability for the transducers is provided. The capital cost shown includes the price of two transducers (\$2,300 each) and a readout device (\$2,200).

EQUIPMENT NAME : Quartz Bourdon-Tube Digital Pressure Gauge
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 6,130
SOURCE 1 : Ruska
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : Kiawah
REFERENCE DETAIL : 1. Suda; 325.
2. Jones, Schoonover & Houser; 534.

DESCRIPTION

The output of an ordinary dip-tube or bubbler probe is a pressure that serves as a measurement of the liquid level in a vessel such as an accountability tank. The digital pressure gauge serves as a measuring device for such a system.

The equipment described consists of a quartz Bourdon tube upon which is mounted a pair of wire wound coils and a mirror. The latter is used to reflect light onto a sensor which indicates when the tube is off-center. The coils are used to return the tube to the null position electromagnetically. The current used to restore the null point is used as a measure of pressure. Typically the instrument is used as a differential manometer with a choice of pressure range. In typical use sensitivity and accuracy are of the order of 0.01 mm Hg. The instrument has been used in a computerized system with automated reading cycles capable of measuring several inputs in sequence. Such a complete system, depending on the complexity desired, would cost in the range of \$30,000-70,000. The cost given above does not include digital readout.

EQUIPMENT NAME : Turbine-Flowmeter Automated Tank Calibrator
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,500
SOURCE 1 : Flow Tech.
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : Kiawah
REFERENCE DETAIL : 1. Raymond; 382.
2. Baumgarten, Brame, Cooper & Robertson; 517.

DESCRIPTION

An automated system for remotely calibrating nuclear-fuel accountability tanks uses 2 turbine meters to measure a quantity of water introduced at up to 40 l/min into the tank to be calibrated and records the quantity and the resulting pressure in the tank. The turbine and diverter calibration data are referenced by the computer when the system is used to calibrate a tank. The short-term uncertainty in the water volume is approximately .02%, which is almost entirely due to the poor reproducibility of the turbine meter measurements. Confidence in the uncertainty figure is retained by measuring the ratio of the two turbine meter frequencies. If the ratio changes by more than .02 %, the turbine meters can be recalibrated in one day.

The calibrator is easily transportable and is intended to be located in an area accessible to personnel even though the tank may be in a canyon or other remote area of intense radiation. The calibrator is designed to be connected to the tank using existing plant tubing for filling the tank and for measuring the liquid level in the tank. The measurements performed by the calibrator will give the tank cross-sectional area as a function of height. The system is intended to replace the laborious method of calibrating tanks by filling them manually in increments using a volumetric test measure.

EQUIPMENT NAME : Pulsed Sonar Sounding Device (AQUATRAK (R))
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Field Evaluation Unit

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 10,000
MAINTENANCE COST : 150
SOURCE 1 : Bartex
REFERENCE 1 : Hilton Head
REFERENCE 2 : 1980 ESARDA
REFERENCE DETAIL : 1. Haupt & Johnson; 217.
2. Ven & DeRegge; 335.

DESCRIPTION

This device employs a nonintrusive technique based upon a timed reflected sonic pulse comparison of a known distance in the propagation path with the unknown distance to the liquid surface. The technique operates within a small diameter (typically 12.7 mm) tube, and may be used over dynamic ranges of greater than 15 m.

The transducer is mounted at the top of the measuring tube, and may be oriented at any convenient angle to the tank or structure. The controller assembly may be installed as far as 150 cable meters from the sensor.

Two versions of the device described in Ref. 1 have undergone successful non-intrusive tests at the Rocky Flats and Savannah River Plants:

SERIES 1100: resolution to 3 mm and calibrated accuracy of 0.025%.

SERIES 2200: resolution to 0.3 mm and calibrated accuracy of 0.001%.

The above cost applies to Series 2200; the price of Series 1100 is about \$2,500.

EQUIPMENT NAME : Radio Frequency Resonance Level Monitor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Used for about 5 years to monitor 11 high level waste tanks at ICPP.

USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 50,000
SOURCE 1 : WINCO
REFERENCE 1 : ENICO-10034
REFERENCE 2 : US Pat. 4170135

DESCRIPTION

This device determines the distance between the top of a tank and the liquid level by measuring the resonant frequency of a simple rugged stainless steel coaxial cavity immersed in the liquid. Energy from a radio frequency source is coupled into and out of the cavity. A computer controls the frequency of the R.F. source and monitors the power level coupled out of the cavity. This power is maximum when the cavity is excited at a resonant frequency. The cavity is a slotted 10-cm pipe with a coaxial sealed central stainless steel tube containing a number of RTD's for solution temperature measurements.

The computer, the frequency source, and the output meter can be multiplexed among a number of probes. Initial tests give a short term repeatability of 0.002% F.S. and a precision of 0.025%; the range is 9-15 m.

The cost given above is a per tank estimate for a 5-tank system.

A related technique, time-domain reflectometry (TDR), is discussed elsewhere in this CATALOG.

EQUIPMENT NAME : Time-Domain Reflectometry
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
SOURCE 1 : IAEA
REFERENCE 1 : IAEA-174
REFERENCE DETAIL : Part E, 32.

DESCRIPTION

Time-domain reflectometry (TDR) is a technique in which a transmission line is formed by placing a conductor near the bottom edge of a tank. The characteristic impedance of the transmission system changes sharply at the air-liquid interface, and this fact enables accurate measurement of liquid level by TDR. The technique uses traditional instruments for high-frequency reflectometry measurements, a coaxial transmission line, and a stainless-steel probe installed at a fixed position in the tank. A system can be designed with measuring probes in ten different tanks to monitor the level in each tank. A coaxial switching unit would be used for multiple tank systems. Tampering with the cable or the tank sensor would alter the measurement signature.

Although the technique has been explored by a number of investigators and is cited in the above reference as a promising approach, no recent developments have been reported and no cost estimates are available.

EQUIPMENT NAME : Electromagnetic Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 3,000
SOURCE 1 : F&P
SOURCE 2 : Foxboro
REFERENCE 1 : LA-8042
REFERENCE DETAIL : Hakkila, Ostenak & Thomas, Jr.; V. III, App. L.

DESCRIPTION

The electromagnetic flowmeter operates on the principle that a conductor moving at right angles through a magnetic field induces a voltage. The magnitude of the potential is proportional to the magnetic field intensity and the flow rate of the conducting fluid. Precision and accuracy of 1% or better are possible. The meter can be used in pipes as small as 2.5mm, at a cost proportional to pipe diameter.

The cost given is for the F&P model 10D1475, capable of measuring flows from 40 cc per minute to 4500 liters per minute.

EQUIPMENT NAME : Mass Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 5,000
SOURCE 1 : MMI
REFERENCE 1 : LA-8042
REFERENCE 2 : AGNS-1040-2.2-50
REFERENCE DETAIL : 1. Hakkila, Ostenak & Thomas, Jr.; V. III, App. L.
2. Murphy & Postles, App. F.

DESCRIPTION

The mass flowmeter is a patented device. The angular deflection of a U-shaped pipe is measured magnetically as the pipe is subjected to oscillation. Seven sizes of meter are available, covering mass flow rates from 1 to 1450 kg/min. Continuous computer-operated data recording is possible. The instrument has been shown to provide an accuracy of 5% in measuring mass flow of simulated process streams.

The cost is \$2300-5000 depending on the size of the meter and type of output (analog or digital or both). The meter has not yet been evaluated in radioactive environments, but such an evaluation will be made at the Idaho Chemical Processing Plant.

EQUIPMENT NAME : Orifice Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,300
SOURCE 1 : F & P
REFERENCE 1 : LA-8042
REFERENCE DETAIL : Hakkila, Ostenak & Thomas, Jr.; V. III, App. L.

DESCRIPTION

Orifice meters are rugged and require little maintenance, hence can be used in radioactive reprocessing plant environments where access is difficult.

Accuracy in the range of 0.5-10% can be expected depending on variations in flow rate and calibration procedures. For accuracy of 1% or better, periodic recalibration is required to correct for corrosion and erosion of the orifice.

EQUIPMENT NAME : Thermal Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,050
SOURCE 1 : Teledyne
SOURCE 2 : Thermal
REFERENCE 1 : AGNS35900-2.2-24

DESCRIPTION

Thermal flowmeters function by measuring either the rate of heat loss to a stream from a heated wire, thermocouple, thermistor, or thin film; or they measure the temperature rise of the stream as it passes through a heated tube. The Teledyne Hastings Raydist Model NALL-5,500 has a range of 5-500 SCCM at a cost of \$1,050; Model NALL-1K, 100K has a range of 1-100 SLPM at the same cost.

The Thermal Instrument Co. Model 59 has ranges from 0-1 to 50K SCCM at a cost of \$1,500 for gases; Model 600 has ranges from 0-1 SCCM minimum to "unlimited" maximum at a cost of \$2,608 for gases, liquids, slurries, and homogeneous solids.

EQUIPMENT NAME : Ultrasonic Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 2,060
SOURCE 1 : L&N
REFERENCE 1 : LA-8042
REFERENCE DETAIL : Hakkila, Ostenak & Thomas, Jr.; V.III, App. L.

DESCRIPTION

There are two types of flowmeters employing ultrasonic techniques. The first is based on the change in velocity of an ultrasonic beam transmitted through a flowing liquid. Transducers generally are mounted in the pipe, but they may be placed exterior to the pipe wall to avoid intrusion into the pipe. This ultrasonic flowmeter can measure flow with an accuracy of 0.5%. The second type uses the normal solid particles, bubbles, and other discontinuities present in most flowing liquids to make a nonintrusive flow measurement. The discontinuities are detected by ultrasonic detectors mounted on the outside of the pipe. Accuracies of 1% or better are anticipated. The technique is being evaluated at ICPP.

The cost given is for an L&N nonintrusive Doppler flowmeter, Cat. 475, which measures flows up to about 13 m/s.

EQUIPMENT NAME : Vortex-Shedding Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,250
SOURCE 1 : F&P
SOURCE 2 : Eastech
REFERENCE 1 : LA-8042
REFERENCE DETAIL : Hakkila, Ostenak & Thomas, Jr.; V. III, App. L.

DESCRIPTION

In vortex-shedding flowmeters, localized vortices or eddies are created by an obstruction placed in the fluid stream. The rate of vortex formation is a function of the flow velocity.

Typical devices use a piezoelectric sensor to monitor liquids or gases, including superheated steam. Vortex-induced deformations of a stainless steel bar placed in a fluid stream are detected by a piezoelectric sensor external to the meter body. The flowmeter electronics translate these deformations into frequency, which is directly proportional to flow rate. The cost given above applies to the Fischer & Porter 2-in. 10LV3000 meter body (\$810) and 50LV3000 Signal Conditioner (\$440), with a 45-800 liter per minute flow range.

EQUIPMENT NAME : Liquid In-Line Sensing Devices
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 350
SOURCE 1 : Honeywell
SOURCE 2 : Nat. Son.
REFERENCE 1 : ORNL/TM-7340
REFERENCE 2 : AGNS35900 2.2-24

DESCRIPTION

This entry covers a variety of commercially available low-cost devices which are capable of detecting liquid in 0.25-1 in. diameter lines or pipes. When applied to process lines which are normally filled with air, they will, therefore, provide signals which may be indicative of SNM diversion in solution form.

The most commonly used sensors include electrical conductivity, optical, pressure, thermal and ultrasonic type devices. The last mentioned type as well as some thermal devices can be installed in nonintrusive fashion.

The capital cost given above covers equipment in various categories available from a number of manufacturers in addition to the one identified. An ultrasonic system with high level alarm is available from National Sonics (Model No. 621S-16) at approximately \$480.00

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EQUIPMENT NAME : Thermal Flow Sensor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class II : Development Prototype

STATUS DETAIL

Sensor operation proven; no additional testing or development scheduled.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Enrichment
Fabrication

CAPITAL COST : 100

SOURCE 1 : WINCO

REFERENCE 1 : WINCO

DESCRIPTION

This nonintrusive thermal sensor detects small flows of liquids or gases in process or instrument lines. It is used to detect small flows that could result from diversion attempts or from leaks. The sensor consists of an electronic package and a number of stainless-steel-clad resistance temperature detectors mounted on the monitored lines. It detects the increased rate of temperature change occurring when a flow in the line cools a heated section of one of the monitored lines.

The quoted cost is an estimate that includes installation of heater and sensor. The necessary computer monitoring would cost \$100-\$2000 per channel depending on number of lines monitored and type of monitoring equipment.

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EQUIPMENT NAME : Ultrasonic Liquid In-Line Sensor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

No problem other than power failure over 3-year plant use.

USEFUL TO : Operator and Inspector

FACILITIES : Reprocessing
Fabrication

CAPITAL COST : 3,000

SOURCE 1 : WINCO

REFERENCE 1 : ENICO-1071

DESCRIPTION

This in-house built device provides a nonintrusive method of detection of water or other liquid in small-diameter process or instrument lines normally containing air. This instrument will detect diversion attempts or abnormal operations that would introduce liquids into the lines. It can also be used for monitoring sampling operations.

The device consists of sixteen flexural-type ultrasonic, piezoelectric sensors connected to a remote electronics package. Water in any of the sensor lines is detected and a characteristic logic signal is generated. The sensors are sealed in a stainless-steel can and may be welded into plant process and instrument lines. The sensors are radiation-resistant and are suited for in-cell installations. Most failure modes will generate the alarm signal.

EQUIPMENT NAME : Transfer-Jet Monitor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Initial plant tests successful. More jet monitors are being installed.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 200
SOURCE 1 : WINCO
REFERENCE 1 : WINCO

DESCRIPTION

The device monitors the operation of steam-operated transfer jets. It provides an indication of the times of transfer initiation and completion and will detect incomplete or improper transfers. The monitor consists of a stainless-steel-clad thermocouple (TC) or resistance-temperature detector (RTD) mounted in-cell on the jet's exit line and a computer-readable, remote temperature indicator. The computer detects transfer initiation by the rise in temperature to the level characteristic of two-phase transfer, measures the duration of transfer, and detects completion by the second temperature rise to steam temperatures.

The quoted cost represents an average and includes an estimate for installation.

EQUIPMENT NAME : Tubing Block
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : In-Process Monitor
MATERIAL TYPE : In-Process Liquids or Gases
STATUS : Class II : Development Prototype
STATUS DETAIL

Tubing blocks have been installed for 3 years in the ICPP; no problem reported

USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 100
SOURCE 1 : WINCO
REFERENCE 1 : WINCO

DESCRIPTION

The tubing block is mounted in instrument and process lines leading to plant vessels to prevent the introduction of tubing into the vessels. The block will prevent diversion of nuclear materials by suction lines pushed through vessel off-gas, calibration, addition, decontamination, or instrument lines. The block is an inexpensive assembly welded from pipe fittings. It provides clean drainage, does not restrict normal flow and contains no easily blocked screens.

EQUIPMENT NAME : Controlled-Potential Coulometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Element Measurement
MATERIAL TYPE : Laboratory Samples
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
 Reprocessing
CAPITAL COST : 10,000
REPLACEMENT COST : 10,000
LIFETIME : 5 Years
SOURCE 1 : NBL
REFERENCE 1 : NBL-311
REFERENCE DETAIL : Frazzini; 46.

DESCRIPTION

A controlled-potential coulometer (Model TLF) employing digital electronics and capable of operating under computer control, has been developed at NBL to fill a need not currently satisfied in the commercial market. Although designed with accurate and precise measurements of plutonium in mind, the instrument may find use in nonnuclear applications of controlled-potential coulometry.

When under computer control and not running samples, the instrument conducts a series of electrical calibrations of the digital integrator using an internal standard resistor. The electrical calibration factor has been shown to be stable to better than 0.001% over extended periods of time and laboratory temperatures. Linearity of output over five decades of current range shows no deviations from the mean greater than 0.04%. Measurements performed on 12 plutonium standards, each 5 mg, from 3 separate preparations revealed a mean recovery of 99.996% with an RSD of 0.033%. The uncertainty includes contributions of sample preparation and purification, in addition to random measurement error. The cost given above is distributed about equally between parts and labor costs.

EQUIPMENT NAME : Atomic-Emission Spectroscopy
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : SNM in Solutions
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
 Enrichment
CAPITAL COST : 200,000
REPLACEMENT COST : 100,000
SOURCE 1 : Ames
REFERENCE 1 : 1981 ESARDA
REFERENCE 2 : Anal. Spec.
REFERENCE DETAIL : Edelson & Fassel; 97.
 Edelson & Fassel; 227.

DESCRIPTION

A high-resolution spectrometer has been used to resolve the isotopic structure of lines emitted by uranium that has been atomized and excited in inductively coupled plasmas. Multi-isotopic analyses of uranium have been performed and high-resolution spectra of simulated dissolver (spent-fuel) solutions have been obtained.

The inductively coupled plasma offers the potential for near-real-time, on-line analysis of the dissolver solutions at a nuclear fuel reprocessing facility. When combined with isotopic correlation techniques, these analyses, which can be performed rapidly and accurately, can in principle provide all the information needed to: (1) verify the total mass of Pu input to the facility; (2) determine the isotopic composition of the Pu and U in the dissolver solution; (3) verify the exposure history of the spent fuel; and (4) identify discrepancies in the material balance of the facility.

The capital cost estimate covers not only the spectroscopic and plasma-generating equipment and a small computer, but also the substantial work of installing the equipment in a total alpha-containment structure.

EQUIPMENT NAME : Mass Spectrometer (Gas-Phase)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
CAPITAL COST : 300,000
MAINTENANCE COST : 10,000
SOURCE 1 : MAT
SOURCE 2 : VG Isotope
REFERENCE 1 : 1978 IAEA
REFERENCE DETAIL : Minato; V. 1, 219.

DESCRIPTION

These instruments operate by electron impact on gaseous samples. They are installed in enrichment plants to determine the U-235 enrichment of the process uranium hexafluoride gas. Since the analysis is performed directly on gas phase samples, the biases inherent in the chemical procedures for preparing thermal emission mass spectrometry samples are avoided. The capital cost quoted above applies to the manufacturers of the currently most widely used commercial systems. Recent developments in the area of quadrupole mass spectrometry may lead to more economical systems.

EQUIPMENT NAME : Mass Spectrometer (Thermal-Emission)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : Laboratory Samples
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : ALL
CAPITAL COST : 300,000
MAINTENANCE COST : 7,000
SOURCE 1 : MAT
SOURCE 2 : VG Isotope
REFERENCE 1 : 1979 INMM
REFERENCE DETAIL : Perrin; 601.

DESCRIPTION

The thermal-emission mass spectrometer is a standard analytical tool used widely in destructive analyses throughout the nuclear fuel cycle.

Three recent developments, when combined, have the potential for greatly improving accountability measurements. The techniques are particularly valuable when measuring the contents of vessels difficult to calibrate by weight or volume. For example, input dissolver accountability measurements benefit greatly from the application of these techniques: (1) capability for isotopic analysis of U and Pu samples at the nanogram level with an accuracy of 0.1 relative %; (2) capability of preparing mixed, solid metal U and Pu spikes with an accuracy of better than 0.1 relative %, and (3) capability for determining the ratio of sample size to total solution measured, independent of both the weight and the volume of the solution being measured. These advances facilitate the use of isotopic dilution mass spectrometry in making more accurate measurements.

Many manufacturers, in addition to those indicated above, supply thermal emission mass spectrometers; one other major manufacturer of advanced devices is CAMECA, a subsidiary of Thomson-CSF. Some custom-built multistage instruments, used where ultrahigh sensitivity is required, are mentioned elsewhere in this CATALOG.

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E Q U I P M E N T F I L E

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EQUIPMENT NAME : Two-Stage Mass Spectrometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : Laboratory Samples
STATUS : Class I : Laboratory Device

STATUS DETAIL

In routine use at SAL, ORNL and various other laboratories.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 300,000
MAINTENANCE COST : 20,000
SOURCE 1 : ORNL+
REFERENCE 1 : J. Mass Spec.
REFERENCE DETAIL : D.H. Smith, W.H. Christie, H.S. McKown, R.L. Walker and
G.R. Hertel, 10, 343 (1972-1973)

DESCRIPTION

A two-stage mass spectrometer with magnetic sectors in tandem and equipped with a pulse counting detection system provides reliable, precise, and accurate isotopic ratio measurements on samples of about 1 ng. This is particularly important for plutonium, where it is desirable to minimize sample size.

EQUIPMENT NAME : Mass Spectrometer (Transportable Quadrupole)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : Laboratory Samples
STATUS : Class IV : Production Model
STATUS DETAIL

This unit was custom-built and can be supplied on request at the cost stated.

USEFUL TO : Inspector
FACILITIES : Enrichment
Fabrication
Reprocessing

CAPITAL COST : 200,000

SOURCE 1 : Balzers

REFERENCE 1 : 1979 ESARDA

REFERENCE DETAIL : Facchetti, Federico, Guzzi, Huber & Rettinghaus; 149.

DESCRIPTION

A commercially available, quadrupole mass spectrometer installed in a truck has served as a field laboratory for the analysis of gaseous uranium hexafluoride samples. A quadrupole instrument was chosen because of its ruggedness.

Measurements involve the comparison of samples and standards because of the need to calibrate the instrument. The abundance sensitivity of the mass spectrometer at the U-238 peak is better than 10 parts per million. The instrument is therefore capable of measuring the minor-isotope ratios reasonably precisely and the major-isotope ratio more precisely. These comments suggest applications for enrichment and fabrication plants. Other applications exist for reprocessing plants. The above capital cost is estimated for a fully automated and computer-controlled instrument.

EQUIPMENT NAME : Mass Spectrometer, Quadrupole
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : Laboratory Samples
STATUS : Class I : Laboratory Device
STATUS DETAIL

ORNL device has been tested successfully at Savannah River for U & Pu analysis
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 120,000
MAINTENANCE COST : 10,000
SOURCE 1 : ORNL+
SOURCE 2 : WINCO
REFERENCE 1 : ACA
REFERENCE 2 : 1983 ESARDA
REFERENCE DETAIL : 1. D.H. Smith et al.; V. 142 (1982), 355.
2. M.W. Echo; 199.

DESCRIPTION

A quadrupole mass spectrometer has been modified by ORNL to perform thermal emission, isotopic ratio measurements. Small samples (1-3 ng) of either U or Pu (or both together) may be analyzed rapidly with a precision of 1-2% and a resolution (for mixed samples) of 300; the isotope dilution technique also allows measurement of element concentrations. The instrument is particularly applicable, in conjunction with the resin bead sampling technique, to dissolver solutions of spent reactor fuel and other cases where samples are difficult to obtain. It can be transported in a van where it is shock-mounted in two cabinets. Each module weighs less than 80 kg.

A related instrument has been developed by WINCO and is being evaluated for routine control laboratory use.

EQUIPMENT NAME : K- or L-Edge Densitometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Approved for limited use by IAEA.

USEFUL TO : Operator
FACILITIES : Fabrication
Reprocessing
CAPITAL COST : 250,000
SOURCE 1 : LANL
REFERENCE 1 : 1980 INMM
REFERENCE 2 : TASTEX
REFERENCE DETAIL : 1. Russo et al.; 730.
2. Task G; 117.

DESCRIPTION

Absorption-edge densitometry is a nondestructive gamma-ray technique for determination of elemental concentrations. The assay requires transmission measurements at photon energies which closely bracket the K- or L- absorption edges of the elemental species under study. In the energy-dispersive mode, the use of high-resolution gamma-ray detectors makes it possible to accurately obtain these transmission measurements in short count times. The results are timely since no sample preparation is required.

The absorption-edge technique is most useful for the assay of homogeneous samples such that the transmitted gamma rays intercept a representative portion of the sample. Some applications to solids have been described, but the technique finds widest application in solution assay. In one of many such possible applications, two radioisotopic sources, Se-75 and Co-57, are used for in-line Pu assay in a reprocessing plant.

EQUIPMENT NAME : K-Edge Densitometer (Compact)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

In limited use by IAEA.

USEFUL TO : Inspector
FACILITIES : Reprocessing
Conversion
CAPITAL COST : 75,000
MAINTENANCE COST : 5,000
SOURCE 1 : LANL
REFERENCE 1 : 1984 ESARDA
REFERENCE 2 : 1984 INMM
REFERENCE DETAIL : 1. Cowder et al.; 261.
2. Hawkins & Kuhn; 273.

DESCRIPTION

Los Alamos National Laboratory has designed, built, and is currently testing a compact K-edge densitometer for use by IAEA inspectors. The unit, which can easily be moved from one location to another within a facility, is positioned outside a glovebox with the body of the instrument inserted into the glove. A fixture inside the glovebox fits around the body and positions a sample holder. A hand-held high purity germanium detector powered by a battery pack and a Davidson portable multichannel analyzer (MCA) is used to measure the transmission through plutonium nitrate solutions at $E = 121.1$ and 122.2 keV. The Davidson MCA is programmed to lead the user through the measurement procedure and perform all the data analyses. The instrument is currently installed at SAL (Seibersdorf), where IAEA personnel are evaluating its accuracy, ease of operation and safety.

EQUIPMENT NAME : K-Edge Densitometer (KfK)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 100,000
SOURCE 1 : KfK
REFERENCE 1 : 1981 ESARDA
REFERENCE 2 : 1982 IAEA
REFERENCE DETAIL : 1. Eberle, Matussek, Michel-Piper & Ottmar; 109.
2. Ottmar, Eberle, Matussek & Michel-Piper; V.II, 147.

DESCRIPTION

The instrument is designed to measure nondestructively the SNM concentration (U and Pu) in solutions. The assay requires a transmission measurement of an X-ray continuum through a solution vial of well-specified transmission length. The X-ray source is a standard 160 kV/19 mA d.c. x-ray unit, and the detector a small planar HPGe detector. The instrument is preferably used for solutions with SNM concentration levels of 20 g/l or higher. It is also capable of providing accurate SNM assays in the presence of high gamma activities from fission products. The measurement accuracy depends on the SNM concentration level. In the optimum range of application (50 g SNM or higher) the accuracy achieved in a 15 min. assay is 0.2-0.3 % (one sigma).

The instrument also provides the option to determine the plutonium isotopic composition from a passive gamma count.

EQUIPMENT NAME : K-Edge/K-XRF (Hybrid) Solution Assay System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 130,000
SOURCE 1 : KfK
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : ESARDA
REFERENCE DETAIL : 1. Ottmar, Eberle, Matussek & Michel-Piper; V.II, 147.
2. Ottmar; No.4 (1983), 19.

DESCRIPTION

The major objective of the hybrid K-edge/K-XRF solution assay system is to provide a timely and accurate uranium and plutonium assay in the highly active input solution at the head end of a reprocessing plant. This is achieved by K-edge measurement for the major element uranium and a simultaneously performed K-XRF analysis for the U/Pu ratio determination. The instrument employs a 160 kV/19 mA d.c. x-ray unit and two planar HPGe detectors for the K-edge transmission and the K-XRF analysis. The K-edge and K-XRF measurements are designed such that they can tolerate interfering gamma activities of a few 100 Ci/l from fission products. The solutions are measured in disposable vials, which are transferred through a mechanically driven transport system from the interior of a hot sample handling cell to the shielded instrument located outside of the hot cell. In a 30 min assay the measurement accuracy achieved for U and Pu is 0.3% and 0.7% (one sigma), respectively, at U/Pu ratios of about 100.

EQUIPMENT NAME : Energy Dispersive X-Ray Fluorescence Analysis
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Operational units installed at SRP, ICPP and LLNL; under further development.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
Enrichment
CAPITAL COST : 50,000
REPLACEMENT COST : 50,000
SOURCE 1 : LLNL
REFERENCE 1 : Hilton Head
REFERENCE 2 : 1981 ESARDA
REFERENCE DETAIL : 1. Camp & Ruhter; 405.
2. Camp & Ruhter; 155.

DESCRIPTION

This technique (EDXRFA) can be used to monitor actinide concentrations and to obtain product accountability information at reprocessing plants. It can be used either off-line or on-line to measure either pure or mixed Th, U or Pu concentrations over a 0.1-500g/l-wide range. Suitably collimated 122-keV gamma radiation from Co-57 excites the actinide K x-rays. Use of a shutter allows passive measurements of Pu isotopics or U enrichment. If aged solutions are to be analyzed, a Cd shutter can be introduced to attenuate the 59.53-keV Am-241 gamma ray. A computer based MCA system allows near-real time concentration information to be obtained.

For process control, measurement times range from 10 to 500 s depending on concentration. Accountability measurements require more time; and for solutions containing plutonium, a passive spectrum must be taken to correct the excited spectrum for effects of variable isotopics (all done automatically by a programmed, computer-based PHA system). Concentrations in single and dual-element solutions have been determined to an accuracy of better than 0.5% after calibration. Use of a third 122-keV Co-57 transmission source allows concentrations to be determined independently of minor changes in solution matrix and of excitation source half-life. Placement of an appropriate actinide metal foil or disc (part of a computer controlled displaceable shutter) behind a process stream pipe allows "calibrations" of on-line systems.

EQUIPMENT NAME : Segmented Gamma Scanner (SGS)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Waste
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Enrichment
Reprocessing
CAPITAL COST : 115,000
SOURCE 1 : Canberra
SOURCE 2 : Jomar
REFERENCE 1 : 1971 INMM
REFERENCE DETAIL : Parker, Reilly, Foley, Walton & East; V. 2, 515.

DESCRIPTION

This equipment is used to measure the quantity of fissile material in containers of waste (usually cans or 208-l drums).

The 414-KeV Pu-239, 765-KeV Pu-238, or 186-KeV U-235 gamma activity is measured with a collimated Ge(Li) gamma detector. A suitable isotope gamma-ray source is located opposite the collimated detector. The sample is rotated and translated for a spiral scan. Emitted and transmitted gamma rays are accumulated for many discrete segments of the spiral scan. The data are corrected for self-absorption by measuring the transmission of the source through the sample. The data are collected and the correction applied as a function of vertical height of the sample to minimize errors due to sample inhomogeneities. The measured activities are used to determine the amount of fissile material in the sample.

The data from the MCA are fed into a programmable calculator. The calculator relates the measured count rates to fissile material content, computes the absorption correction, and prints out the results relative to vertical height along the sample and also the total assay value for the sample. The data reduction process takes about 1 minute after the scanning is completed.

The above devices differ in some details (see manufacturers' literature). The cost given is an upper estimate for the 208-l drum SGS; the 19-l can system costs about \$95,000. In-line systems are also available at K\$ 110-120.

EQUIPMENT NAME : In-Line Gas-Phase Enrichment Monitor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
CAPITAL COST : 100,000
SOURCE 1 : LANL
REFERENCE 1 : Hilton Head
REFERENCE DETAIL : Strittmatter, Stovall, and Sprinkle; 63.

DESCRIPTION

The in-line enrichment monitor is designed to provide continuous measurements of the enrichment of gas-phase UF₆ feed, product, and tails material. The gas-phase UF₆ enrichment is determined by combining gamma ray measurements of U-235 and total uranium concentrations. The U-235 concentration is determined from a measurement of the 185.7-keV gamma rays emitted from the decay of U-235, and the total uranium concentration is determined by measuring the transmission through the UF₆ gas of 60-keV gamma rays from an external Am-241 source.

The germanium detector-based enrichment monitor has been designed based on experience with an in-plant monitor prototype and on operational and facility design constraints specific to the Portsmouth Gas Centrifuge Enrichment Plant. Test results indicate that assay accuracies of 0.5% relative (one sigma) are achievable for assays ranging from 0.2 to 3.0% U-235.

In addition to the above reference, data evaluation problems are discussed in a paper by Strittmatter et al., presented at the ESARDA/INMM Joint Specialist Meeting on NDA Statistical Problems, Ispra, September 12-14, 1984.

EQUIPMENT NAME : Stabilized Assay Meter (SAM-II)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model

STATUS DETAIL

In routine in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 4,000
SOURCE 1 : Eberline
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : SAND 80-0002

DESCRIPTION

The SAM-II is a compact, portable assay meter. It consists of a detector (usually a sodium-iodide-photomultiplier combination), a bias supply, and 2 single-channel analyzers. The most common use is to measure the U-235 enrichment of thick uranium samples. One channel is set to measure the 186 KeV gamma-rays of U-235; the second is set at some higher energy to measure the Compton continuum due to U-238 daughters. When properly calibrated, this background can be automatically subtracted from the U-235 line to give a number that is proportional to enrichment. The instrument can also be used to measure gamma-ray emissions of plutonium or other radioactive materials. The above cost includes an RD-19 detector and shield.

EQUIPMENT NAME : Brookhaven Survey Assay Meter (BSAM)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model

STATUS DETAIL

Device is in routine use at U.S. licensee and DOE facilities.
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 12,000
SOURCE 1 : IRT
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Zucker, Chase, Stephani, Fiarman & Alberi; V. 2, 191.

DESCRIPTION

The BNL Survey Assay Meter (BSAM) was developed to supplant the Stabilized Assay Meter (SAM-II). The BSAM incorporates the operational features of the SAM-II with improvements and several new features. One of the new features is the interfacing of a built-in pocket calculator to the nuclear electronics. The calculator serves as a digital readout, performs calculations needed for the instrument's operation, and can be used independently for other calculations. Another new feature is a set of internal preset conditions for the more commonly met assay situations, U-235 (via the 185.6-KeV peak), Pu (375-KeV complex), and Pu (375-450 KeV, to minimize Am-241 contributions).

The BSAM design accommodates germanium and cadmium telluride diode detectors and proportional counters besides photomultiplier-based detectors. The instrument is packaged so that its outer case is the normal carrying container. It can be slung over the operator's shoulder, freeing hands for the detector, calculator, etc., or it can be used on a table. The internal rechargeable cells make the unit independent of power lines for a normal work day.

The cost given covers the instrument plus a sodium-iodide detector doped with Am-241.

EQUIPMENT NAME : Hand-Held Assay Probe (HM-4)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Uranium
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine use by IAEA.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 8,000
SOURCE 1 : NNC
REFERENCE 1 : ISPO-146

DESCRIPTION

The Hand Held Assay Probe (HM-4) is a portable, light weight (2 kg) hand-held gamma ray assay meter designed to permit quick detection or semi-quantitative assay of uranium content, enrichment, or plutonium content, in circumstances where it is difficult to set up and employ a fixed detector. Typical applications might include checking fuel rods for voids or dummy pellets, assaying UF₆ cylinders etc. The unit is completely self-contained and employs a 1.9 cm x 1.9 cm NaI detector with Am-241 stabilization of the high voltage bias supply. Temperature compensation for differences in the Am-241 alpha particle and gamma ray response is included. Two SCA counting channels are provided, which can be set to cover the 186 keV peak of U-235 and a background region, or the 300-450 keV region for Pu-239 counting. The HM-4 is battery-operated by 6 size AA rechargeable batteries. Nickel-cadmium batteries, which provide about 12 hours of continuous operation, are employed. The counting times can be selected from several values covering from 2 to 60 sec. or can be set to infinity.

EQUIPMENT NAME : Hand-Held Detector for UF6 Cylinder Assay
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class IV : Production Model

STATUS DETAIL

In routine use by IAEA

USEFUL TO : Inspector
FACILITIES : Enrichment
CAPITAL COST : 40,000
REPLACEMENT COST : 30,000
LIFETIME : 10 Years
SOURCE 1 : ORTEC
SOURCE 2 : PGT
REFERENCE 1 : K/OA-5206

DESCRIPTION

This device consists of a high-resolution, high-sensitivity HP Ge detector with a cylindrical lead collimator (2.5cm thick), machined to measure. The system can determine U-235 enrichment of solid UF6 stored in Model 30B product cylinders (3% U-235) with precision and accuracy of 2%. Feed UF6 (0.7% U-235) in Model 48Y cylinders may be assayed at the 6 to 8% level. The method is based on measurement of the 186-KeV gamma ray of U-235 through the cylinder walls, followed by correction for wall gamma-ray attenuation.

EQUIPMENT NAME : UF6 Sample Bottle Enrichment Meter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Custom made; tests finished at the ORGDP.

USEFUL TO : Inspector
FACILITIES : Enrichment
CAPITAL COST : 45,000
REPLACEMENT COST : 35,000
LIFETIME : 15 Years
SOURCE 1 : ORGDP
REFERENCE 1 : K/OA-5615
REFERENCE 2 : K/OA-5014, Rev.1

DESCRIPTION

This meter can determine U-235 enrichment in solid UF6 stored in Model 1S and 2S sample bottles. Relative precision and accuracy of 1% are obtained for feed (0.7% U-235) and product (3% U-235) grade UF6. For tails-like (~ 0.4% U-235) material the accuracy is 1% and the precision 2%. The determination is based on measurement of the 186 KeV gamma rays of U-235 through the bottle walls, with a portable HP Ge detector, followed by correction for wall gamma-ray attenuation. The meter is provided with tungsten-alloy collimators and shields, and with sample-bottle fixtures for good counting geometry reproduction.

EQUIPMENT NAME : Portable Plutonium Isotopic Analysis Unit (PIAU)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Plutonium
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL
Last significant change fall 1983; 4 field units being evaluated by IAEA.
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 10,000
REPLACEMENT COST : 15,000
SOURCE 1 : LLNL
REFERENCE 1 : IEEE TNS
REFERENCE 2 : UCRL-53506
REFERENCE DETAIL : Ruhter & Camp; 29 (1), 838 (1983).

DESCRIPTION

A portable microprocessor unit has been developed that can be used by inspectors to analyze suitably recorded Pu gamma-ray spectra. The microprocessor-analyzer connection is direct through a parallel interface. The unit incorporates a DEC LSI-11/2 16 bit microprocessor. It utilizes a 20-character vacuum fluorescent display to prompt the user and display error messages, a 20-character thermal printer, and a simple numeric keypad for input. Software is resident on 16,000 words of PROM memory.

The unit analyzes 4 peak groupings in the 110-210 KeV or 6 peak groupings in the 110-400 KeV region of the Pu spectrum. Gaussian and exponential tail terms are used to describe peak shape. A relative efficiency curve is established from isotopically related peaks. The only input information required for spectrum analysis is the 148- and 208-KeV peak positions and the Pu-242 abundance and associated error. If the Pu-242 abundance is unknown, it is calculated empirically from the Pu-240 and Pu-241 abundances. Results are available in 70-90 seconds after encoding and include Pu isotopic ratios, isotopic weight % of total Pu, U-235/Pu-239 ratio if applicable, and days since separation (growth of Am-241).

The above unit is used by IAEA in conjunction with Cicero (8K) MCA via a parallel interface connection. Slight modifications will allow the PIAU to accept data from other major commercial MCA's.

EQUIPMENT NAME : High-Resolution Gamma-Ray Spectrometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Plutonium
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Latest at-line version to be operational at SRP in late 1985.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
Enrichment

CAPITAL COST : 50,000

REPLACEMENT COST : 50,000

LIFETIME : 2 Years

SOURCE 1 : LLNL

REFERENCE 1 : TASTEX

REFERENCE 2 : UCRL-52950

REFERENCE DETAIL : Task H; 133.

DESCRIPTION

Gamma-ray spectrometry utilizes the unique energy and intensity patterns of the gamma rays emitted by each Pu isotope. When these radiations interact with a high-resolution germanium detector, a spectrum of pulses is produced that can be sorted, stored, and subsequently analyzed by the computer portion of the system.

The first off-line system for solution analysis was demonstrated in the reprocessing plant at Tokai-mura, Japan. It was designed to provide isotopic and total plutonium analyses that can be easily monitored by an inspector. A small, undiluted portion of process solution is drawn into a specially designed cell that contains a built-in monitor to correct for small changes in the detection response. Complete results can be obtained in times as short as 15 minutes. A similar system has been used at SRP since 1973 (see also the entry under "Energy Dispersive X-Ray Fluorescence Analysis"). The capital cost covers the sample cell, detector, electronics and computer system with peripheral devices. A Cd-109 reference source is not required if only isotopic analyses are desired. Precisions and accuracies of 1% can be obtained routinely for both freshly processed and aged samples.

EQUIPMENT NAME : High-Resolution Gamma-Ray Spectrometer (II)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Last significant change March 1984; unit being evaluated at SRP.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
Enrichment

CAPITAL COST : 50,000

REPLACEMENT COST : 50,000

SOURCE 1 : LLNL

REFERENCE 1 : UCRL-86737

DESCRIPTION

A two-detector, LLNL designed, HPGe system has been delivered to SRP. By coupling the Pu isotopic results from this system with those from calorimetry, total Pu content is determined in sealed canisters containing nondescript scrap material of Pu. The two-detector system is also capable of yielding highly accurate isotopic results on either pure Pu oxide or mixed U + Pu oxide samples in relatively short times (5 min).

This system uses an LLNL-developed method for measuring isotopic abundances of plutonium in nondescript samples. The analysis code called MGA (Multi Group Analysis) runs on PDP-11 model computers and incorporates several unique features. One is that spectroscopic data are obtained from all useful groups of peaks in a system, including the 100 kev grouping. All the data are integrated into a single set of internally consistent and appropriately weighted equations that are solved by the method of least squares. The analysis program has different run-time options and can accommodate data from one or two detectors, thereby providing considerable latitude in sample versatility and type. No calibration is required other than an initial characterization of peak shape parameters for the detector(s) chosen.

EQUIPMENT NAME : Rocky Flats Assay Meter (RFAM)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
STATUS DETAIL

Widely used for measurement of miscellaneous plutonium-containing streams.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 3,500
SOURCE 1 : Ludlum
REFERENCE 1 : Lawless

DESCRIPTION

The Rocky Flats Assay Meter (RFAM) is a portable assay instrument that consists of a commercially available digital ratemeter interfaced to a pocket calculator. The instrument offers a simple and inexpensive alternative to the nuclear instrument module packages more commonly used for these applications. RFAM units can be easily moved from one application to another and advantage can be taken of the battery mode of operation. The ability to calculate instantaneously the results, using a multitude of constants or curves, is the greatest advantage. This feature is available on other instruments at considerably higher cost. The variety of detectors and ease of installation for process control is also advantageous.

The RFAM was developed to provide a simple instrument technology for measuring the characteristics of Pu hold-up in a Pu processing facility. Improved hold-up measurement technology will enhance accountability, nuclear safety, process control and security functions within a Pu processing facility.

Maintenance of these systems can be accomplished by the individual operator simply by isolating the defective component, unplugging and replacing it. Since the components cost so little, spares can be stocked and defective units sent back to the manufacturer for repair. This provides low cost maintenance and rapid repair. The cost given is for a Model 2200-12 Ludlum ratemeter interfaced to a Hewlett Packard 75 continuous memory calculator.

EQUIPMENT NAME : Threshold Detector for Gamma Spectrometry
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Fuel (Spent)
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Storage
Reprocessing
CAPITAL COST : 10,000
SOURCE 1 : LANL
REFERENCE 1 : 1980 INMM
REFERENCE DETAIL : Cobb & Phillips, 708.

DESCRIPTION

The use of detectors that are sensitive to gamma-energy thresholds, for example Be(γ ,n) detectors, provides the capability of rapidly measuring the presence of specific fission products. Gamma rays having energies greater than 1660 KeV interact with beryllium to produce neutrons that can be counted using a U-235 fission chamber. The principal gamma ray contributing to the production of neutrons via the (γ ,n) reaction is the 2186-KeV gamma ray from the Pr-144 fission product (half-life = 17 minutes), which is in secular equilibrium with its parent Ce-144 (half-life = 284.5 days). This technique provides information about the presence of a fission product; therefore, it provides a higher level of verification for spent-fuel assemblies than that obtained from gross-gamma measurements.

The capital cost is for the detector and ancillary electronics.

EQUIPMENT NAME : NDA Reference Materials for Scrap and Waste
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Uranium
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Interlaboratory exercise completed; evaluation of results in progress.

USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing

SOURCE 1 : NBL

REFERENCE 1 : Kiawah

REFERENCE 2 : Hilton Head

REFERENCE DETAIL : 1. Voeks & Trahey; 25.
2. Voeks; 177.

DESCRIPTION

The degree of sophistication already achieved by a number of NDA systems thus far has made possible the evaluation of such systems by accepted calibration and standardization procedures. However, the physical standards or reference materials required to establish measurement compatibility within the national measurement system are not yet available. Three materials have now been prepared to serve as prototype NDA uranium reference materials for scrap and waste in an interlaboratory evaluation program to be administered by the New Brunswick Laboratory. They are (1) an ion exchange resin, (2) a cellulose fiber, and (3) a synthetic calcined ash.

The synthetic ash is packaged in polypropylene containers and the cellulose and resin in tin plate cans lined with oleoresin. The weights of each were carefully measured. The ion exchange resin, a styrene-divinylbenzene polymer, and cellulose fiber, a carbohydrate, represent low density, low Z organic materials. The synthetic calcined ash represents slightly higher density, intermediate Z refractory oxides. All three materials were prepared with varying percentages (0-15%) of 93% enriched uranium. Although most facilities do not routinely measure materials containing uranium with an enrichment this high, 93% was selected so that counting times during analysis would be short. It was felt that this was a necessary trade-off in order to complete the measurement phase of the evaluation program in a timely manner.

EQUIPMENT NAME : Autoradiography
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
STATUS DETAIL
In use at ANL-West ZPPR.
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reactor
Reprocessing
Critical
Fuel Storage
CAPITAL COST : 11,500
MAINTENANCE COST : 900
SOURCE 1 : ANL
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : ANL-NDA-5
REFERENCE DETAIL : Brumbach, Roche & Perry; 109.

DESCRIPTION

This technique uses currently available gamma-ray-sensitive film to record gamma emissions from U and Pu samples in less than one hour. With longer exposures, the beta rays from U-238 daughters can be detected. The technique has been used to verify U and Pu coupons in critical assemblies and in assembly drawers. It can also be used to verify signatures of other forms of nuclear material.

The method is termed "passive" when spontaneous events are recorded and "active" when critical configurations of material induce the recording of prompt-fission gamma rays and beta and gamma rays from short-lived fission products. The main deficiency of autoradiography is its qualitative nature, but it is useful in making an item inventory of SNM in a critical facility.

The capital cost given is for an immobile, automatic film processor (Kodak RP X-OMAT, Model M7B), and the maintenance cost for the silver-based film required to perform one inventory at a critical facility. If paper film techniques prove acceptable, a portable processor for about \$2000 and film at about \$500 per inventory can serve. It is also possible to process the film manually at much lower cost.

Other useful references are ANL-78-27 and ANL-NDA-2.

EQUIPMENT NAME : Low Pu Solution Assay Instrument (LOSAI)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive L X-ray
MATERIAL TYPE : SNM in Waste
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Units undergoing tests/evaluation at LANL Pu Facility and Savannah River Lab.
USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 60,000
SOURCE 1 : LANL
REFERENCE 1 : 1983 ESARDA
REFERENCE DETAIL : S.T. Hsue, et al.; 209.

DESCRIPTION

The LOSAI is a hybrid chemical and nondestructive analysis technique for the determination of Pu concentration in effluent solutions. It assays the L x-ray emission rate from U generated by Pu alpha decay to determine the Pu concentrations. The dynamic range is approximately 0.03 mg to 1 g Pu/l. These effluent solutions nominally contain Am; if the Am/Pu ratio is greater than 0.3, then a simple trioctylphosphine oxide (TOPO) separation is applied to the effluent. This separation takes five minutes.

EQUIPMENT NAME : Random Driver
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
STATUS DETAIL
Both 3- and 4-detector models are commercially available.
USEFUL TO : Operator and Inspector
FACILITIES : Reactor
Enrichment
Fabrication
CAPITAL COST : 140,000
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : Nuc. Mat.
REFERENCE 2 : S&U
REFERENCE DETAIL : Atwell, Foley & East; V. III, N. III, 171 (1974).

DESCRIPTION

Used for assaying containers of material containing high concentrations of enriched U-235, the random driver is an active-neutron interrogation system which induces fissions in the fissile material within a sample, hence "driving" the sample. Since the neutrons emanating from the Am-Li source have energies below their fission thresholds, the technique is insensitive to the Th-232 and U-238 content in a sample. Yet the source energy is high enough to achieve the penetrability required for assaying samples of high fissile mass, i.e., the problem of sample self-shielding is minimized. The "randomness" of the driver pertains to the nature of the source; the neutrons produced in the (alpha,n) reaction are random and not correlated with one another. This characteristic enables scintillation detectors to distinguish uncorrelated source neutrons from fission-produced neutrons (which have high probabilities of being emitted in pairs and triplets) by demanding that two events be detected within a short coincidence interval.

For a 1000-second counting time, the U-235 sensitivity is 12 grams for a net signal equal to three standard deviations of the background.

EQUIPMENT NAME : Shuffler (Cf-252)-Mod. 1 (Fast/Thermal Neutron)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
STATUS DETAIL

This is a class entry; several more specialized units are listed below.

USEFUL TO : Operator
FACILITIES : All
CAPITAL COST : 300,000
LIFETIME : 10 Years
SOURCE 1 : IRT/NNC
SOURCE 2 : LANL
REFERENCE 1 : LA-7315
REFERENCE 2 : S&U
REFERENCE DETAIL : Menlove, Ensslin, Krick & Hsue; Appendix A, A-1.

DESCRIPTION

The Cf-252 Shuffler is used for the assay of fissile material in a wide variety of bulk samples. The principle consists of active neutron interrogation using a Cf-252 source (about one billion neutrons/sec.) and counting the induced delayed neutrons using high-efficiency He-3 detectors. The detectors can be used in the passive mode to measure Pu-240 effective or in the combined active/passive modes to measure both Pu and U-235 in MOX. The unit is useful for the measurement of bulk UO2 samples, HEU metal, U-Th fuel, MOX and various types of scrap and waste.

The above information applies to the basic concept; the cost (an average) includes software and hardware required to tie the instrument into the plant computer system. Examples of more specialized modifications which are either in limited operation or development follow: 1. a compact version for small sample assay including UF6 (K\$85); 2. a compact version, designed to fit in a hot cell port, for measuring Pu (K\$50); 3. a small version, to fit under a glove box, for assaying HEU in finished product and scrap (K\$320, available commercially); 4. a large unit for measuring up to 208 l drum size packages of enriched U scrap (K\$400, available commercially); 5. a large unit, installed in a production facility, to measure enriched U scrap and waste. (ca. K\$700).

A related system for assaying THTR pebbles (SIGMA) has been developed at JRC/Ispra; see p. 317 of the reference "1979 ESARDA".

EQUIPMENT NAME : Sb-Be Photoneutron Interrogation System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing
SOURCE 1 : KFA
SOURCE 2 : JRC
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : 1984 ESARDA
REFERENCE DETAIL : 1. Filss; V. II, 252.
2. Dell'Oro et al.; 371.

DESCRIPTION

This system utilizes selective measurement of fission neutrons produced by irradiation with quasi-thermal neutrons which are emitted from a Sb-Be source. At KFA-Juelich the detection limit (source rate equivalent) is

- 5 mg U-235 (3mg Pu) in 0.1 l. samples
- 50 mg U-235 (25mg Pu) in 5 l. samples
- 1 g U-235 (600mg Pu) in 200 l. barrels

under typical conditions. The system is operable in the presence of high levels of radioactivity from fission products. A related system called PHONID is under study at JRC (Ispra).

EQUIPMENT NAME : Active Well Coincidence Counter (AWCC)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Uranium
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Operator and Inspector

FACILITIES : Reactor
Fabrication

CAPITAL COST : 60,000

LIFETIME : 15 Years

SOURCE 1 : NNC

SOURCE 2 : IRT

REFERENCE 1 : LA-7882-MS

REFERENCE 2 : LA-9608-MS

DESCRIPTION

An Active Well Coincidence Counter (AWCC) has been developed to assay uranium fuel material in field inspection applications. The operation of the AWCC is based on active neutron interrogation using a small AMLi neutron source and counting the induced fission neutrons with high-efficiency He-3 detectors operated in the coincidence mode. In comparison with the conventional fast random-driver assay system, the AWCC is more portable, light-weight, stable and less subject to gamma-ray backgrounds. The AWCC is not unlike a High-Level Neutron Coincidence Counter (HLNCC) with neutron sources; the former possesses superior counting efficiency, but both use the same electronics system. LA-7823-M gives more background information on the AWCC.

The unit is useful for the measurement of bulk UO₂ samples, high-enrichment uranium metals, LWR fuel pellets, and U-233-Th fuel materials, which have very high gamma-ray backgrounds. By removing the AMLi source, the unit can measure U-238 and plutonium in the passive neutron coincidence mode.

Jomar Systems is another commercial source of this equipment. The capital cost covers the detector, two AMLi sources, and associated electronics (the electronics package is the same as for the HLNCC).

EQUIPMENT NAME : Uranium Neutron Coincidence Collar
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fuel (Fresh)
STATUS : Class IV : Production Model
STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : Fabrication
Reactor
CAPITAL COST : 30,000
LIFETIME : 15 Years
SOURCE 1 : NNC
SOURCE 2 : IRT
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : LA-7528-M
REFERENCE DETAIL : Menlove & Keddar; V.II, 105.

DESCRIPTION

This transportable active-neutron interrogation system for light water reactor fuel assemblies, hereafter called the collar, was designed to assay pressurized water reactor and boiling water reactor fuel assemblies. An AMLi neutron source, with spectrum moderated by the polyethylene frame of the assay system, actively interrogates a fuel assembly for fissile content with subthreshold thermal and epithermal neutrons. A large fraction of the thermal and epithermal neutrons entering the fuel assembly cause fissions to occur in the fissile material. A fission neutron spectrum is thus induced; the yield is a function of the fissile mass in the fuel assembly and has an average neutron energy higher than that obtained from the moderated AMLi source. He-3 detectors are used; they measure the relative fluence of the induced fission neutrons from the fuel assembly.

Jomar Systems is another commercial source of these devices. The capital cost covers only sources and detectors. The electronics system is the same as for the HLNCC and AWCC, and would add about \$15,000 to the total cost.

EQUIPMENT NAME : Fuel-Rod Scanner
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fuel (Fresh)
STATUS : Class IV : Production Model
USEFUL TO : Operator
FACILITIES : Fabrication
Reactor
CAPITAL COST : 500,000
MAINTENANCE COST : 50,000
REPLACEMENT COST : 500,000
LIFETIME : 10 Years
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : LA-4705-MS
REFERENCE DETAIL : Menlove, Forster & Smith; 6.

DESCRIPTION

Designed primarily for quality control tests of nuclear fuel rods, the scanner also serves to help in checking the nuclear materials balance in a fuel fabrication plant and in assuring reactor operators that delivered fuel meets specifications.

The scanner, with a rod conveyance system, standard nuclear electronic modules, and minicomputer hardware, operates by irradiating uranium or plutonium dioxide in fuel rods with moderated neutrons from a Cf-252 source. Fission-product gamma rays are detected. Measurements include uranium enrichment and the geometrical location of fissile material. The commercial units currently available provide rapid detection of, and details on, anomalous rods, while only rarely rejecting one within specifications. A typical system would include the rod transport mechanism, irradiators, Cf-252, detection electronics, interface, hardware, analysis and display computer, and appropriate software elements. The cost given above is approximate; the exact price would depend on the peripherals included and also on the number of units purchased. Jomar Systems is another source of this equipment.

EQUIPMENT NAME : Spent Fuel Assembly Assay System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fuel (Spent)
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
 Reprocessing
CAPITAL COST : 500,000
SOURCE 1 : ORNL
REFERENCE 1 : 1979 INMM
REFERENCE 2 : 1981 INMM
REFERENCE DETAIL : 1. Ragan, Ricker, Chiles, Ingersoll & Slaughter; 334.
 2. Blakeman, Ricker, Ragan, Difilippo, & Slaughter, 9.

DESCRIPTION

LWR or LMFBR spent-fuel assemblies (also called subassemblies in LMFBRs) can be assayed rapidly and accurately by a nondestructive assay system using active-neutron interrogation and prompt-neutron detection. Assembly penetration is achieved by 24-keV (Sb-Be) interrogation neutrons; the spent fuel neutron background is overridden by using strong interrogating sources and prompt-neutron signals, and background gammas are absorbed by lead. Experiments using fresh fuel assemblies and canisters of spent BWR fuel have demonstrated the potential for assaying, with errors less than 3%, three spent plutonium-fueled assemblies per hour. Calculations, validated by experiments, predict even better performance for fresh or uranium-fueled assemblies. The total fissile content of an unknown assembly is obtained by comparison of the measurement with that for a nearly identical standard reference assembly.

EQUIPMENT NAME : Spent-Fuel Assembly Monitor (KfK)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fuel (Spent)
STATUS : Class IV : Production Model

STATUS DETAIL

System currently in operation at WAK reprocessing plant.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Reactor
Fuel Storage

CAPITAL COST : 600,000

SOURCE 1 : KfK

REFERENCE 1 : 1982 IAEA

REFERENCE DETAIL : Wuerz, V. II, 165.

DESCRIPTION

The spent fuel assembly monitor is based on combined active and passive neutron counting. The monitor is primarily developed for the objective of criticality control in the head end of a reprocessing plant, but can be used for safeguards applications as well as independent verification of the shipper's data. The system uses a Cf-252 source with a strength of up to one billion neutrons/sec. for the active neutron interrogation, and fission chambers as neutron detectors. Combination of the active and passive mode allows determination of the burnup of uranium fuel assemblies with an uncertainty of 1200 MW.d/tHM, and of the initial U-235 enrichment with an accuracy of 5%, without knowledge of any shipping data. Using these data, the total plutonium content can be determined from isotopic correlations with an accuracy of 0.3 kg/tHM for PWR and about 0.5 kg/tHM for BWR fuel assemblies.

The capital cost refers to a fully automated system for both the active and passive measurements as presently installed at the fuel storage pond of the WAK reprocessing plant. A simplified version for burnup verification from a passive measurement alone would cost about \$250,000.

EQUIPMENT NAME : Leached Hull Monitor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM in Waste
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 500,000
SOURCE 1 : ORNL
REFERENCE 1 : ORNL/TM-8445
REFERENCE 2 : LA-7784-MS

DESCRIPTION

An instrument has been developed for assaying the residual fissile material in chopped sections of the fuel cladding (leached hulls) after the fuel dissolution process in a reprocessing plant. An Sb-124-Be source elicits a fission response from a canister of leached hulls. Induced fission neutrons are measured by He-3 or BF3 detectors after traversing a borated polyethylene filter which attenuates source neutrons, thus minimizing source background. Experiments have been performed using a canister of simulated hulls into which one or more uranium pellets were inserted at various locations. Results indicated that 500 mg of fissile material in a 12-l. canister can be detected and assayed within 30 min. with an estimated error of 30%.

The technique is described in Reference 1; Reference 2 provides a general discussion of leached hull measurement capability as of 1979.

EQUIPMENT NAME : Isot'ic Source Assay System/Fissometer (ISAS/ISAF)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 100,000
SOURCE 1 : IRT
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : S&U
REFERENCE DETAIL : Gozani; 322.

DESCRIPTION

Both the isotopic source assay system and fissometer (ISAS and ISAF) are active-neutron systems for nondestructive analysis of fuel and waste throughout the nuclear fuel cycle.

The concept behind these devices is that several prompt neutrons and gamma rays follow a fission event induced by an active-neutron source. Since these prompt emissions are correlated in time, they can be distinguished from the random source emissions.

The ISAS employs a collimated Cf-252 source of fast neutrons and detects prompt neutrons and gammas. The sample can be rotated and moved for uniform coverage and the source spectrum modified by means of a moderator to allow study of fissile or fertile isotopes preferentially. The ISAF allows larger samples and employs an uncollimated Am-Li source of slower neutrons.

EQUIPMENT NAME : Differential Die-Away System for Waste Assay
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM in Waste
STATUS : Class IV : Production Model
STATUS DETAIL

Systems are in use at various DOE facilities.

USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 550,000
SOURCE 1 : LANL
REFERENCE 1 : 1983 INMM
REFERENCE DETAIL : J.T. Caldwell et al.; 75.

DESCRIPTION

This equipment consists of a pulsed thermal-neutron interrogation system with detection of prompt fission neutrons. It has been used to detect trans-uranics at sensitivities less than 1 nCi/g for high-density waste in 200-liter barrels. A linear response over 3 orders of magnitude in mass has been demonstrated for U-235 or Pu-239. An improved version with detectors on all sides has been installed at ORNL. The 14-MeV interrogation neutrons arise from a DT pulsed neutron generator, and the detector system consists of He-3 proportional counters.

The capital cost covers the neutron generator, the interrogation detector and system, and the electronics. A larger crate size version has been constructed and is being evaluated at Rockwell International, Rocky Flats Plant.

EQUIPMENT NAME : Crated Waste Assay Monitor (CWAM)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM in Waste
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Delivery of the system to GCEP is scheduled for summer 1985.

USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
CAPITAL COST : 1,036,000
SOURCE 1 : LANL
REFERENCE 1 : 1983 INMM
REFERENCE 2 : 1984 ESARDA
REFERENCE DETAIL : 1. E.R. Shunk et al.; 80.
2. R.A. Harlan et al.; 273.

DESCRIPTION

This system has been developed for NDA of sealed containers of selected waste from gas centrifuge enrichment plants such as the one at Portsmouth, which may not be accessible to inspectors. The principal types of waste involved are spent alumina from UF₆ chemical trays, in 208 liter drums, and non-burnable solid waste, in 1.36 cubic meter wooden crates.

The CWAM consists of a "gazebo"-like enclosure, about 2.62 m high and 2.84 m in diameter. An air pallet is used to move the waste containers around. The walls, roof, and base are made of aluminum modules which contain the neutron detectors sandwiched between thick graphite/polyethylene layers. The operation of the CWAM is based on pulsed thermal neutron interrogation of the waste matrix followed by neutron die-away counting between pulses. A neutron generator produces pulses of 14-MeV neutrons which are thermalized in the walls of the cavity and then reflected into the rotating waste matrix. The measurements are controlled electronically, and the data are handled automatically by a state-of-the-art data acquisition system. A sensitivity of 10 mg U-235 is estimated for CWAM based on results from proof-of-principle measurements conducted with a device designed for similar applications. Similar devices are being developed in the U.S. and abroad for application to assorted SNM wastes. The above capital cost is the contract cost for this first-of-a-kind unit; additional units would cost 10-15% less.

EQUIPMENT NAME : Dual-Range Thermal-Neutron Coincidence Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Fuel (General)
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Critical
MOX
Fabrication
CAPITAL COST : 40,000
LIFETIME : 15 Years
SOURCE 1 : NNC
SOURCE 2 : IRT
REFERENCE 1 : TANS
REFERENCE DETAIL : Ensslin et al.; V. 27 (1977), 182.

DESCRIPTION

Used for measurement of bulk PuO₂ and plutonium content in fuel plates in a fuel drawer of a critical facility or in a vault canister, this instrument consists of a sample cavity surrounded by a polyethylene annulus to thermalize the neutrons from the sample. Several He-3 proportional counters are incorporated in the polyethylene to detect the thermal neutrons. A polyethylene shield outside the detectors reduces the neutron counting rate caused by room background. The detector pulses are sent to a shift-register coincidence counting module which simultaneously measures and records the totals and coincidence counting rates. Depending on the internal configuration, the counter operates at either low (8%) counting efficiency for high neutron activities or high (20%) efficiency for low neutron activities.

Jomar Systems is another commercial source of these devices. The capital cost is for the counter without the electronics system which is the same as for the HLNCC and would add \$15,000-\$20,000 to the total cost.

EQUIPMENT NAME : Neutron Well Coincidence Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
 Reprocessing
 Critical
CAPITAL COST : 40,000
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Zucker & Fainberg; 313.

DESCRIPTION

The type of counter covered under this heading is available from several suppliers in addition to those cited, for example Jomar Systems. It consists of a cylindrical hollow in a moderator which has neutron-sensitive proportional counters, either BF3 or He-3, embedded in it together with the appropriate electronics. The technology involved was developed primarily for the assay of Pu, based on the spontaneous fission of Pu-240. However, the above authors and others cited by them have shown that it can also be used for U-238 (and hence for LEU) despite the much higher spontaneous fission half-life of U-238 in comparison to Pu-240.

The cost quoted above includes the electronics package and represents a minimum. Similar devices designed to be more flexible as to sample size may cost appreciably more.

EQUIPMENT NAME : Neutron Well Coincidence Counter (KfK)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM in Waste
STATUS : Class IV : Production Model

STATUS DETAIL

Counter in operation at the KfK Waste Treatment Plant.
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing
CAPITAL COST : 250,000
SOURCE 1 : KfK
REFERENCE 1 : EUR 6629 EN
REFERENCE DETAIL : Eyrich, Kuechle & Shafiee; 159.

DESCRIPTION

This neutron well coincidence counter is primarily used for the assay of plutonium in low-active waste (LAW) in 200 l. barrels. The device provides capability for the counting of total and coincident neutron rates from these waste barrels. It consists of a polyethylene annulus of 80 cm inner and 120 cm outer diameter,, with a height of 110 cm. Two rings of 4 cm diameter and 100 cm active length BF3 counters are embedded in this annulus, each ring consisting of 36 counters. Additional counters are located in the top and bottom area of the cavity. For the assay of middle-active waste (MAW) a 7 cm thick lead annulus can be inserted into the well to protect the BF3 counters from gamma radiation. This mode allows operation with activities up to 100 Ci in the barrel.

Detection limits in the coincidence counting mode (at a signal-to-back-ground ratio of 0.5) range between 5 and 10 mg Pu for LAW, and 75 and 150 mg Pu for MAW, where the lower limits refer to uncompacted laboratory waste, and the higher limits to waste in concrete matrix. Similarly, detection limits (at 3 sigma) from total neutron counting range between 2 and 6 mg Pu for LAW, and 6 and 12 mg Pu for MAW.

EQUIPMENT NAME : High-Level Neutron Coincidence Counter (HLNCC)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine use by IAEA.

USEFUL TO : Operator and Inspector

FACILITIES : Fabrication
Reprocessing
MOX
Critical

CAPITAL COST : 43,000

SOURCE 1 : IRT

SOURCE 2 : Jomar

REFERENCE 1 : 1978 IAEA

REFERENCE 2 : LA-7779-M

REFERENCE DETAIL : Krick et al.; V. 2, 51.

DESCRIPTION

This transportable device was developed for the assay of plutonium. It was designed to measure the effective Pu-240 mass in samples which may have a high Pu content. The term "high-level" refers to the capability to handle large (several kg) Pu oxide or metal samples and the associated high neutron count rates. The counter measures coincident fission neutrons in the presence of a random neutron background with an efficiency of ~ 1%. Total Pu content is calculated from the Pu isotopics. Correction procedures for removing non-linearities in the counter response due to multiplication effects in the samples are being developed for metal and oxide samples. The detector consists of 18 He-3 proportional counters embedded in six polyethylene slabs, which form an hexagonal well. Top and bottom end-plugs can be used to form a closed sample-counting cavity. The detector weighs approximately 35 kg. A portable package featuring shift-register coincidence counting electronics was designed for use with the detector. The electronics package is interfaced to a HP-97 programmable calculator and standard data communications devices. Two AMLi neutron sources for about \$6000 each can make this into an active device (see AWCC). About \$28,000 of the cost is for the detector and about \$15,000 for the versatile electronics package used for this and several other related neutron counters. An upgraded device (HLNCC II) capable of handling even higher count rates is being tested at the IAEA.

EQUIPMENT NAME : Plutonium Neutron Coincidence Collar
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Fuel (Fresh)
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : Fabrication
Reactor
CAPITAL COST : 30,000
SOURCE 1 : NNC
SOURCE 2 : IRT
REFERENCE 1 : LA-9288-MS

DESCRIPTION

A passive coincidence collar has been developed for the assay of fuel assemblies containing plutonium (LWR-MOX and FBR). The neutrons originating from spontaneous fission reactions are measured using normal neutron coincidence counting to determine the Pu-240 effective mass.

The efficiency and die-away time of the coincidence collar have been modified by placing cadmium and polyethylene sleeves around each He-3 detector tube. The resulting efficiencies can be varied from 5 to 17% and the die-away times from 10 to 55 microseconds. The optimum combination is selected to correspond to the plutonium mass to be measured. Jomar Systems is another commercial source of these devices. The capital cost does not cover the electronics system, which is the same as for the HLNC and the AWCC; it would add about \$15,000 to the total cost.

EQUIPMENT NAME : Inventory Sample Coincidence Counter (ISCC)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 20,000
SOURCE 1 : LANL
REFERENCE 1 : 1983 ESARDA
REFERENCE DETAIL : Menlove; 231.

DESCRIPTION

This small neutron coincidence system quantitatively verifies the amount of plutonium in product inventory samples. The system is highly portable and can be used conveniently at a product sampling area. Solutions withdrawn from a reprocessing plant can be assayed in the vials normally used to transfer samples to an analytical laboratory. Pellets and powders can also be assayed.

The detector contains 16 He-3 tubes. The sample cavity will accommodate a sample vial encased in the various plastic bags needed for its removal from a glove box. The detector has been designed so that its response is insensitive to the plastic bagging.

An absolute detector efficiency of 35 per cent was determined using a calibrated Cf-252 source. A measurement precision of 0.5 per cent can be obtained in a 1000-s measurement for 15 ml. of solution containing 250g Pu/l. (20 per cent Pu-240). Similar precisions can be obtained for PuO₂ pellets and powders in the same mass range.

This unit is small enough to be contained in a carrying case for both transfer and operation and can, therefore, be used in the tight spatial constraints of product sampling stations.

Jomar Systems is another commercial source of ISCC's. The electronics package is the same as for the HLNCC and would add \$15,000 - \$20,000 to the above cost.

EQUIPMENT NAME : Special Coincidence Counter Heads
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
Conversion

CAPITAL COST : 30,000

SOURCE 1 : IRT/NNC

SOURCE 2 : LANL

REFERENCE 1 : 1983 ESARDA

REFERENCE DETAIL : Menlove, 231.

DESCRIPTION

All detector heads use the standard HLNCC electronics. The cost estimate is for each individual head.

1. FBR Fuel Pin Tray-A Counter- This counter is designed for verification of FBR fuel pins contained in storage trays. It consists of a flat array of He-3 tubes in polyethylene slabs. The uniform response region is ~55 cm long and 30 cm wide.

2. Channel Coincidence Counter-This counter is designed for verification of metallic plutonium coupons in fast critical assemblies. These are typically found in rectangular storage drawers (5 cm x 5 cm x 40 cm). The counter can also be used for MOX fuel rods. The detector is a rectangular array of polyethylene with 8 He-3 tubes. A 7 cm x 7 cm channel runs the full length (97 cm) of the detector. This channel is large enough to hold FCA fuel drawers and certain fuel rod trays, but is small enough to permit high and reasonably uniform coincidence counting efficiency.

3. Bird Cage Counter-This counter is designed for the same plutonium metal coupons as used in the channel coincidence counter, but for the specific application in which it is necessary to make measurements inside a "bird cage" where the coupons are stored and transferred. The detector is a rectangular polyethylene lattice with He-3 tubes that has an open interior region to set over the cylindrical "bird cage" storage canister.

EQUIPMENT NAME : Universal Fast Breeder Reactor Subassembly Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Fuel (Fresh)
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reactors
CAPITAL COST : 30,000
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : LA-10226-M

DESCRIPTION

This neutron coincidence counter is specifically designed for measurement of fast breeder reactor fuel assemblies. The system can accommodate the full range of geometries and masses found in fast breeder assemblies.

The detector contains 12 He-3 detectors in a cylindrical container that has a door which can be opened to accommodate side entry of samples. Maximum sample diameter is 16.5 cm and the uniform counting (flat response) region in the detector head is 105 cm.

The undermoderated detector has an efficiency, for a Cf-252 source in an empty counter, of 7.0%.

The electronics package is the same as for the HLNCC. The capital cost estimate is for the detector head alone.

EQUIPMENT NAME : Solution Neutron Coincidence Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM in Solutions
STATUS : Class I : Laboratory Device
USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 70,000
SOURCE 1 : LANL
REFERENCE 1 : TANS
REFERENCE DETAIL : Ensslin et al.; V. 39 (1981), 335.

DESCRIPTION

This coincidence counter is designed to measure flowing or stationary solutions. The interior cavity accommodates a 1 liter sample cylinder. The end caps provide access tubing for flowing solutions. Two rings of He-3 proportional counters are embedded in polyethylene which tightly surrounds the sample cylinder. The counter is designed for high efficiency and insensitivity to the presence of moderator in the solutions. A shield for external radiation is provided. Assay precision and accuracy are on the order of 1 to 2% for 2 to 100g Pu/liter solutions. Conventional shift register coincidence circuitry is employed for data processing. Possible applications include bulk assay of loaded tanks and assay of flowing streams containing fission products. The above cost includes the electronics.

EQUIPMENT NAME : Plutonium Nitrate Bottle Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM in Solutions
STATUS : Class IV : Production Model
STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Conversion
CAPITAL COST : 30,000
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : LA-10009-M

DESCRIPTION

This neutron coincidence counter is specifically designed for assay of plutonium nitrate in large storage bottles. The system can be used in a reprocessing plant or in a nitrate-to-oxide conversion facility. The detector contains 12 He-3 tubes embedded in polyethylene and surrounding a sample cavity with a 10 cm diameter and 1.05 m height. This corresponds to a volume of ca. 7.5 l. of nitrate solution.

The detector is designed to be undermoderated, i.e., to have less polyethylene wall thickness than would be the case for maximum counting efficiency. This design was adopted because of the high hydrogen content in the bottles and the desire to keep the counter weight low. The efficiency for a Cf-252 source in an empty counter is 8.4%. A support cart is used for moving the detector and electronics.

The electronics package is the same as for the HLNC. The capital cost estimate is for the detector head alone.

EQUIPMENT NAME : End-Crop Box Counter (ECBC)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Uranium
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator
FACILITIES : Fabrication
CAPITAL COST : 167,000
SOURCE 1 : LANL
REFERENCE 1 : LA-9781-M

DESCRIPTION

The counter was developed to measure up to 600 kg of low-enriched uranium in as many as 100 pieces. Typical enrichments are 0.7, 0.9 and 1.2% U-235. Samples are sealed in wooden shipping crates (tare weight 25 + 5kg). Matrix containments are Zircaloy and copper, up to 25 wt%. Signal is from spontaneous fission of U-238. Six detector banks composed of He-3 tubes embedded in polyethylene slabs completely surround the sample. Precisions of 1% or better and accuracies of 1-2% are obtained in 1000-s counts. The HP-85 minicomputer controls the counting electronics and requires a daily measurement control.

EQUIPMENT NAME : Reactor Power Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Miscellaneous
STATUS : Class II : Development Prototype

STATUS DETAIL

Above system in limited use by IAEA.

USEFUL TO : Inspector
FACILITIES : Reactor
CAPITAL COST : 10,000
SOURCE 1 : LANL
REFERENCE 1 : 1979 INMM
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Dowdy, Robba, Hastings & France; 689.

DESCRIPTION

A microprocessor-based reactor power monitor was developed to provide an operator-independent history of the power output of a nuclear power plant. The monitor is based on a correspondence of leakage neutron flux with reactor thermal power. The sensor is a proportional counter filled with He-3, which is used to detect thermal neutrons outside the biological shield. The monitor is placed in a tamper-resistant, tamper-indicating enclosure against the biological-shield wall. The system has a stand-alone capability of approximately four days on battery power and records the power level every hour. The above cost applies to newly built units incorporating currently (1984) available components.

EQUIPMENT NAME : Fuel-Drawer Scanner
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : Fuel (General)
STATUS : Class II : Development Prototype

STATUS DETAIL

Equipment has been used at ZPPR and is available for similar applications.

USEFUL TO : Operator and Inspector
FACILITIES : Critical
CAPITAL COST : 150,000
SOURCE 1 : LANL
REFERENCE 1 : 1980 INMM
REFERENCE DETAIL : Pratt, Caldwell, France, Hastings, Hsu & Shunk; 795.

DESCRIPTION

This is an integrated scanning system incorporating highly efficient collimated neutron and high-purity germanium gamma detectors with an on-line microprocessor to perform rapid inventorying of U and Pu fuel drawers from fast critical assemblies. On-line least-squares-fit procedures provide quantitative comparisons at a rate exceeding two drawers per minute. For Pu-containing fuel, the neutron scan data can be related to the included Pu-240 isotopic mass; individual Pu-239, Pu-241, and Am-241 isotopic contents are obtained from simultaneous scans of the appropriate isolated gamma lines.

A conveyor belt carries the drawer past a collimated high-efficiency neutron detector and a collimated high-resolution gamma detector. The neutron detector is housed in a polyethylene collimator assembly and consists of 12 He-3 proportional counters. The measured neutron detection efficiency is approximately 5% and the measured spatial full width at half maximum (FWHM) is about 50 mm. The gamma detector is a high-purity germanium detector, with a detection efficiency of 20% of the efficiency of a sodium iodide detector. The gamma detector collimator gives a FWHM of about 10 mm. The system is designed with a sensitivity adequate to detect the presence or absence of a typical 2.5 cm long Pu fuel plate in a drawer containing as much as 1 M (total) of Pu fuel in one or more rows, and in the presence of a variety of coolant, structural and fertile mockup materials.

EQUIPMENT NAME : Nondestructive Spent Fuel Verification (ION-1)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : Fuel (Spent)
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

System authorized for limited IAEA inspector use.

USEFUL TO : Inspector
FACILITIES : Reactor
AFR Storage
Reprocessing
CAPITAL COST : 15,000
SOURCE 1 : LANL
REFERENCE 1 : LA-9438-MS

DESCRIPTION

This system provides a nondestructive technique for verifying operator-declared values of burnup and the consistency of declared cooling times. The portable measurement system uses the ION-1 electronics unit and a "fork" detector. The detector measures the neutron and gamma-ray signatures from opposite sides of the fuel assembly using ion chambers operated in the current mode and neutron detectors (usually U-235 fission chambers). Measuring opposite sides reduces the effects of asymmetrical radial distributions giving an average of the cross section. Neutron emission rates of fuel assemblies can be correlated with burnup through a power law relationship which is established empirically for each type of fuel assembly measured.

By plotting the measured gross gamma-ray signal divided by declared burnup as a function of cooling time, the consistency of the operator-declared values can be verified. The values should approximate an inverse time relationship for typical irradiation histories.

EQUIPMENT NAME : Multi-Energy Gamma Assay System (MEGAS-II)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : SNM in Waste
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator
FACILITIES : All
CAPITAL COST : 250,000
SOURCE 1 : Jomar
REFERENCE 1 : CONF-820424-3
REFERENCE 2 : Kiawah
REFERENCE DETAIL : 1. D.A. Close et al.; 292.
2. Harlan; 622.

DESCRIPTION

MEGAS-II is a segmented scanner used for assaying low-density transuranic (TRU) wastes packed in 57-liter cartons. The original system has been upgraded. The original NaI detector has been replaced by an NaI crystal that optimizes TRU detection capability using L x-rays and gamma rays of less than 100 KeV. This thinner crystal also results in a decreased Compton scattered background. With this detector, the detection limit for Am-241 at the three sigma level above background is less than 5 pCi/g for a 500-s count (approximately 6 kg of low density wastes in a 57-liter carton).

The presence of fission products severely decreases the TRU detection limit for even thin NaI detectors. The recent addition of a high-resolution hyperpure planar Ge detector allows the assay of TRU isotopes even in the presence of substantial gamma and x-ray backgrounds. An estimate is that TRU assay of 10 nCi/g can still be made even in the presence of 400 nCi of Cs-137 (65 nCi Cs-137/g). Also added were four banks of PE-moderated He-3 neutron detectors (six tubes per bank). The measured detectability limit for this system is 10 mg typical reactor-grade PuO₂. This limit applies to a net signal three-sigma above background for a 1000-s run time using the total neutron count. The above system cost includes MCA and computerized data handling capability; the stripped-down original system would cost about \$ 120,000.

Additional information may be found on p. 515 of Ref. "IAEA Alpha".

EQUIPMENT NAME : Multichannel Analyzer (Portable)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
STATUS DETAIL

In routine use throughout nuclear industry and by inspectors (including IAEA).
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 8,950
SOURCE 1 : Davidson
SOURCE 2 : ND
REFERENCE 1 : See Description

DESCRIPTION

Portable MCA's (2048-8192 channels) are now available from a number of sources in addition to those named above. They can display and record gamma ray spectra obtained from NaI or high resolution (Ge(Li) or intrinsic Ge) detectors. The reader is referred to the technical reports and catalogs issued periodically by the manufacturers. Advanced designs include interfaces that allow use by remote control via a variety of modes. All are designed for field use in rugged environments. The cost given above applies to the ND model 6 and Davidson Model 2056-4K (both 4096 channels, weight less than 7 kg). The Canberra Series 10 includes 4,096 (\$7,900) and 8,192 (\$8,900) channel models which weigh about 4 kg. EG & G ORTEC (see Source "ORTEC") is another leading U.S. source of portable MCA's.

EQUIPMENT NAME : Multichannel Analyzer (Stationary)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 16,000
SOURCE 1 : Canberra
SOURCE 2 : Silena
REFERENCE 1 : See Description

DESCRIPTION

Used for general gamma-ray and particle spectrometry, multichannel analyzers are the final electronic devices which perform classification of the pulses from nuclear detectors according to their size and thereby generate energy spectra of the sources under observation.

MCA's are now available from many more companies, in the U.S. and abroad, than those listed above. Advanced models feature up to 65,536 channels and advanced display, analysis and interface features. The capital cost given above is for the highly advanced Canberra Series 90. EG & G ORTEC (see Source "ORTEC") and ND are other major U.S. sources. Silena is mentioned because the IAEA has adopted the Silena Cicero (8K) for routine use, particularly in connection with the LLNL Plutonium Isotopic Analysis Unit described elsewhere in this CATALOG. The reader is referred to the technical reports and catalogs issued periodically by the manufacturers.

EQUIPMENT NAME : On-Line Alpha Monitor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Alpha
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 26,500
SOURCE 1 : IRT
REFERENCE 1 : Nuc. Safe.
REFERENCE 2 : LA-8042
REFERENCE DETAIL : 1. Hofstetter, Tucker, Kemmerlin, Gray & Huff; 124.
2. Hakkila, Ostenak & Thomas, Jr.; V. III, App. L.

DESCRIPTION

On-line alpha monitors are used to monitor certain aqueous process streams in reprocessing plants to verify that excess plutonium is not discharged from columns to waste or recycle, or to determine how much is discharged. Alpha monitors measure total alpha intensity, which for reprocessing solutions arises primarily from Pu-238. Hence, isotopic composition must be known. Commercially available alpha monitors have been evaluated in actual process streams for continuous quantitative determination of plutonium in the concentration range from 0.001 to 0.1 g/l. with relative standard deviation of 12%. Interferences from beta activity up to a 10,000 beta/alpha activity ratio and from gamma radiation up to 0.5 mCi/l. are eliminated by detector design and electronic discrimination.

The cost is for a system complete with electronics.

EQUIPMENT NAME : Calorimeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Heat
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model

STATUS DETAIL

Used along with gamma measurements, calorimetry is becoming widely accepted.

USEFUL TO : Operator and Inspector

FACILITIES : Reprocessing
Fabrication

CAPITAL COST : 100,000

MAINTENANCE COST : 1,000

REPLACEMENT COST : 80,000

LIFETIME : 10 Years

SOURCE 1 : Mound

SOURCE 2 : ANL

REFERENCE 1 : Nuc. Mat.

REFERENCE 2 : 1984 ESARDA

REFERENCE DETAIL : 1. Lemming et al.; V. IX, No. 2, 109 (1980).
2. Beets et al.; 231.

DESCRIPTION

Calorimeters assay Pu in solid form (metal, oxide, scrap, etc.) by measuring the heat output. The heat output per unit mass varies with isotopic composition from 2.3 to >15 W/kg of Pu. The necessary isotopic information can be obtained most conveniently by gamma ray measurements. Calorimeters are usually tailored to sample mass, shape and wattage level. Three sizes are of primary interest: (i) a small sample calorimeter for individual pellets, small groups of pellets, or small archival samples, etc.; (ii) a calorimeter for cans or jars of material (a few hundred to a few thousand grams); and (iii) a fuel rod calorimeter, for rods one or four meters in length. Pre-equilibration and end point prediction techniques are available to shorten the time required to attain thermal equilibrium. The price of a system depends on the precision required and on whether the units are to be transportable or stationary. Calorimeters range in price from \$30,000 to \$70,000, and the price of the associated electronics is \$25,000-40,000.

Another reference is Nuc. Safe., the article on p. 158 by Roche, Perry, Jung and Haumann.

EQUIPMENT NAME : Ultrasonic Gauge
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Sound
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Conversion
 Enrichment
 Fabrication
CAPITAL COST : 2,500
SOURCE 1 : KB
REFERENCE 1 : 1980 INMM
REFERENCE DETAIL : Ricci, Fields & Rushton, 720.

DESCRIPTION

Gamma ray assay of UF₆ in cylinders requires knowledge of the cylinder wall thickness so that appropriate attenuation corrections may be made. The wall thickness may be measured using commercially available ultrasonic gauges. The principle of operation is measurement of the sound travel time through a material and analysis of echoes from the material boundaries.

Gauges of this type may be obtained from a number of other sources, in addition to the one cited.

EQUIPMENT NAME : Ultrasonic Heavy Water Analyzer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Sound
MATERIAL TYPE : Heavy Water (HW)
STATUS : Class II : Development Prototype
STATUS DETAIL

Technique has been successfully tested at SRP, IAEA and elsewhere.

USEFUL TO : Operator and Inspector
FACILITIES : HW Prod.
Reactors
CAPITAL COST : 10,000
SOURCE 1 : BNL
SOURCE 2 : Panamet.
REFERENCE 1 : 1981 INMM
REFERENCE DETAIL : M.S. Zucker; 252.

DESCRIPTION

The ultrasonic method for assaying light/heavy water mixtures is based on the essentially linear relationship between acoustic velocity in the liquid and the mole fraction of deuterium oxide. The observed behavior can be closely predicted if it is assumed that light and heavy water are completely miscible and noninteractive. As originally applied to assay of heavy water in 210 l drums, the method employed a commercial ultrasonic thickness gauge which required the operator to dial in trial values of the velocity until the "thickness" readout matched the separately measured drum diameter. This device has been superseded by a microprocessor-based portable instrument (velocimeter) which measures the velocity directly. The microprocessor is designed to contain empirical expressions for the speed of sound in normal and pure heavy water as functions of temperature, and for the deviation of the speed of sound from linear interpolation between the above two expressions as a function of mole fraction. Once temperature and drum diameter are dialed in via a numeric keypad, the velocimeter allows direct readout of the mole fraction.

This non-nuclear method has been tested over a wide range of compositions and found to yield accuracies of better than 1%.

EQUIPMENT NAME : Fresh-Fuel Bundle Counter (CANDU)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Fuel (Fresh)
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

In routine use in CANDU stations.

USEFUL TO : Inspector
FACILITIES : Reactor
CAPITAL COST : 4,300
MAINTENANCE COST : 600
REPLACEMENT COST : 2,600
LIFETIME : 5 Years
SOURCE 1 : AECL WNRE
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : IAEA-STR-90
REFERENCE DETAIL : Boase et al.; V. 1, 429.

DESCRIPTION

The fresh fuel bundle counter is designed to record forward and reverse movements of fresh fuel during on-line fueling of CANDU reactors. The instrument will monitor time and number of bundles moved, and will perform self-reliability checks and record unusual incidents. The instrument is housed in a tamper-resistant containment and has its own internal power supply. The counter uses electro-mechanical switches which are activated by the passage of a bundle. Three switches are used to detect the direction of bundle movement. Three separate digital registers record the number of bundles loaded, the number removed in the reverse direction, and the number of "unusual events". An "unusual event" is one which does not meet the timing sequence of the switches for a normal bundle-loading operation at the normal loading speed. The registers are enclosed and accessible only to an inspector, and thus the results of tampering are not visible to the operator.

The costs given are upper limits and the lifetime is a lower limit.

EQUIPMENT NAME : Spent-Fuel Bundle Counter (Sandia)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Fuel (Spent)
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Equipment has operated at the Pickering CANDU reactor station since 1976.

USEFUL TO : Inspector
FACILITIES : Reactor
CAPITAL COST : 70,000
SOURCE 1 : SNL
REFERENCE 1 : 1976 IAEA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Sinden, Hodgkinson, Campbell & Cosanke; V. 2, 279.

DESCRIPTION

This counter is capable of unattended monitoring of the passage of spent-fuel bundles. The counter uses Geiger-Mueller (G-M) tubes to detect the characteristic gamma-radiation profiles of single bundles or of bundle pairs from CANDU reactors. Digital logic circuits in the electronics system determine when bundles are present based on the pulse rate from the G-M tubes. The collimated detectors are spaced 1.5 bundle-lengths apart so that single bundles can be distinguished from bundle pairs. The logic circuits identify the direction of transfer by determining which detector senses the bundles first. The numbers of bundles, numbers of transfers, and directions of transfers are recorded by the system. All detectors, electronics, and counters are contained within tamper-indicating enclosures.

EQUIPMENT NAME : Spent-Fuel Bundle Counter (CANDU)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Fuel (Spent)
STATUS : Class IV : Production Model

STATUS DETAIL

In routine use in 600 MWe CANDU stations.

USEFUL TO : Inspector
FACILITIES : Reactor
CAPITAL COST : 30,000
MAINTENANCE COST : 1,000
REPLACEMENT COST : 30,000
LIFETIME : 15 Years
SOURCE 1 : AECL CRNL
REFERENCE 1 : Nuc. Mat.
REFERENCE 2 : AECL-6209
REFERENCE DETAIL : Zarecki et al. V. IX, No. 2, 49 (1980).

DESCRIPTION

Irradiated fuel bundles pass sequentially through the field of view of four Geiger counters for detection. A microprocessor analyzes the sequence of the Geiger counter signals and determines the number and direction of bundles transferred. The readouts include a bundle tally and a printed log of the times and dates of transfers. The electronics and readouts are housed together with the system power supply in a tamper-indicating container.

The bundle counter is basically an upgraded version of the Sandia bundle counter. The capital cost covers a complete set of redundant spare parts. It does not include costs of collimation required for proper operation of the Geiger counters.

EQUIPMENT NAME : Spent-Fuel Bundle Gamma-Ray Verifier
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Fuel (Spent)
STATUS : Class IV : Production Model
STATUS DETAIL

Equipment is in routine use at a CANDU station.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing

CAPITAL COST : 70,000
REPLACEMENT COST : 26,000
SOURCE 1 : AECL CRNL
REFERENCE 1 : Kiawah
REFERENCE 2 : IAEA-STR-90
REFERENCE DETAIL : Lipsett, Irvine & Williams.

DESCRIPTION

The transfer of bundles from interim to long-term storage at the Bruce CANDU reactors is made through an interconnecting trench under approximately 10 meters of water. Bundles (24) are loaded onto a transfer tray in two rows, two such trays are moved through the trench to constitute a transfer. Spent-fuel verification would be done at the end of the transfer trench by measuring and assessing the gamma-ray spectrum from each fuel bundle while in motion at about 1 cm/s. An 8.8 m long, air-filled, aluminum collimator with slotted lead filters allows for the spectrometry and is the equipment involved here. The spectrometry equipment is not included in the cost.

Experimental work has demonstrated the feasibility of the gamma spectrometry verification method. NaI spectrometry, in conjunction with lead filtering and properly selected instrumentation, appears to be the most suitable choice, although germanium spectrometry could also be adapted to the purpose. Radiation from the fuel can easily be detected and thus unirradiated or dummy fuel would be discovered. Characteristic signal variations due to fuel elements in the bundle as well as signal steps or depression at bundle edges can be used to separate bundles and allow them to be tallied. The best signal characteristics were associated with the isolated high-energy gamma ray from Pr-144. By combining with signals from Zr-95 and Cs-137 the equipment can be used for an approximate assay of the fuel for comparison to the irradiation records.

EQUIPMENT NAME : Minolta Surveillance Camera
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 1,000
MAINTENANCE COST : 250
LIFETIME : 3 Years
SOURCE 1 : IAEA
SOURCE 2 : Psychotron
REFERENCE 1 : SAND 80-1762
REFERENCE 2 : SAND 80-0002

DESCRIPTION

This system consists of two Minolta XL-400 Super-8 movie cameras used in a single-frame mode. The cameras are triggered by an auxiliary timer which can be set for a fixed picture-taking interval ranging from 1/2 minute to over 90 minutes. The intervals used most often are between 5 and 20 minutes between exposures. The cameras are enclosed in a tamper-safe deep-drawn container which is sealed after installation (and resealed after change of film and batteries). Two cameras are installed in each case to increase reliability. Both cameras are adjusted to view the same scene. Then, if one camera malfunctions, the other will supply surveillance data. The frame capacity is increased to 7200 frames through use of special, thin, Kodak movie film. All power is supplied from a battery pack.

The original system, using the Minolta XL-400 with the "Flash Timer," was deployed at a large number of field locations. This basic system has been replaced with the Minolta XL-401 and an improved timer. Although the system is in routine IAEA use, it cannot operate at low light levels, does not have time/date annotation, and has inadequate film capacity for some applications. These additional capabilities have been realized on a Class III basis as a result of developments in the FRG, as noted elsewhere in this CATALOG, and Japan. The capital cost applies to the present system (with two cameras in a sealed container), and the lifetime is the mean time to total system failure.

EQUIPMENT NAME : Film Camera System (CANDU)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model
STATUS DETAIL
: Routine use in 600 MWe CANDU Stations.
USEFUL TO : Inspector
FACILITIES : Reactor
CAPITAL COST : 9,000
MAINTENANCE COST : 1,350
REPLACEMENT COST : 9,000
LIFETIME : 10 Years
SOURCE 1 : Kelk
SOURCE 2 : AECL C-Ops
REFERENCE 1 : 1981 ESARDA
REFERENCE 2 : IAEA-STR-90
REFERENCE DETAIL : Zarecki, Smith & Vodrazka; 355.

DESCRIPTION

The system consists of a Minolta Super 8-mm Camera with automatic exposure control. The camera is triggered by either a motion-detection trigger or a gamma trigger in addition to fixed- and random-period timers. The system is capable of taking 7200 frame exposures without reloading. Date and time are displayed on each frame. The camera, electronics and back-up power supply, capable of providing power for 7200 frame exposures over 100 days of camera operation, are housed in a single tamper- and humidity-proof container.

EQUIPMENT NAME : KfK ELMO Camera System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class 2.1 : Field Evaluation Unit

STATUS DETAIL

Industrial production of the system has begun on a limited scale.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing

CAPITAL COST : 5,000
SOURCE 1 : KfK
REFERENCE 1 : ESARDA
REFERENCE 2 : JOPAG/04.84PRG82
REFERENCE DETAIL : C. Brueckner; No.3 (1982), 6.

DESCRIPTION

The system uses modified ELMO 612 Super-8 cameras. They are equipped with an automatic control device for aperture and exposure time up to 30 s, so that satisfactory pictures can also be obtained under poor lighting conditions. Each camera is coupled to its own auxiliary timer and battery pack. The time settings are adjustable from 1 to 29 min. The entire camera-timer system can be tested at 4 frames/minute by pushing a button. Also battery capacity and film insertion can be tested. By means of a mirror system, date and time from an auxiliary display can be superimposed onto the pictures. The display is triggered by the timer. With this system, other information can also be added to the pictures.

The frame capacity is up to 14,400 frames, using 61-mm cassettes. For the electronic clock (timer) an independent battery is used, which allows operation of the clock for 2 years at a minimum.

Each camera with timer and power supply is housed in its own tamper-safe container, which can be sealed after installation, and which is easy to decontaminate.

EQUIPMENT NAME : Surveillance TV and Recording System (STAR)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Fuel (Spent)
STATUS : Class IV : Production Model

STATUS DETAIL

Sixteen systems purchased by the IAEA for routine field use.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 65,000
LIFETIME : 10 Years
SOURCE 1 : SNL
SOURCE 2 : MRL
REFERENCE 1 : 1984 SNL

DESCRIPTION

The STAR System provides surveillance from two CCTV cameras. These cameras utilize a Charge Coupled Device (CCD) receiving element for increased service life and reliability. The video signal is transmitted via a single coaxial cable (up to 600 meters) to a recording and review console. At the console the video signal from each camera is checked for indication of tampering with the cable or the camera. The two signals are combined into a single video signal which is processed by a video motion detector. Time, date, and event information (status of tampers, motion detection, and loss of mains power) are added to the video signal which is recorded at selected intervals on one of two redundant video recorders. A variety of selectable options for special operating modes is provided. The system allows considerable operator interface through extensive use of prompting information displayed on the monitor, and simplification of hardware communications requirements.

During playback of previously recorded video information, the playback speed can be adjusted from a frame-by-frame advance to twice normal. The system can also search for any events which were indicated at the time of recording and, if any such events are found, stop the search to display the still frame at the time of event indication.

EQUIPMENT NAME : MINISTAR System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Class III systems under test and evaluation by IAEA and Euratom.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 8,000
LIFETIME : 10 Years
SOURCE 1 : SNL
REFERENCE 1 : 1984 SNL

DESCRIPTION

The Mini Surveillance Television and Recording (MINISTAR) System uses the latest solid state camera and small portable battery powered recorder technology available in late 1982.

The MINISTAR consists of: (1) a Camera Assembly containing a solid state camera, (2) a Video Recording Assembly (VRA), and (3) an accessories case containing a battery charger. All of these subsystems may be located adjacent to each other and inter-connected with short cables, or all three may be located in different facility locations.

The Camera Assembly contains a NEC-VCI-B106 mono-chrome or a Hitachi VKC-2000 color solid state camera which operates on 12 volts supplied by the VRA.

The VRA contains the Video Tape Recorder (VTR), the Control Electronics Module (CEM) for operating the MINISTAR System, and a back-up battery. The unmodified SL-2000 recorder can be operated in any of its normally designed "record" and "playback" modes. A time-date generator inside the CEM annotates the video. The battery in the VRA will supply a minimum of 3 hours of recording capability when facility power is interrupted.

The battery charger, contained in the accessories case, operates on facility power of 115 VAC or 220 VAC, at a frequency of 50 HZ or 60 HZ. Low voltage wiring is used to connect the 12 VDC battery charger output to the VRA.

EQUIPMENT NAME : Psychotronic Surveillance System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 30,000
MAINTENANCE COST : 3,000
LIFETIME : 5 Years
SOURCE 1 : Psychotron
SOURCE 2 : IAEA
REFERENCE 1 : 1980 CS
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Sonnier; 151.

DESCRIPTION

This television surveillance system consists of one or two cameras, remotely operated by a control unit with a built-in video "splitter," which divides the screen into two parts. Each camera can be located as far as 500 meters from the control unit. The camera is a Hitachi HV-16 modified to accept a standard silicon diode vidicon (RCA-4532). All the components of the control unit (video recorder, triggering device, video calendar-clock, emergency power supply, etc.) are built into a sealed housing. The Hitachi SV-612 or SV-613 time-lapse video recorder has been modified for this system. It can record 36,000 groups of five single-frame pictures (minimum exposure limit) on a standard 720-meter magnetic tape. The built-in clock superimposes on each picture the date and time when it was taken.

The system operates on line current. Rechargeable batteries built into the control unit automatically power the system for several hours in the event of line-power failure. Performance has not been as high as desired, and improvements are in prospect. The key lifetime limitation is the wearing out of the electro-mechanical video recorder.

EQUIPMENT NAME : Closed-Circuit Television System (CANDU)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model

STATUS DETAIL

Routine use in 600 MWe CANDU Stations.
USEFUL TO : Inspector
FACILITIES : Reactor
CAPITAL COST : 230,000
MAINTENANCE COST : 40,000
REPLACEMENT COST : 230,000
LIFETIME : 10 Years
SOURCE 1 : AECL C-Ops
REFERENCE 1 : 1981 ESARDA
REFERENCE 2 : IAEA-STR-90
REFERENCE DETAIL : Zarecki, Smith & Vodrazka, 355.

DESCRIPTION

The system is designed for surveillance in the reactor vaults, fuelling-machine rooms, and the storage bay of CANDU reactors. It is comprised of four RCA and four Edo Western video cameras; three digital motion-detection systems, two with masking capabilities; two floppy-disc video recorders; six video cassette recorders; two microprocessor control systems; and one tape printer. It is capable of recording 100,000 frames to full capacity. Each video frame records the day, month, year, and time as well as the originating camera's number.

Reliability is achieved by component redundancy and by using a micro-computer to monitor each function or subsystem. If a failure is detected, a back-up component is switched on-line or the function is bypassed. Radiation resistance is achieved by using radiation-resistant cameras (withstanding up to 1000 rads/day) containing a minimum number of electronic components. Whenever possible, electronics and control functions are removed from the camera and placed in the central control unit.

Development has begun on a modification to further improve reliability and at the same time reduce the replacement cost.

EQUIPMENT NAME : Spent-Fuel-Bundle Cerenkov Verifier (CANDU)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Fuel (Spent)
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

System is currently undergoing tests.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
CAPITAL COST : 30,000
MAINTENANCE COST : 1,500
REPLACEMENT COST : 30,000
SOURCE 1 : AECL WNRE
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : IAEA-STR-90
REFERENCE DETAIL : Boase et al., V. I, 431.

DESCRIPTION

Development work has been completed on a verifier for viewing Cerenkov light emanating from spent fuel. The verifier combines a commercial ultra-violet-sensitive night viewing device with a filter and a quartz or a mirror lens. When used in conjunction with polycarbonate filters over the room lights, the system can be used to view the ultra-violet end of the Cerenkov spectrum under ambient room lighting conditions. A camera may be attached to the verifier to photograph the spent fuel for record purposes.

The costs stated are upper limits.

EQUIPMENT NAME : Improved Cerenkov Viewing (Night-Vision) Device
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Fuel (Spent)
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Improved unit is in limited use at IAEA.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing

CAPITAL COST : 15,000

SOURCE 1 : Varo

REFERENCE 1 : 1980 ESARDA

REFERENCE 2 : 1984 ESARDA

REFERENCE DETAIL : 1. Dowdy, Nicholson & Caldwell; 353.
2. Same; 145.

DESCRIPTION

The original night-vision device can be used to obtain qualitative information from the Cerenkov glow from spent fuel assemblies. It intensifies the light image thousands of times to make it visible long after the radioactive decay has made the glow invisible to the naked eye. Such information as the uniformity of the glow, the spatial distribution, the overall intensity and the general appearance of the assemblies can be useful in establishing their authenticity. The method is rapid, and the instrument is lightweight and easy to use.

The night-vision device has been combined with a photometric unit that mounts on top of the Varo unit; special optics have been placed between the objective lens and the image intensifier. Special apertures have been provided that allow selected fields of view to be measured by the photometer. This combined instrument called the improved Cerenkov viewing device (ICVD) gives quantitative light intensity measurements even after very long cooling periods, with good reproducibility.

EQUIPMENT NAME : Fuel Verification Periscope
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Fuel (General)
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for limited in-field use by IAEA.

USEFUL TO : Inspector
FACILITIES : Fuel Storage
Reactor
Reprocessing
CAPITAL COST : 17,000
SOURCE 1 : ITI
REFERENCE 1 : POTAS
REFERENCE DETAIL : Task E.35; 157.

DESCRIPTION

This periscope provides a means for inspectors to read the serial numbers of fuel assemblies in storage ponds. The periscope consists of two components. The first is a basic 2.5 m long optical telescope designed to penetrate a water surface and having both a two- and ten-power magnification and a special swivel mount. The second component is a set of optical extenders to be used if water turbidity requires closer viewing. The two parts each have special carrying containers and weigh 24 kg and 80 kg, respectively, when packed.

The above cost applies to the model currently available; modifications planned for future models are likely to decrease the cost.

EQUIPMENT NAME : Portal Radiation Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 23,000
SOURCE 1 : TSA
SOURCE 2 : NNC
REFERENCE 1 : LA-7646
REFERENCE 2 : LA-5681

DESCRIPTION

These portal monitors are sensitive to gram quantities of U-235 and Pu-239 and to 1 microcurie amounts of Ra-133, Cs-137, and Co-60. Capable of checking about fifty persons per minute, the units employ plastic scintillators for gamma-ray radiation detection, constantly monitor background radiation, and monitor occupancy by infrared or microwave sensors. Operation is automatic and the alarm level is adjustable.

The capital cost given is for one shielded portal monitor and a single-detector control unit.

Similar monitors are available from IRT and Jomar Systems and also from various foreign sources (for example BEFIC in France, AERE Harwell in England, and Herfurth GmbH in Germany).

EQUIPMENT NAME : Safeguards Doorway Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 60,000
SOURCE 1 : UKAEA
REFERENCE 1 : 1984 ESARDA
REFERENCE DETAIL : Riley & Williams; 125.

DESCRIPTION

This is a neutron-sensitive doorway for unattended operation, which incorporates a swinging door mechanism to increase transit time and give good detection geometry. The doorway incorporates neutron detectors with associated electronics, a microprocessor-controlled counting and statistical analysis system, and data storage, all within the tamper-resistant doorway enclosure. Stored data can be read out by the inspector. Also included is a camera system to photograph unusual events. The cost given above is an estimate based on the present stage of development.

EQUIPMENT NAME : Vehicle Portal Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class IV : Production Model

STATUS DETAIL

Field evaluation completed.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 40,000
SOURCE 1 : TSA
SOURCE 2 : Jomar
REFERENCE 1 : 1983 INMM
REFERENCE DETAIL : Fehlau; 294.

DESCRIPTION

This gateside monitor utilizes plastic scintillators. It has four 7 cm by 91 cm organic scintillators, with two on each side of the vehicle. These gateside monitors are used to carry out measurements on vehicles approaching an exit gate. The separation between detectors is 4 m.

Monitoring takes place when outgoing traffic is sensed approaching an exit gate. Ideally, the vehicle halts and then proceeds through the portal at a speed of 8 km/h or less. A unique signal denotes monitoring in progress, and this changes to visual and audible indication when SNM is detected. Sensitivity levels of approximately 1 gram of plutonium can be obtained in passenger cars or pick-up trucks. The monitor detector columns are tall enough to monitor tractor-semitrailer rigs, although the sensitivity is reduced to about 10 g plutonium for thick-walled trailers.

The cost quoted above is an average; currently available estimates are in the \$35,000-42,000 range.

EQUIPMENT NAME : Vehicle Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

In routine use at LANL.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 120,000
SOURCE 1 : LANL
REFERENCE 1 : 1984 INMM
REFERENCE DETAIL : Fehlau, Coop, Garcia & Martinez 66.

DESCRIPTION

The motive in constructing this monitor was to minimize the separation between the detectors and the vehicle without obstructing traffic. The monitor utilizes a pit to house its underground array of seven plastic scintillation detectors that are optimized for the detection of shielded plutonium. Aluminum diamond plate and grating are used for vehicle support to minimize absorption of gamma radiation, and moisture problems are minimized through a gravity drain in the pit and waterproof encapsulation of the detectors. An overhead array of four plastic scintillation detectors is supported on a canopy. A microprocessor control module applies a sequential hypothesis testing procedure to minimize the monitoring time. Nuclear material is detected by sensing intrinsic gamma radiation while the vehicle is parked in the monitor.

EQUIPMENT NAME : (Yes/No) Electronic Dosimeter
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 300
SOURCE 1 : XETEX
SOURCE 2 : RMD
REFERENCE 1 : IEEE TNS
REFERENCE 2 : LA-8584-MS
REFERENCE DETAIL : Wolf, Umbarger & Entine; V. NS-26, N. 1, 777 (1979).

DESCRIPTION

Electronic dosimeters have the desirable attribute of being unaffected by most environmental hazards, relatively inexpensive, quickly and easily read (readings may be obtained at any time and may be followed by resetting or not), designed with memory survival on battery failure, and can, in principle, be made to detect the emplacement of shielding material. The most desirable features of electronic dosimeters for yes/no monitor application are low-power detector voltage supply and low-power liquid crystal display, or separate reader to further reduce power. The choice of detector can be made to meet space and power requirements; the inherent radiation detection properties can be made similar for CdTe and GM counters. The battery lifetime requirements for use of electronic dosimeters with yearly interrogation can be met using lithium batteries.

The sources mentioned above are actively engaged in the development of these devices, and readers are referred to their technical reports and catalogs. Recent developments and future plans should make it possible to sense and display both total dose and dose rate in one small package. The dose-rate feature could be used to detect shielding of the monitor during an attempted SNM diversion.

EQUIPMENT NAME : (Yes/No) Radio-Luminescent Dosimeter
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Fuel (Spent)
STATUS : Class IV : Production Model

STATUS DETAIL

In use at CANDU stations; also designated for routine IAEA use.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing

CAPITAL COST : 2,000
REPLACEMENT COST : 1,000
SOURCE 1 : Toshiba
REFERENCE 1 : IAEA-174
REFERENCE 2 : IAEA-STR-83
REFERENCE DETAIL : Part E, 274.

DESCRIPTION

This monitor is a glass dosimeter which functions by a technique called radio-photo-luminescence of fluoro-glass. If these dosimeters have been exposed to gamma radiation (from spent fuel), the glass will fluoresce when stimulated with ultraviolet light. The intensity of the fluorescence is proportional to the absorbed dose. The intensity is compared to a set of reference glasses with known exposures to obtain an estimate of the dose.

The dosimeters are installed at ports, holes, and other locations where fuel elements can be removed but normally are not. The dosimeters are placed so that they cannot be shielded, and they are installed inside or in conjunction with seals to prevent tampering. They are periodically removed and replaced with fresh dosimeters. The exposures are measured to detect (qualitatively only) whether or not spent fuel has passed the location.

The cost of these dosimeters reflects their use as described in Reference 2. The general description is taken from SAND 80-0002.

EQUIPMENT NAME : Thermoluminescent Dosimeter (TLD)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Fuel (Spent)
STATUS : Class IV : Production Model

STATUS DETAIL

Designated for routine IAEA use; also used in Japanese nuclear industry.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 10,000
MAINTENANCE COST : 100
SOURCE 1 : Harshaw
SOURCE 2 : Victoreen
REFERENCE 1 : Nuc. Tech.
REFERENCE 2 : LA-8584-MS
REFERENCE DETAIL : Ohno & Matsuura; V. 47, 485 (1980).

DESCRIPTION

Thermoluminescent dosimeters (TLDs) possess many interesting properties for application to measurements of gamma dose rates from reactor spent fuel and their distributions. They have a very large dynamic range, are physically small, and are readable over an integrated dose rate extending from 10 mR to 100,000 R. Exposure times can be made as short as 1 min., and the light output is approximately linear over very broad ranges of integrated dose rates. In addition, TLDs are available commercially with normal Li, Li-6 and Li-7. This offers the possibility of separating the contributions from neutrons and gamma rays. Readers for heavily dosed TLDs can be simple and inexpensive because little more than a heater and a photodiode are required. The use of TLDs could cause some operational problems because some type of closed underwater positioning system would be required to send the TLD packet down to the spent fuel and retrieve it for readout. TLDs can be recycled almost indefinitely, thus limiting the inventory required. Because the apparatus needed for a pond fuel-assembly inventory could be cumbersome and would become contaminated, it should be installed permanently in each facility.

The capital cost shown above is the approximate price of the basic system, which is the one most useful for safeguards applications. The maintenance cost covers enough LiF powder for one charge each of 100 dosimeters. For further details the reader is referred to the manufacturers' literature.

EQUIPMENT NAME : Hand-Held Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class IV : Production Model

STATUS DETAIL

In routine use at DOE facilities.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 1,995
SOURCE 1 : NNC
SOURCE 2 : CMS
REFERENCE 1 : LA-6359
REFERENCE 2 : LA-7646

DESCRIPTION

The hand-held monitor is used to search vehicles, packages, and personnel for nuclear material by measuring increases in gamma radiation over the background rate. The original unit, called a personnel-vehicle monitor (PVM), uses sodium iodide scintillation detectors and calculates an alarm level equal to the mean gamma-radiation background count within a set time interval (usually 0.3 sec) plus a selectable fraction of the background (commonly selected as 40% of the background to reduce false alarms to 2%). When the alarm level is exceeded, the unit emits tones to signal detection of nuclear material. Another unit is also in use, called a delta rate monitor (DRM), which adds a selectable number of counts to the background-count level to establish an alarm level. The DRM is designed to operate more effectively in a higher gamma-radiation background than the PVM. The newest unit, the HHD-440 applies a plastic scintillation detector and a moving average detection method.

The hand-held monitor is designed to detect small amounts of nuclear material with much higher probability than conventional hand-held monitors with audible monitoring of individual counts. It is designed for field use in low traffic areas to perform the same functions as vehicle or personnel portal monitors at a much lower cost.

EQUIPMENT NAME : Shelf Monitor System (II)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class II : Development Prototype

STATUS DETAIL

Present field evaluation unit designed to monitor a total of 2000 items.

USEFUL TO : Operator and Inspector
FACILITIES : Fuel Storage
CAPITAL COST : 40,000
LIFETIME : 10 Years
SOURCE 1 : SNL
REFERENCE 1 : 1982 INMM
REFERENCE DETAIL : H.D. Arlowe: 82.

DESCRIPTION

This shelf-monitoring system has been developed for use in an operational storage facility to satisfy inventory and safety requirements remotely. The system monitors the presence of every container many times each second. In addition, complete inventories can be taken on demand or at periodic intervals at the rate of about 600 containers per minute. The inventory system monitors container and ambient temperatures, providing a data base for calculating container heat flow (thereby inferring SNM heat production), as well as detecting temperature anomalies. A capacitively-read label has been applied to the bottom of each SNM container. A 20-bit binary serial number is read and stored by shelf location in the memory of the system controller. A shelf monitor unit is placed under each SNM container to collect these data, which are serially transmitted by cabling to the system processor.

The system is expected to cost \$40,000 for the processor and \$60 for each shelf position.

EQUIPMENT NAME : Label (Adhesive) Seal
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
MAINTENANCE COST : 1
SOURCE 1 : Advertape
SOURCE 2 : Designer
REFERENCE 1 : SAND 80-0002
REFERENCE 2 : SAND 78-0400

DESCRIPTION

The label seal is constructed of vinyl or paper with pressure-sensitive adhesive backing. It is slitted to prevent easy removal without tearing. Attempts to remove the seal by means of solvents will cause the ink used for background printing to run or will cause the label material to disintegrate. The seal may also be used to list data of interest to the inspector.

Label seals can be procured with printed or perforated serial numbers. They are employed where containment can be achieved by sticking the seal over two or more adjacent surfaces. The seals are inexpensive and easy to apply. However, there is no assurance that a seal has not been removed and replaced by one with similar markings. While the signature of the inspector can be written on each seal as an identification, it is possible to print similar seals, forge the signatures, and replace the seals between inspections. Label seals can provide effective short-term verification of containment but are inadequate for applications where they cannot be frequently checked by an inspector.

The above cost represents the purchase price of the seal.

EQUIPMENT NAME : Cup-and-Wire Seal (Type E)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class IV : Production Model

STATUS DETAIL

In routine use by the IAEA.

USEFUL TO : Inspector
FACILITIES : All
MAINTENANCE COST : 1
SOURCE 1 : Am. Cast.
REFERENCE 1 : SAND 78-0400
REFERENCE 2 : SAND 80-0002

DESCRIPTION

The seal consists of two cup-shaped pieces stamped and formed from brass sheeting. A wire is threaded through holes in the container and through holes in one piece of the seal. The two wire ends are tied and the two pieces snapped together to enclose the knot. Reliability depends on how difficult it would be to penetrate the container, to cut and repair the wire, or to separate and resnap the two cup-shaped pieces without leaving evidence of tampering. The seals are numbered serially for identity. To prevent substitution, a unique, random pattern is applied to the inside of one or both cups and photographed at IAEA headquarters. It is necessary to remove a seal and return it to an IAEA office in order to compare the random pattern with the original photograph.

The cups have been manufactured for many years for less demanding applications. The IAEA has developed and improved the procedures for unique marking and verification. The above cost represents the price of the seal itself.

EQUIPMENT NAME : Metallic Seals
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class IV : Production Model
STATUS DETAIL

Double Cap Seal in widespread use by IAEA; Type X in limited use.

USEFUL TO : Inspector
FACILITIES : All
MAINTENANCE COST : 5
SOURCE 1 : SNL
REFERENCE 1 : 1984 SNL
REFERENCE 2 : SAND 80-2699

DESCRIPTION

In the early 1960's, the IAEA began wide scale use of the commercially available Type E cup-and-wire seal. As experience was gained in using this seal, the IAEA indicated the desire for a metallic seal with improved tamper and corrosion resistance. This desire was fulfilled with the Double Cap Type E and the Type X metallic seals.

The Double Cap seal consists of a standard 1.9 cm diameter Type E seal to which is added a larger 2.5 cm diameter copper cup seal top. A circular portion is removed from the Type E seal top, and this top is soldered to the inside of the larger cup seal top. The resultant combined top, the Double Cap, is then used in the same manner as the standard Type E seal top. Application of this top provides a protective metallic shield around the outer circumference of the Type E seal bottom.

The Type X seal is made of hardened stainless steel. The seal plug (top portion) contains spring fingers which lock into a groove when inserted into the body (bottom portion). The body contains two stainless steel spring washers which capture the spring fingers and prevent unlatching.

The above cost represents the approximate price of the seals themselves.

EQUIPMENT NAME : Optical Cap Seal
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Fuel (Spent)
STATUS : Class II : Development Prototype
STATUS DETAIL

Undergoing tests at Chalk River Nuclear Laboratories.

USEFUL TO : Inspector
FACILITIES : Spent Fuel
Storage
CAPITAL COST : 400
SOURCE 1 : AECL CRNL
REFERENCE 1 : 1982 IAEA
REFERENCE 2 : CRNL-2668
REFERENCE DETAIL : Stirling et al.; V. I, 365.

DESCRIPTION

A removable, optically verifiable safeguards seal for CANDU spent fuel storage has been developed based on the use of unique crystal patterns in pure zirconium as an identity/integrity element. The seal has been designed to be easily installed and removed using simple tooling.

Since the seal is optically verified, a wide range of commercially available equipment and procedures can be used, including those already in use by the IAEA. Furthermore, the use of optical verification allows the level of scrutiny to be adjusted to match the degree of confidence required to be certain that diversion of spent fuel has not occurred.

EQUIPMENT NAME : Ultrasonic Cap Seal (ARC-SPAR)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Fuel (Spent)
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Currently undergoing tests.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage

CAPITAL COST : 12,500

MAINTENANCE COST : 1,200

SOURCE 1 : AECL CRNL

SOURCE 2 : SNL

REFERENCE 1 : 1982 IAEA

REFERENCE 2 : Nuc. Mat.

REFERENCE DETAIL : 1. Backer, Smith & Allen; V. I, 438.
2. Zarecki et al.; V. IX, No. 2 49 (1980).

DESCRIPTION

Spent CANDU fuel bundles are placed in interlocking trays in the storage bays. After some cooling time the trays are stacked one on top of another. The sides of the trays form a tamper-indicating enclosure. A tamper-indicating cover is placed on the top tray. Two tie-rods of special design are passed through the stack; an ultrasonic AECL Random Coil (ARC) seal is attached to the top of each rod and secures the top cover.

The seal contains a random coil of stainless steel wire from which a unique acoustic signature can be acquired. The signature can be recorded upon installation of the seal and can be rechecked later to verify the identity and integrity of the seal. The signature is acquired by means of an ultrasonic transducer carried by a tool which is placed on the seal. An electronic seal pattern reader (SPAR) processes and records the signature in digital form.

The seal design is based on work originally carried out at Ispra (1978 IAEA; V. 1, 561). AECL modified the integrity/identity element design for practical application. The electronic read-out unit was developed by Sandia National Laboratories. With minor differences it is also used for the ultrasonic fuel assembly identification device (FAID). The capital and maintenance costs given above are for one read-out unit; each seal costs \$450.

EQUIPMENT NAME : Photogr. In Situ Verifiable (PIV) Seal System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Under field evaluation by IAEA and JRC/Ispra.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 10,000
MAINTENANCE COST : 10
SOURCE 1 : SNL
REFERENCE 1 : 1984 SNL
REFERENCE 2 : SAND 84-0458

DESCRIPTION

The in situ verifiable fiber optic seal system (previously known as COBRA) consists of fiber optic loop material, seal bodies, a seal signature recorder/verifier and a special shipping case. The seal uses a jacketed, multi-strand plastic fiber optic cable which is cut to the required length in the field. The cable ends are inserted into a one-piece seal body. The seal body contains a serrated blade which, when pressed in place, severs a portion of the cable fibers in a random manner. A unique signature, produced by the uncut fibers, is viewed and photographed by the seal signature recorder/verifier at the loop termination. The blade is designed to cut additional fibers and change the signature if it is displaced from its initial position in order to release the fiber optic loop. An optional blade lock pin is available to provide increased resistance against blade removal. The recorder/verifier camera is designed to operate automatically when the seal is inserted into a viewer receptacle. In situ verification is accomplished by comparing a Polaroid photograph obtained during the inspection visit with the photograph obtained when the seal was initially installed. Recording and verifying the seal are manageable under awkward conditions by transferring the seal image to the camera system in the recorder/verifier via a flexible, one-meter long fiber optic image guide.

EQUIPMENT NAME : VACOSS-3 Electronic Sealing System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 1,800
REPLACEMENT COST : 1,800
LIFETIME : 5 Years
SOURCE 1 : ProCom
SOURCE 2 : KFA
REFERENCE 1 : 1981 INMM
REFERENCE 2 : 1984 ESARDA
REFERENCE DETAIL : 1. Arning, Reuters & Bueker; 360.
2. Richter et al.; 131.

DESCRIPTION

A new electronic seal system, VACOSS-3, developed by ProCom GmbH (Aachen) and the Nuclear Research Center Juelich within the framework of an IAEA research contract, allows simple installation, verification and the possibility of remote verification, and provides high tamper resistance. Moreover, the system is able to store data from several seals and the seals can be used as often as desired. The system consists of three microcomputer-based components, the seal unit with a fiber-optic light guide and two types of adapter boxes. The seal stores up to ten opening and closing events, the present status of the fiber-optic light guide, and the status of battery and seal housing. Seal data are encrypted for tamper-safed data transmission. With adapter box I the seal can be initialized and data read out and decrypted; it will be used by the inspector. With adapter box II only encrypted seal data can be read out; it is designed for remote verification with the operator's aid and transmission via telephone.

The main functions of the system are to: detect opening and closing operations of its light-guide circuit; store these events along with their opening and closing times; report and react to manipulation attempts at the seal; and communicate with the adapter boxes. The adapter-box programs are used by the operator in interactive fashion.

The above costs are for the adapter boxes; each seal costs \$1,700.

EQUIPMENT NAME : Shrink-Tubing Seal
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Under field evaluation by the IAEA.

USEFUL TO : Inspector
FACILITIES : Enrichment
MAINTENANCE COST : 3
SOURCE 1 : BNL
SOURCE 2 : SNL
REFERENCE 1 : 1984 SNL
REFERENCE 2 : ISPO-98

DESCRIPTION

The shrink-tubing seal is used to prevent unauthorized removal of UF6 through cylinder valves.

One clear shrink-tube with a triangular dot pattern and a second clear shrink-tube marked with a square numbered matrix are used to enclose the valve of a UF6 storage cylinder. Due to the random nature of shrinking when heat is applied, the two separately shrunk tubes will form a unique random dot/matrix signature. Such patterns at two or more random locations are recorded for later verification. 0

An offset split washer, bonded to the valve coupling nut with a rapid cure adhesive, will fix the two sleeves to the cylinder and provide a means to damage the sleeving if access is attempted by tampering with the valve. An alternate tamper-indicating method places a tip indicator under the tubing prior to shrinking.

Comparison of the sketch or photo of the patterns made at the time of installation and at the time of verification will indicate any removal or attempted replacement of the seal. Cuts on the sleeving will be noticeable by visual inspection. Attempts to unscrew the valve with the shrink-tubing installed will cause the split washers to cut the tubing, or the tip indicator will show that the valve was turned.

The above cost represents the approximate price of the seal.

EQUIPMENT NAME : Integrated Monitoring System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : In-Plant Monitor
MATERIAL TYPE : Miscellaneous
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Under long-term field evaluation by SNL.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 20,000
SOURCE 1 : SNL
REFERENCE 1 : 1984 SNL

DESCRIPTION

The Integrated Monitoring System (IMS) consists of three basic elements: (1) Intrusion Monitors, (2) a Data Collection Module (DCM), and (3) an Inspector Display Module (IDM). Detection and state-of-health data from the intrusion monitors are provided to the DCM, where they are time-annotated and stored. Using the IDM, the inspector requests the DCM data, which are provided on a printer in the IDM. The IMS has been designed to monitor areas which contain nuclear material or other items of safeguards interest and have been declared to be inactive. The DCM can also be used to collect information from a variety of other types of monitors, and is configured to provide, where necessary, a trigger signal to optical surveillance equipment. Such a trigger can be used to provide multiple scenes of the safeguards-related event occurring in the area of interest.

EQUIPMENT NAME : Laser Spent-Fuel Cover
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : In-Plant Monitor
MATERIAL TYPE : Fuel (Spent)
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Extensive tests of prototype and full unit at Ispra fuel pool are imminent.

USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing

CAPITAL COST : 15,000

SOURCE 1 : BNL

SOURCE 2 : SNL

REFERENCE 1 : 1980 INMM

REFERENCE 2 : 1980 CS

REFERENCE DETAIL : 1. Fiarman, Bieber & Zucker; 201.
2. Fiarman & Davis; 162.

DESCRIPTION

The system involves laser beams sweeping through the spent fuel storage pool. The laser spent-fuel cover (LSFC) system provides the inspector with a listing of those pool locations where assembly movement has taken place and the time of each movement.

The list of fuel movements generated by the LSFC system can be compared with the corresponding individual TV or movie-camera frames, with radiation or acoustic monitors, and with facility records. The LSFC system information can be used to examine those assemblies that have been moved, using various fuel-assembly scanning devices now under development, ignoring the majority which have not been moved.

The detection system surveys the region of the pool above the storage racks and below the surface of the pool and effectively keeps watch on the part of space through which any fuel movement must occur. Moreover, this region between the surface of the pool and the tops of the storage racks, particularly nearer to the latter, is relatively free of activity extraneous to the actual movement of fuel. Therefore a surveillance scheme confined to this layer is not only focused on the most appropriate region but is also free of distraction by events other than those of concern to the inspector. A prototype has been successfully demonstrated at the Atominstitut, Vienna.

EQUIPMENT NAME : Bar Coding
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Identification
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model

STATUS DETAIL

Equipment commercially available and in safeguards use.

USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 3,700
LIFETIME : 25 Years
SOURCE 1 : Intermec
SOURCE 2 : HP
REFERENCE 1 : 1983 INMM
REFERENCE 2 : Kiawah
REFERENCE DETAIL : 1. Keswani & Bieber; 263.
2. Brodda; 55. Marsden; 221.

DESCRIPTION

Bar codes are a family of information-encoding systems in the form of alternating black bars and white spaces such as appear on products in super-markets. A printer for \$2000, and a portable reader with memory for \$1700 constitute a basic system.

An operator could use bar codes for rapid inventory control, while an inspectorate could employ bar codes on Label Seals for seal identification.

A related technique is optical scanning of ordinary characters instead of bar codes.

EQUIPMENT NAME : Seal Pattern Reader (SPAR)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Identification
MATERIAL TYPE : Containments
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Under long term evaluation by IAEA.

USEFUL TO : Inspector
FACILITIES : CANDU
LWR

CAPITAL COST : 12,000

SOURCE 1 : SNL

REFERENCE 1 : Nuc. Mat.

REFERENCE 2 : 1984 SNL

REFERENCE DETAIL : Allen & McKenzie; V. XII, No. 2, 54 (1983).

DESCRIPTION

The SPAR is designed to read, store, and compare the identity/integrity signatures of ultrasonic seals and, on command, to output data. Current applications are the reading of AECL Random Coil (ARC) seals, and the BWR FAIDs. Future applications include seals being developed at JRC, Ispra and BNFL, Risley.

The SPAR is a microprocessor-based system. It uses a 0.25 mega-bit bubble memory cassette for the storage of the facility name and, for example for the ARC/SPAR System, serial numbers and identity patterns for up to 50 seals. The SPAR requires separate bubble memory cassettes for each facility. It operates interactively, printing the prompting menus on a five-inch printer. The inspector is thus guided through the entire seal reading and verification process.

The software for reading ARCs can be configured for either the inspector or the laboratory. The laboratory configuration has a few additional features not accessible in the inspector version.

The inspector SPAR requires a bubble memory cassette with the facility name. Calibration data for the facility may be added to this cassette. After seal installation, the seal serial number is input and the SPAR interrogates the seal identity, showing these data in the bubble cassette. Subsequent readings provide a correlation coefficient between read and stored signatures.

EQUIPMENT NAME : BWR Fuel Assembly Ident. Device (FAID/SPAR)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Identification
MATERIAL TYPE : Fuel (General)
STATUS : Class III : Field Evaluation Unit

STATUS DETAIL

Under field evaluation at the FRG Kahl reactor.

USEFUL TO : Inspector
FACILITIES : BWR
Fuel Fab.
Reprocessing

CAPITAL COST : 12,000

MAINTENANCE COST : 100

LIFETIME : Years

SOURCE 1 : SNL

REFERENCE 1 : 1984 ESARDA

REFERENCE 2 : 1984 SNL

REFERENCE DETAIL : Brueckner et al.; 99.

DESCRIPTION

The BWR Fuel Assembly Identification Device/Seal Pattern Reader (FAID/SPAR) System is designed to uniquely identify fuel assemblies during the entire fuel cycle. It also detects viable access routes to the fuel.

The system has been demonstrated on an Exxon Nuclear fuel assembly. The upper tie-plate is removed by depressing it and turning 8 locking elliptical cylinders through 90 degrees; the fuel pins may now be withdrawn. The installation of a FAID requires replacement of the normal tie rod nut by a special tie-rod nut with a locking collet. This is the only change required in the fuel assembly. A fracture link is welded into the body of the FAID. When the FAID is installed on the assembly, the lower part of the fracture link irreversibly engages in the locking collet of the tie-rod nut. Removal of the FAID to gain access to the elliptical locking cylinder breaks the fracture link. Part of the FAID protrudes into the upper tie-plate and this prevents removal of the FAID by unscrewing the tie-rod nut together with the FAID.

The FAID is interrogated ultrasonically by three 10 MHZ transducers. Outputs of these transducers are fed to the SPAR, where identity signatures are compared and correlation coefficients calculated. Two transducers are for identity measurements and the third checks the integrity of the fracture link.

The capital and maintenance costs represent the price of the reader and seal, respectively.

EQUIPMENT NAME : Fuel-Assembly Ident. System (Magnetic-Inclusion)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Identification
MATERIAL TYPE : Fuel (Fresh)
STATUS : Class I : Laboratory Device
STATUS DETAIL
See description. If tests are successful, spent fuel will be investigated.
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reactor
Reprocessing
Fuel Storage
CAPITAL COST : 20,000
SOURCE 1 : BNL
SOURCE 2 : GE Wilming
REFERENCE 1 : 1980 CS
REFERENCE DETAIL : Fiarman & Moodenbaugh; 104.

DESCRIPTION

A small percentage of uranium dioxide LWR fuel pellets from at least one major manufacturer contains iron inclusions of the order of 100 ppm relative to the weight of a pellet, i.e. 1 mg. These inclusion-loaded pellets are randomly situated in a finished assembly and are detectable by simple coil pickup systems through which the fresh fuel is passed. Small coil systems looking at rods and at 3 x 3 mockup assemblies have demonstrated the ease of identification of these pellets. In an assembly, the random size and location of these pellets constitute a unique signature which is integral to the fuel and involves no changes to the assembly manufacturing process.

A full-sized coil system is being built at the Atominstitut, Vienna, Austria and will be tested on fresh BWR assemblies at the Zwentendorf Reactor.

EQUIPMENT NAME : LOVER (Local Verification System)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Communication
MATERIAL TYPE : Miscellaneous
STATUS : Class I : Laboratory Device
STATUS DETAIL

A demonstration system is operating at KFA Juelich.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 120,000
MAINTENANCE COST : 5,000
REPLACEMENT COST : 60,000
LIFETIME : 15 Years
SOURCE 1 : KFA
REFERENCE 1 : 1982 INMM
REFERENCE 2 : 1984 INMM
REFERENCE DETAIL : 1. Bueker, Arning, Reuters; 156.
2. Lauppe, Richter, Stein; 73.

DESCRIPTION

The LOVER system is designed to monitor remotely the status of containment and surveillance sensors. In the basic concept the system is structured into three hierarchy levels, the sensor level, the decentralized data collection and storage level, and the central monitoring level. Safeguards-relevant data as well as status data of the sensors and the equipment itself can be transmitted in both directions. The components in the three levels can operate independently in the sense that no information loss occurs in the event of a transmission line interruption or an equipment failure in any one hierarchy level. The system is intended to be used, for example, in a nuclear installation, with a data collection station for several sensor units in each building and one central monitoring unit collecting the data from different data collection stations. The system can easily be extended in both directions, i.e. the number of units in each level may be increased as well as the number of levels, allowing several central monitoring units to be controlled from a regional safeguards office. The sensor level and the data collection and storage level are connected by a party line, and the data transmission between the data collection units and the central monitoring unit is established by telephone lines.

Demonstration and testing of the system is further reported in Ref. 2 above.

EQUIPMENT NAME : Plutonium Product-Area Monitor
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Communication
MATERIAL TYPE : Miscellaneous
STATUS : Class III : Field Evaluation Unit
STATUS DETAIL

Further developments sponsored under U.S. and Japanese support programs.

USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 100,000
SOURCE 1 : WINCO
REFERENCE 1 : IASTEX
REFERENCE 2 : 1979 INMM
REFERENCE DETAIL : 1. Task I; 147.
2. Harris & Wagner; 666.

DESCRIPTION

This is a computerized system in which sensor signals from the product area of a reprocessing plant are continually monitored by a HP9845T computer. In turn, this provides real-time displays and printouts and maintains historical data files. This system thus monitors the current status of the product area and provides summaries, listings, and plots of the data. Signals in the system, as installed at the Power Reactor and Nuclear Fuel Development Corporation (PNF) plant (Tokai-mura, Japan) include high-precision pneumatic bubbler-probe signals, plant precision level and density signals, thermocouple signals, load-cell signals, valve status signals, and assorted signals from pumps and other monitors. There are approximately 200 sensors. The computer is equipped with flexible disc drives and other accessories, such as interface equipment, multiplexers, etc. Further development effort is currently underway, designed to improve hardware reliability, so that data required by the IAEA can be selected by the on-line computer and stored on magnetic media. These stored data can then be used by IAEA inspectors on their off-line computer. The capital cost shown is an estimate for the computer and interfacing equipment only and does not include the sensors as these are usually installed in a plant of this type already.

EQUIPMENT NAME : Resin Bead Sampling
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Transportation
MATERIAL TYPE : Laboratory Samples
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 100
SOURCE 1 : BioRad
SOURCE 2 : ORNL+
REFERENCE 1 : ANCHAM
REFERENCE DETAIL : Smith, Walker & Carter; V. 54 (1982), 827A.

DESCRIPTION

Subject to proper chemical treatment, U and Pu can be separated from solutions containing fission products and higher actinides (such as reprocessing plant input solutions) by absorption on anion resin beads. An aliquot of sample solution is shaken with about 1000 beads for a few minutes, and the beads are transferred to a small (0.7 x 4.0 cm) plastic column. The beads are now ready for mounting on the filament of a mass spectrometer equipped with a pulse counting detection system. While this micro-technique is an important advance in isotopic or element (by adding appropriate spikes to the sample solution) analysis of spent fuel, its special value for safeguards lies in the transportation area. The beads are free of fission product activity and each bead contains only nanograms of U and Pu. The small columns can thus, in principle, be shipped safely and conveniently between facilities and laboratories, or between different laboratories for intercomparison. Air transportation of resin bead samples has been accomplished successfully, and the IAEA is exploring the institutional aspects of routine international air shipments.

EQUIPMENT NAME : Pu Air-Transportable Model 2 Package (PAT-2)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Transportation
MATERIAL TYPE : Laboratory Samples
STATUS : Class IV : Production Model

STATUS DETAIL

Five PAT-2 containers and maintenance spares provided to IAEA.

USEFUL TO : Inspector
FACILITIES : Fabrication
Reprocessing
CAPITAL COST : 20,000
SOURCE 1 : Bendix
SOURCE 2 : NBL
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : 1984 SNL
REFERENCE DETAIL : C.E. Pietri et al.; 404.

DESCRIPTION

The PAT-2 package consists of several major components. The protective overpack consists of a double-walled stainless steel outer body with an internal redwood layer, and a titanium inner assembly with an internal maplewood layer. Located within this overpack is a spherical iron-base superalloy primary vessel containing a secondary stainless steel capsule. This capsule can accommodate both PuO₂ safeguards samples, packaged in small containers, and a NBL-designed low pressure dissolution flask with leakproof closure. Samples can be pre-weighed by the shipper and dissolved by the receiver directly in the container, thus avoiding weight change problems commonly encountered in shipping hygroscopic PuO₂ samples.

The PAT-2 package complies with U.S. regulations concerning Pu air transport and with applicable IAEA rules, and has been licensed in the U.S. by both NRC and DOT. The IAEA has presented a training course and qualified an initial cadre of inspectors for future use of PAT-2 in international safeguards.

EQUIPMENT NAME : Mobile Safeguards Van
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Transportation
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 250,000
MAINTENANCE COST : 6,000
LIFETIME : 10 Years
SOURCE 1 : US NRC
SOURCE 2 : PNL
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : 1978 IAEA
REFERENCE DETAIL : 1. Martin, Brown & Ting; 277.
2. Sorenson, Fager & Braver; V. 2, 193.

DESCRIPTION

The references describe two mobile vans used respectively by the NRC and by PNL. These are set up for use to evaluate licensees' measuring systems, verify measurements, and make independent measurements. The NRC van is equipped with a gamma-ray spectrometry system, a neutron well coincidence counter, and ISAF. The PNL van is equipped with two gamma-ray spectrometry systems, two segmented gamma scanners (one large and one small), a gross neutron counter, and a neutron well counter (with interchangeable end plugs and reflectors for active or passive assay).

The NDA equipment is moved from the van into the process or storage area where the nuclear material is located. The primary difference between the two van concepts referenced is integration of measurement performance and data analysis. With the PNL van, each NDA instrument is connected by an instrument cable to the computer system located in the van. This allows for automated equipment control, operation, and data analysis that allows the operator to receive real-time measurement results.

The capital cost of the PNL van is broken down into \$50,000 for the vehicle, which includes power generators and the fire protection system; \$175,000 for instrumentation; and \$25,000 for installation. The NRC van costs \$95,000.

EQUIPMENT NAME : Passive Environmental Monitor (PASEM)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Env'tl. Monitor
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model

STATUS DETAIL

In routine use by IAEA.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 50
SOURCE 1 : SNL
REFERENCE 1 : 1984 SNL

DESCRIPTION

PASEM is a small package which can be inserted into existing C/S equipment enclosures to obtain data on temperature, humidity and radiation experienced by the equipment. The monitor will be useful in defining C/S equipment operating environments, analyzing malfunctions and detecting tamper attempts using extreme environmental conditions. The PASEM can also be used in a stand-alone mode to determine basic facility environments.

PASEM contains sensors which passively record maximum and minimum temperature, maximum relative humidity and cumulative radiation dose between inspections. It is packaged in a vented container to allow stabilization of temperature and humidity. Radiation sensors record temperatures in the range of -10 degree C to 50 degree C, relative humidity in the range of 50% to 90%, and gamma radiation in the range of 10 mRads to 10 MRads. The temperature sensor is of the bimetallic type and can be reset once the exposure limits are recorded by the inspector. The humidity sensor is of the card variety, which changes appearance with each 10% increment of relative humidity. It is designed to be read and replaced, if activated. Two radiation sensors are used: (1) a LiF Thermoluminescence Dosimeter (10 mRads to 10 MRads), designed to be returned to IAEA headquarters for analysis; (2) an in-situ radio-chromic dosimeter which indicates gamma exposure greater than 1000 Rads.

EQUIPMENT NAME : ELCODRUM, Tamper-Resistant Container
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Sealed Container
MATERIAL TYPE : SNM (Miscellaneous)
STATUS : Class I : Laboratory Device
STATUS DETAIL

Prototype has been successfully tested at KFA Juelich.

USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 2,000
REPLACEMENT COST : 2,000
LIFETIME : 2 Years
SOURCE 1 : KFA
SOURCE 2 : ProCom
REFERENCE 1 : 1984 INMM
REFERENCE DETAIL : Bueker, Nicolai, Arning, Reuters; 80.

DESCRIPTION

The safeguarding of SNM requires the use of a container with opening and surface area protection, which means that any access to the material, whether by opening or damaging the container shell, must be recorded. Based on the optoelectronic sensor principle, a 208-l. drum has been developed for which both opening status and surface integrity may be verified at any time in a tamper-proof manner. This may be done either in situ or by a computer-aided remote verification system.

The drum accommodates an inner drum which is open at the top and contains light guides at the bottom and side wall. The lid of the drum is composed of two parallel layers, the space between which is likewise equipped with a light guide loop. The light guides of the drum and the lid each consist of a single piece and are 40 and 10 m long, respectively. They are unsheathed and have a diameter of 125 m. The spacing between the light guide tracks is approximately 5 cm. When the drum is closed, the two light guides are automatically linked with each other by means of internal connector plugs and connected to a VACOSS-3 seal. This produces a closed light-guide circuit covering the entire container surface. The spaces between the drums and the lid layers are filled with polyurethane foam which (1) fixes the light guides and (2) provides tamper-proofing; the foam will have to be removed mechanically, thereby damaging the light guides and providing detection.

REFERENCE : 1971 INMM
TITLE :
Nuclear Materials Management (Proceedings of the 12th Annual Meeting)
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1971
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1976 IAEA
TITLE :
Safeguarding Nuclear Materials
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1976
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : 1978 IAEA
TITLE :
Nuclear Safeguards Technology 1978
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1979
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : 1979 ESARDA
TITLE :
1st Annual Symposium on Safeguards and Nuclear Materials Management
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1979
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : 1979 INMM
TITLE :
Nuclear Materials Management (Proceedings of the 20th Annual Meeting)
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1979
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1980 CS
TITLE :
Proc. of the 1st Sem. on Containment and Surveil. Techniques for Int'l Sfgds
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1980
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : 1980 ESARDA
TITLE :
2nd Annual Symposium on Safeguards and Nuclear Materials Management
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1980
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : 1980 INMM
TITLE :
Nuclear Materials Management (Proceedings of the 21st Annual Meeting)
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1980
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1981 ESARDA
TITLE :
3rd Annual Symp. on Safeguards and Nuclear Materials Management
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1981
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : 1981 INMM
TITLE :
Institute of Nuclear Materials Management (Program of the 22nd Annual Meeting)
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1981
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1982 IAEA
TITLE :
Nuclear Safeguards Technology 1982
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1983
PUBLISHER : Int. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : 1982 INMM
TITLE :
Nuclear Materials Management (Proceedings of the 23rd Annual Meeting
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1982
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1983 ESARDA
TITLE :
5th Annual Symposium on Safeguards & Nuclear Materials Management
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1983
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : 1983 INMM
TITLE :
Nuclear Materials Management (Proceedings of the 24th Annual Meeting
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1983
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1984 ESARDA
TITLE :
6th Annual Symposium on Safeguards & Nuclear Materials Management
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1984
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : 1984 INMM
TITLE :
Nuclear Materials Management (Proceedings of the 25th Annual Meeting
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1984
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : 1984 SNL
TITLE :
Containment & Surveillance Equip. Developmt. Activities at Sandia for IAEA ...
AUTHORS :
C.L. Schuster, C.S. Sonnier
TYPE OF REFERENCE :
COPYRIGHT DATE : 1984
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : ACA
TITLE :
Analytica Chimica Acta
TYPE OF REFERENCE : Journal Article
COPYRIGHT DATE :
PUBLISHER : Elsevier
CITY : Amsterdam
STATE OR COUNTRY : Holland

REFERENCE : AECL-6209
TITLE :
Devel. of Irrad. Fuel Bundle Counters for 600MW CANDU Reactor Safegds Systems
AUTHORS :
V. Allen, W. Shorey & A. Stirling
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : Atomic Energy of Canada Ltd.
CITY : Chalk River Ont.
STATE OR COUNTRY : Canada

REFERENCE : AGNS-1040-2.2-50

TITLE :

Nuc. Mat'ls Control & Acct'g System Evaluation Report-FY 78 Integrated U Run

AUTHORS :

J.M. Crawford, M.H. Ehinger, C. Joseph & M.L. Madeen

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1978

PUBLISHER : Allied-General Nucl. Services

CITY : Barnwell

STATE OR COUNTRY : SC

REFERENCE : AGNS35900-2.2-24

TITLE :

Process Monitoring & Process Surveillance Demonstration Program

AUTHORS :

H.R. Kight

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1979

PUBLISHER : Allied-General Nucl. Services

CITY : Barnwell

STATE OR COUNTRY : SC

REFERENCE : AGNS35900-2.4103

TITLE :

Application of Analytical Chemis. Methods to Remote or Containment Conditions

AUTHORS :

L. Jordan & T. Williams

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1980

PUBLISHER : Allied-General Nucl. Services

CITY : Barnwell

STATE OR COUNTRY : SC

REFERENCE : ANCHAM

TITLE :

Analytical Chemistry

TYPE OF REFERENCE : Journal Article

COPYRIGHT DATE :

PUBLISHER : American Chemical Society

CITY : Washington

STATE OR COUNTRY : DC

REFERENCE : ANL-78-27
TITLE :
Autoradiography as a Safegds Inspec. Technique for Unirrad LWR Fuel Assemblies
AUTHORS :
S.B. Brumbach & R.B. Perry
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : Argonne National Laboratory
CITY : Argonne
STATE OR COUNTRY : IL

REFERENCE : ANL-NDA-2
TITLE :
Autoradiography as a Safeguards Inspection Technique for Plutonium Fuels
AUTHORS :
S.B. Brumbach & R.B. Perry
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Argonne National Laboratory
CITY : Argonne
STATE OR COUNTRY : IL

REFERENCE : ANL-NDA-5
TITLE :
Applications Guide for Plutonium Autoradiography
AUTHORS :
S.B. Brumbach
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Argonne National Laboratory
CITY : Argonne
STATE OR COUNTRY : IL

REFERENCE : ANSI N15.18
TITLE :
Mass Calibration Techniques for Nuclear Material Control
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1975
PUBLISHER : Amer. Nat'l Standards Inst.Inc
CITY : New York
STATE OR COUNTRY : NY

REFERENCE : Anal. Spec.
TITLE :
Proceedings of the 26th Conf. on Anal. Chem. in Energy Technology
AUTHORS :
W.S. Lyon, Ed.
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1984
PUBLISHER : Elsevier
CITY : Amsterdam
STATE OR COUNTRY : Holland

REFERENCE : BNL 51450
TITLE :
Safeguards Instrumentation: A Computer-Based Catalog
AUTHORS :
Leslie G. Fishbone and Bernard Keisch
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Brookhaven National Laboratory
CITY : Upton
STATE OR COUNTRY : NY

REFERENCE : BNL-30660
TITLE :
User's Guide to "Safeguards Instrumentation: A Computer-Based Catalog"
AUTHORS :
E.J. Blittner & D.K. Kirby
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Brookhaven National Laboratory
CITY : Upton
STATE OR COUNTRY : NY

REFERENCE : CONF-820424-3
TITLE :
Proc. of the ANS Topical Mtg. on the Treatment and Handling of Rad. Wastes
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1982
PUBLISHER : Battelle Press
CITY : Columbus
STATE OR COUNTRY : OH

REFERENCE : CRNL-2668
TITLE :
An Optical Safeguards Seal for CANDU Spent Fuel Storage
AUTHORS :
G.P. Lynch & R.E. Martin
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Atomic Energy of Canada Ltd.
CITY : Chalk River
STATE OR COUNTRY : Ontario

REFERENCE : ENICO-10034
TITLE :
Fast Correlation Processing for R.F. Liquid Level Measurements
AUTHORS :
W.J. Harris
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Exxon Nuclear Idaho Co., Inc.
CITY : Idaho Falls
STATE OR COUNTRY : Idaho

REFERENCE : ENICO-1071
TITLE :
Flexural Type Ultrasonic Liquid In-Line Sensor
AUTHORS :
T.C. Piper
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Exxon Nuclear Idaho Co., Inc.
CITY : Idaho Falls
STATE OR COUNTRY : ID

REFERENCE : ENICO-1080
TITLE :
Precision Level/Density Scanner
AUTHORS :
Boland & Deveraux
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1982
PUBLISHER : Exxon Nuclear Idaho Co., Inc.
CITY : Idaho Falls
STATE OR COUNTRY : ID

REFERENCE : ESARDA
TITLE :
ESARDA Bulletin
TYPE OF REFERENCE : Journal Article
COPYRIGHT DATE :
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : EUR 6629EN
TITLE :
International Meeting on Monitoring of Pu-Contaminated Waste
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1979
PUBLISHER : CEC (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : Hilton Head
TITLE :
Proc. of the Conf. on Safeguards Technology (CONF-831106, sponsored by ANS)
AUTHORS :
Hakkila et al., Eds.
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1984
PUBLISHER : U.S.DOE/NBL
CITY : Argonne
STATE OR COUNTRY : IL

REFERENCE : IAEA-174
TITLE :
IAEA Safeguards Technical Manual
TYPE OF REFERENCE : Book
COPYRIGHT DATE : 1976
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : IAEA-STR-83
TITLE :
General Considerations in Safeguarding CANDU Reactors by Item Accounting & CS
AUTHORS :
M. Honami & D. Jung
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : IAEA-STR-90
TITLE :
Safeguarding Nuclear Material at CANDU Reactors (Rev. 1)
AUTHORS :
D.W. Jung
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : IEEE TNS
TITLE :
IEEE Transactions on Nuclear Science
AUTHORS :
The Institute of Electrical and Electronics Engineers, Inc.
TYPE OF REFERENCE : Journal Article
PUBLISHER : The Institute of EEE, Inc.
CITY : New York
STATE OR COUNTRY : NY

REFERENCE : ISPO-146
TITLE :
Instruction Manual: Hand Held Assay Probe
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : National Nuclear Corp.
CITY : Mountain View
STATE OR COUNTRY : CA

REFERENCE : ISPO-78
TITLE :
Safeguarding Large Uranium Hexafluoride Cylinders
AUTHORS :
S. Fiarman
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Brookhaven National Laboratory
CITY : Upton
STATE OR COUNTRY : NY

REFERENCE : J. Mass Spec.
TITLE :
International Journal of Mass Spectrometry & Ion Physics
TYPE OF REFERENCE : Journal Article
COPYRIGHT DATE :
PUBLISHER : Elsevier
CITY : Amsterdam
STATE OR COUNTRY : Holland

REFERENCE : JOPAG/04.84PRG82
TITLE :
Development of an Optical Surveillance System
AUTHORS :
Ch. Brueckner et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Kernforschungszentr. Karlsruhe
CITY : Karlsruhe
STATE OR COUNTRY : FRG

REFERENCE : K/OA-5014, Rev 1
TITLE :
Gamma-Ray Spectrometric Determination of UF₆ Assay ..
AUTHORS :
E. Ricci
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Union Carbide Corp.-Nuc. Div.
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : K/OA-5206
TITLE :
Field Testing of UF₆ Cyl. Gamma-Ray Measuring Equip. for Intern. Safeguards
AUTHORS :
L.W. Fields & E. Ricci
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1982
PUBLISHER : Union Carbide Corp.-Nuc. Div
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : K/DA-5615
TITLE :
UF6 Sample Bottle Assay Meter
AUTHORS :
E. Ricci
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Union Carbide Corp.-Nuc. Div.
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : K/DA-5626
TITLE :
A 20-Ton Capacity Load-Cell-Based Weighing System for Uranium Hexafluoride..
AUTHORS :
McAuley, Kane & Fairberg
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1985
PUBLISHER : Martin Marietta Energy Syst.
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : Kiawah
TITLE :
Measurement Technology for Safeguards and Materials Control (NBSSP-582)
AUTHORS :
T.R. Canada & B.S. Carpenter, Eds.
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1980
PUBLISHER : National Bureau of Standards
CITY : Washington
STATE OR COUNTRY : D.C.

REFERENCE : LA-10009-M
TITLE :
Plutonium Nitrate Bottle Counter
AUTHORS :
Menlove et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Los Alamos National Laboratory
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-10226-M
TITLE :
Universal FBR Subassembly Counter Manual
AUTHORS :
Menlove et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Los Alamos National Laboratory
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-4705-M6
TITLE :
Nuclear Safeguards Research & Development, Jan.-Apr. Program Status Report
AUTHORS :
G.R. Keepin, ed.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1971
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-5681
TITLE :
Portal Monitor for Diversion Safeguards
AUTHORS :
W. Chambers et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1974
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-6359
TITLE :
Hand-Held Personnel and Vehicle Monitors
AUTHORS :
W. Kunz, W. Chambers, C. Henry, S. France, D. Millegan & R. Hastings
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1976
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-7315

TITLE :

Concepts for Inventory Verification in Critical Facilities

AUTHORS :

D. Cobb, J. Sapir, E. Kern & R. Dietz

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1978

PUBLISHER : Los Alamos Scientific Lab.

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-7528-M

TITLE :

Portable Active Neutron Interrogation System for LWR Fuel Assemblies

AUTHORS :

J. Brandenberger, H. Menlove & E. Medina

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1978

PUBLISHER : Los Alamos Scientific Lab.

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-7646

TITLE :

On-Site Inspection Procedures for SNM Doorway Monitors

AUTHORS :

P. Fehlau, T. Sampson, C. Henry, J. Bieri & W. Chambers

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1979

PUBLISHER : Los Alamos Scientific Lab.

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-7779-M

TITLE :

The High-Level Neutron Coincidence Counter (HLNCC): Users' Manual

AUTHORS :

Krick & Menlove

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1979

PUBLISHER : Los Alamos Scientific Lab.

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-7784-MS
TITLE :
The Measurement of Leached Hulls
AUTHORS :
T.D. Reilly
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-7823-M
TITLE :
Description and Operation Manual for the Active Well Coincidence Counter
AUTHORS :
Howard O. Menlove
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-7882-MS
TITLE :
Experimental Comparison of the AWCC with the Random Driver
AUTHORS :
H.O. Menlove et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-8042
TITLE :
Materials Management in an Internationally Safeguarded Fuel Reprocessing Plant
AUTHORS :
E. Hakkila et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-8584-MS

TITLE :

Radiation Detectors as Surveillance Monitors for IAEA Safeguards

AUTHORS :

P. Fehlau & E. Dowdy

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1980

PUBLISHER : Los Alamos Scientific Lab.

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-9288-MS

TITLE :

Passive/Active Coincidence Collar for Total Pu Msmt. of MOX Fuel Assemblies

AUTHORS :

H.O. Menlove

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1982

PUBLISHER : Los Alamos National Laboratory

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-9438-MS

TITLE :

Nondestr. Verific. with Minimal Movement of Irradiated LWR Fuel Assemblies

AUTHORS :

J.R. Phillips et al.

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1982

PUBLISHER : Los Alamos National Laboratory

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-9608-MS

TITLE :

Field Tests & Evaluations of the IAEA AWCC

AUTHORS :

Krick & Rinard

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1982

PUBLISHER : Los Alamos National Laboratory

CITY : Los Alamos

STATE OR COUNTRY : NM

REFERENCE : LA-9781-M
TITLE :
End-Crop Box Counter Manual
AUTHORS :
Sprinkle & Stephens
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1983
PUBLISHER : Los Alamos National Laboratory
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : Lawless
TITLE :
RFAM, Rocky Flats Assay Meter
AUTHORS :
J.L. Lawless
TYPE OF REFERENCE : Draft Report
COPYRIGHT DATE : 1981
PUBLISHER : Rockwell International
CITY : Golden
STATE OR COUNTRY : Colorado

REFERENCE : NBL-311
TITLE :
Progress Report for the Period October 1982 through September 1983
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : U.S. DOE New Brunswick Lab.
CITY : Argonne
STATE OR COUNTRY : IL

REFERENCE : NUREG-0274
TITLE :
Catalog of Physical Protection Equipment
AUTHORS :
Wolf Haberman et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : The MITRE Corporation
CITY : Bedford
STATE OR COUNTRY : MA

REFERENCE : NUREG/CR-0602
TITLE :
Active Nondestructive Assay of Nuclear Materials
AUTHORS :
T. Gozani
TYPE OF REFERENCE : Book
COPYRIGHT DATE : 1981
PUBLISHER : USNRC
CITY : Washington
STATE OR COUNTRY : D.C.

REFERENCE : NUREG/CR-2078
TITLE :
Handbook of Nuclear Safeguards Measurement Methods
AUTHORS :
D. Rogers, Ed.
TYPE OF REFERENCE : Book
COPYRIGHT DATE : 1983
PUBLISHER : Monsanto Research Company
CITY : Miamisburg
STATE OR COUNTRY : OH

REFERENCE : Nuc. Mat.
TITLE :
Nuclear Materials Management
TYPE OF REFERENCE : Journal Article
PUBLISHER : Inst. of Nuc. Mat'ls. Mngement
CITY : Chicago
STATE OR COUNTRY : IL

REFERENCE : Nuc. Safe.
TITLE :
Nuclear Safeguards Analysis
AUTHORS :
E.A. Hakkila, Ed.
TYPE OF REFERENCE : Book
COPYRIGHT DATE : 1978
PUBLISHER : American Chemical Society
CITY : Washington
STATE OR COUNTRY : D.C.

REFERENCE : Nuc. Tech.
TITLE :
Nuclear Technology
TYPE OF REFERENCE : Journal Article
COPYRIGHT DATE :
PUBLISHER : Amer. (& European) Nucl. Soc.
CITY : LaGrange Park
STATE OR COUNTRY : IL

REFERENCE : ORNL/TM-7340
TITLE :
Selection and Testing of Liquid Sensing Devices...
AUTHORS :
E. Blakeman et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Oak Ridge National Laboratory
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : ORNL/TM-8445
TITLE :
A Proof-of-Principle Experiment for NDA of Leached Fuel Hulls
AUTHORS :
G.G. Slaughter et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1983
PUBLISHER : Oak Ridge National Laboratory
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : POTAS
TITLE :
Program for Technical Assistance to IAEA Safeguards - Fourth Program Plan
AUTHORS :
International Safeguards Project Office
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Brookhaven National Laboratory
CITY : Upton
STATE OR COUNTRY : NY

REFERENCE : S&U
TITLE :
Detection of Fissionable Materials by Nondestructive Means
AUTHORS :
R. Sher & S. Untermyer II
TYPE OF REFERENCE : Book
COPYRIGHT DATE : 1980
PUBLISHER : American Nuclear Society
CITY : LaGrange Park
STATE OR COUNTRY : IL

REFERENCE : SAND 78-0400
TITLE :
Security Seal Handbook
AUTHORS :
David L. Poli
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : Sandia Laboratories
CITY : Albuquerque
STATE OR COUNTRY : N.M.

REFERENCE : SAND 80-0002
TITLE :
Containment & Surveillance Equipment Compendium
AUTHORS :
Frederick O. Luetters
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : N.M.

REFERENCE : SAND 80-1762
TITLE :
Functional Evaluation of Film Cameras Suitable for Surveillance
AUTHORS :
C.L. Henderson, R.L. Martinez & C.E. Robertson
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : SAND 80-2699
TITLE :
Metallic Seals
AUTHORS :
D. Poli
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : SAND 81-0001
TITLE :
PAT-2 Safety Analysis Report
AUTHORS :
J.A. Anderson, et al.
TYPE OF REFERENCE :
COPYRIGHT DATE : 1981
PUBLISHER : Sandia National Laboratory
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : SAND 84-0458
TITLE :
PIV Seal System Description and Operators Manual
AUTHORS :
R.D. Fellerhoff, G.L. Harvey
TYPE OF REFERENCE :
COPYRIGHT DATE : 1984
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : TANS
TITLE :
Transactions of the American Nuclear Society
TYPE OF REFERENCE : Journal Article
PUBLISHER : American Nuclear Society
CITY : LaGrange Park
STATE OR COUNTRY : IL

REFERENCE : TASTEX

TITLE :

TASTEX: Tokai Advanced Safeguards Technology Exercise (TRS No.213)

TYPE OF REFERENCE : Book

COPYRIGHT DATE : 1982

PUBLISHER : IAEA

CITY : Vienna

STATE OR COUNTRY : Austria

REFERENCE : UCRL-52879

TITLE :

Determination of Pu Isotopic Abundances by Gamma-Ray Spectrometry

AUTHORS :

R. Gunnink et al.

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1980

PUBLISHER : Lawrence Livermore Laboratory

CITY : Livermore

STATE OR COUNTRY : CA

REFERENCE : UCRL-52883

TITLE :

On-Line Determ. of U & Pu Process- & Product Stream Concentrations by EDXRFA

AUTHORS :

D.C. Camp & W.D. Ruhter

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1979

PUBLISHER : Lawrence Livermore Laboratory

CITY : Livermore

STATE OR COUNTRY : CA

REFERENCE : UCRL-52950

TITLE :

Evaluation of TASTEX Task H

AUTHORS :

R. Gunnink et al.

TYPE OF REFERENCE : Technical Report

COPYRIGHT DATE : 1981

PUBLISHER : Lawrence Livermore Laboratory

CITY : Livermore

STATE OR COUNTRY : CA

REFERENCE : UCRL-53506
TITLE :
A Portable Microcomputer for the Anal. of Pu Gamma-Ray Spectra
AUTHORS :
W.D. Ruhter
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1984
PUBLISHER : Lawrence Livermore Laboratory
CITY : Livermore
STATE OR COUNTRY : CA

REFERENCE : UCRL-86737
TITLE :
Pu Isotopic Analysis of Nondescript Samples by Gamma-Ray Spectroscopy
AUTHORS :
R. Gunnink
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Lawrence Livermore Laboratory
CITY : Livermore
STATE OR COUNTRY : CA

REFERENCE : US Pat. 4170135
TITLE :
Coaxial Cavity for Measuring Level of Liquid in a Container
AUTHORS :
G.L. Booman & F.R. Phelps
TYPE OF REFERENCE : Patent
COPYRIGHT DATE : 1979
PUBLISHER : U.S. Patent Office
CITY : Washington
STATE OR COUNTRY : D.C.

REFERENCE : WINCO
TITLE :
Private Communication
AUTHORS :
F. Cartan, F.L. Bentzen, E.P. Wagner
TYPE OF REFERENCE :
COPYRIGHT DATE :
PUBLISHER : Westinghouse Idaho Nuc. Co.
CITY : Idaho Falls
STATE OR COUNTRY : ID

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REFERENCE : WINCO
TITLE :
Private Communication
AUTHORS :
F. Cartan, F.L. Bentzen, E.P. Wagner
TYPE OF REFERENCE :
COPYRIGHT DATE :
PUBLISHER : Westinghouse Idaho Nuc. Co.
CITY : Idaho Falls
STATE OR COUNTRY : ID

SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
AECL C-OPS	Atom. Ener. of Can. Ltd.	R. Gilbert J. Vones	Sheridan Park Mississauga Ontario Canada LSK1B2 416-823-9040
AECL CRNL	Atom. Energy of Canada, Ltd	A. Stirling E. Payne	Chalk River Nuc. Labs. Ontario Canada KOJ1JO 613-584-3311
AECL WNRE	Atom. Ener. of Canada, Ltd	D. Jung D. Chen	Whiteshell Nucl. Res. Estab. Pinawa, Manitoba Canada ROE1LO 204-753-2311
ANL	Argonne National Lab.	C. Roche R. Perry	9700 S Cass Ave. Argonne IL 60439 312-972-3925
AUTO	Automatic Control Systems		9009 Freeway Dr. Macedonia OH 44056 216-467-2186
Advertape	Advertape, Inc.		1189 Montauk Hwy East Patchogue NY 11772 516-286-0100
Am. Cast.	Am. Casting & Manu. Corp.		40 Commercial St Plainview NY 11803 516-349-7010
Ames	Ames Laboratory	M. Edelson V. Fassel	Iowa State Univ. Ames Iowa 50011 515-294-4922
BEFIC	BEFIC		89-93 rue des Alpes; SIL1C S15 94623 Rungis France

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SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
BLH	BLH Electronics		42 4th Avenue Waltham MA 02154 617-890-6700
BNL	Brookhaven National Lab.	Technical Supp. Org.	Dept. Nuc. Ener. Bldg. 197-C Upton NY 11973 516-282-2924
Balzers	Balzers	C. Stupak	8 Sagamore Pk Rd Hudson NH 03051 603-889-6888
Bartex	Bartex, Inc.	H. Barnes	PO Box 3348 Annapolis MD 21403 301-261-2987
Bendix	The Bendix Corporation		Kansas City Div. P.O. Box 1159 Kansas City MO 64141
Bio Rad	Bio-Rad Laboratories		2200 Wright Ave. Richmond CA 94804 415-234-4130
CAMECA	CAMECA Instruments Inc.		2001 West Main Street Stamford CT 06902 203-348-5252
CMS	CMS, Inc.	Jim Doyle	6446 Caroldale Place Goleta CA 93117 805-964-7581

SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
Canberra	Canberra Industries, Inc.	P. Bianchi D. H. Neville	45 Gracey Avenue Meriden CT 06450 203-238-2351
DJ	D.J. Instruments, Inc.		18 Republic Road N. Billerica MA 01862 617-667-5301
Davidson	D.S. Davidson Company	Donald Davidson	19 Bernhard Road North Haven CT 06473 203-288-7324
Designer	Designer Decal, Inc.		131 N Pittsburgh Spokane WA 99202
Eastech	Eastech Inc./Kessler-Ellis		120 First Ave. Atlantic Highway NJ 07716 800-225-2115
Eberline	Eberline Instrument Corp.		Box 2108 Santa Fe NM 87501 505-471-3232
F&P	Fischer & Porter Co.	R. Patterson	775 Warminster Rd. Warminster PA 18974 215-674-6000
Flow Tech.	Flow Technology, Inc.		P.O. Box 21346 Phoenix AZ 85036 602-268-8776
Foxboro	The Foxboro Co.		Bristol Park Bldg. 52-1 Foxboro MA 02035 617-543-8750

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SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
GE Wilming	General Electric Company	Charles M. Vaughan	PO Box 780 Wilmington NC 28401 919-343-5000
HEDL	Westinghouse Hanford Co.	R. Carlson	P.O. Box 1970 Richland WA 99352 509-942-7538
HP	Hewlett-Packard		Brookside ParkRd 1 Harbison Way Columbia SC 29210 803-732-0400
Harshaw	Harshaw Chemical Company	R. Marbury	6801 Cochran Rd Solon OH 44139 216-248-7400
Herfurth	Herfurth GmbH		Beerenweg 6-8 Postfach 500648 2 Hamburg 50 FRG
Honeywell	Honeywell Proc.Contr.Div.		1100 Virginia Av Fort Washington PA 19034 800-526-7843
IAEA	Intl. Atomic Energy Agency	E. Kerr	Sect. for Tech. Services A-1400 Vienna Austria
IRT	IRT Corporation	Kenneth Alvar	P.O.Box 85317 7650 Convoy Ct. San Diego CA 92138 619-450-4343

SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
ITI	Instrument Technology, Inc	D.A. Carignan	Box 381 Mainline Drive Westfield MA 01085 413-562-3606
Intermec	Intermec Corp.		P.O. Box 360602 Lynnwood WA 98036 206-743-7036
JRC	Joint Research Centre	S. Crutzen M. Cuypers	I-21020 Ispra (Varese) Italy
Jomar	Jomar Systems	C. Hodge D. Jones	1143 18th St. Los Alamos NM 87544 505-662-9811
KB	Krautkramer-Branson Inc.		P.O. Box 350 Lewistown PA 17044 800-233-7183
KFA	KFA Juelich GmbH	H. Bueker B. Richter	Postfach 1913 D-5170 Juelich 1 FRG
Kelk	G. Kelk Ltd.		Toronto Ontario Canada 416-445-5850
KfK	Kernforsch-Zentr. Karlsruhe	H. Ottmar	Postfach 3640 D7500 Karlsruhe 1 FRG
L&N	Leeds & Northrup		Sumneytown Pike North Wales PA 19454 215-643-2000

SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
LANL	Los Alamos National Lab.	P. Fehlaue G.E. Bosler	Los Alamos NM 87545 505-667-5061
LLNL	Lawrence Livermore N.L.	David C. Camp	PO Box 808 Livermore CA 94550 415-422-6680
Ludlum	Ludlum Measurements, Inc.		P.O. Box 248 Sweetwater TX 79556 915-235-5494
MAT	Finnigan MAT		355 River Oaks Parkway San Jose CA 95134 408-946-4848
MMI	Micro Motion, Inc.		7070 Winchester Circle Boulder CO 80301 303-530-0530
MRL	Missouri Research Labs.		630 Haines Ave. N.W. Albuquerque NM 87102 505-243-6772
Mettler	Mettler Instrument Corp.		PO Box 71 Hightstown NJ 08520 609-448-3000
Mound	MRC-Mound	J.F. Lemming W.W. Rodenburg	PO Box 32 Miamisburg OH 45342 513-865-4020
NBL	New Brunswick Laboratory	C.D. Bingham	9800 S. Cass Ave Argonne IL 60439 312-972-2442

SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
ND	Nuclear Data Inc.	K.R. Thompson	Golf & Meacham Rds. Schaumburg IL 60196 312-884-3621
NNC	National Nuclear Corp.	S. Untermyer	1904 Colony St. Mountain View CA 94043 415-962-9220
Nat. Son.	National Sonics Corp.		250 Marcus Blvd. Hauppauge NY 11788 516-273-6600
ORGDP	Martin Marietta En. Syst.	E. Ricci	P.O. Box P Oak Ridge TN 37830 615-574-8138
ORNL	Oak Ridge National Lab.	E.D. Blakeman C. Ricker	Instr./Contr.Div P.O. Box X Oak Ridge TN 37830 615-574-5567
ORNL+	Oak Ridge National Lab.	J.A. Carter D.H. Smith	Anal. Chem. Div. P.O. Box Y Oak Ridge TN 37831 615-574-2454
ORTEC	EG & G ORTEC		100 Midland Rd Oak Ridge TN 37830 615-482-4411
Ormond	Ormond, Inc.		
PGT	Princeton Gamma-Tec.		1200 State Road Princeton N.J. 08540 609-924-8980

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SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
PNL	Battelle Pacific NW Labs	Brian Smith N. Harms	Richland WA 99352 509-942-4436
Paducah	Martin Marietta Energy Sys	E. Kohler	Paducah KY 42001 502-444-6311
Panamet	Panametrix	G. Elfbaum	221 Crescent St. Waltham MA 02254 617-899-2719
Parosci	Paroscientific, Inc.		4500 148 Ave. N.E. Redmond WA 98052 206-883-8700
ProCom	ProCom GmbH	F. Arning	Luisenstrasse 41 D-5100 Aachen FRG
Psychotron	Psychotronics GmbH		Vienna Austria
RMD	RMD, Inc.		44 Hunt St. Watertown MA 02172 617-926-1167
Ruska	Ruska Instrument Corp.	E. Moser	P.O. Box 742688 Houston TX 77274 713-975-0547
SNL	Sandia National Labs.	C.L. Schuster C.S. Sonnier	PO Box 5800 Albuquerque NM 87185 505-844-2124

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SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
Sartorius	Sartorius Balances		c/o Brinkmann Cantaigue Road Westbury NY 11590 516-334-7500
Silena	Silena S.P.A.		Via Negroli 10/A I-20133 Milano Italy
TSA	TSA/Geoscience		4919 N. Broadway Boulder CO 80302 303-447-8553
Teledyne	Teledyne Hastings-Raydist		P.O. Box 1275 Hampton VA 23661 804-723-6531
Thermal	Thermal Instrument Co.		217 Sterner Mill Road Trevose PA 19047 215-355-8400
Toshiba	TokyoShibaura Elec. Co,Ltd	M. Sandoh	13-12 Mita 3- chome, Manata-ku Tokyo Japan 108
UKAEA	Atomic Energy Research Est	B.W. Hooton R.J. Riley	AERE Harwell Oxfordshire OX 11 0RA England
USNRC	US Nuclear Regulatory Comm	W. Martin	Region I 631 Park Avenue King of Prussia PA 19406

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SOURCE	SOURCE NAME	CONTACTS	ADDRESS & PHONE
VG Isotope	VG Instruments, Inc.	M.L. Ortega	300 Broad Street Stamford CT 06901 203-322-4546
Varo	Varo, Inc.	Russ Lyons	Texas Division 2201 W. Walnut Garland TX 75040 214-272-3561
Victoreen	Victoreen, Inc.		10101 Woodland Ave. Cleveland OH 44104 216-795-8200
WINCO	West. Id. Nucl. Co.	F.O. Cartan	P.O. Box 4000 Idaho Falls ID 83403 208-526-2354
XETEX	XETEX, Inc.	K. Sinclair	660 National Ave Mountain View CA 94043 415-964-3261