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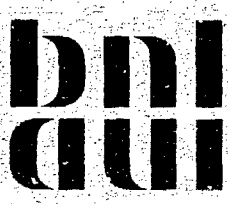
SAFEGUARDS INSTRUMENTATION A COMPUTER-BASED CATALOG

Leslie G. Fishbone and Bernard Keisch



August 1981

TECHNICAL SUPPORT ORGANIZATION
DEPARTMENT OF NUCLEAR ENERGY

BROOKHAVEN NATIONAL LABORATORY
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TABLE OF CONTENTS

INTRODUCTION

A. General Remarks

SAFEGUARDS INFORMATION: A COMPUTER-BASED CATALOG has been assembled by the Technical Support Organization at Brookhaven National Laboratory in response to a request of April 18, 1980 from the Office of Safeguards and Security, U.S. Department of Energy. The information contained in this CATALOG is needed to provide a data base for safeguards studies and to help establish criteria and procedures for international safeguards for nuclear materials and facilities.

The CATALOG primarily presents information on new safeguards equipment. It also describes entire safeguards systems for certain facilities, but it does not describe the inspection procedures that would require use of the equipment. Because international safeguards as administered by the International Atomic Energy Agency (IAEA) do not include physical security, devices for physical protection (as opposed to containment and surveillance) are not included.

A key goal has been to obtain cost information. An attempt has been made to list capital costs, annual maintenance costs, replacement costs, and useful lifetime for the equipment. Some of these data have been difficult or impossible to determine. Recognize especially that, whereas costs for commercially available equipment are almost always actual supplier prices (list--without discounts), costs for equipment under development are almost always estimates, though by individuals having long experience with nuclear instrumentation. In all cases, the costs refer to U.S. dollars in early 1981.

For equipment which is commercially available, representative sources have been listed whenever available. It has not been the intention to give exhaustive lists of suppliers. A citation in no way represents a recommendation of those suppliers, nor does omission of a supplier imply that such a supplier is less qualified than those given.

B. The Computer Data Base

A computer data base was developed to store the information contained in this report and to produce the report itself. Three separate files have been established: for equipment (Section VII), for references (Section VIII), and for sources (Section IX). The information in the last two is self-explanatory. That in the first requires the following line-by-line explanation (lines are omitted in an entry if no information is available):

EQUIPMENT NAME - Self-explanatory.

USE CATEGORY - One of four terms (Section V lists the equipment by this categorization):

1. Materials Accountancy (MCA)
2. Containment-Surveillance (CS)
3. Process Monitoring (PM)
4. Inspector Use (IU)

In a sense, the first three of these (and possibly the first two) exhaustively categorize all equipment, with the last overlapping the others. With the caveat that the terms are not mutually exclusive, the IU category should be understood as describing those instruments that an inspector would literally carry around or are under the in-

spectorate's exclusive control; generally, IU instruments are also MCA instruments.

GENERAL TYPE - One of many precise descriptive terms for the equipment. Presently, these are as follows (Sections IV and VII list the equipment by this categorization):

1. Activity Monitor
2. Bundle Counter
3. Communication
4. Density Measurement
5. Identification
6. Isotope Measurement
7. Mass Measurement
8. Material Monitor
9. NDA: Active Gamma
10. NDA: Active Neutron
11. NDA: Heat
12. NDA: Passive Alpha
13. NDA: Passive Gamma
14. NDA: Passive N&G
15. NDA: Sound
16. NDA: Passive Neutron
17. Optical Surveillance
18. Portal Monitor
19. SNM Monitor
20. Seal

21. Transportation

22. Volume Measurement

The distinction between equipment for nondestructive assay (NDA) and as a special-nuclear-material (SNM) monitor is that the former is intended primarily for quantitative purposes--generally, for MCA purposes--while the latter is intended for qualitative or alarm purposes--generally, for CS purposes. N&G in point 14 above means neutrons and gamma rays.

MATERIAL TYPE - One of many descriptive or inclusive terms giving the primary material upon which the equipment operates or with which it is associated. Presently, these terms are as follows (Section VI lists the equipment by this categorization):

1. Containments
2. Fresh Fuel
3. Fuel
4. Gamma Emitters
5. Gases or Liquids
6. Laboratory Samples
7. Liquids
8. Miscellaneous
9. Plutonium
10. Radioactive Material in Any Form
11. Reactor
12. SNM Neutron Emitters
13. SNM Samples

14. SNM in Solutions

15. SNM in Waste

16. Spent Fuel

17. Uranium

18. Uranium Hexafluoride

STATUS - One of four classifications (taken from page 19 of the POTAS reference; see the Reference File, Section VIII):

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 the IAEA can comment on the approach and future design options. In most cases the equipment will be operated by the designer.

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.

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.

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.

Three caveats apply. First, not all of the equipment in this CATALOG has been designed expressly for the IAEA; this blurs the distinction between Classes II and III. Second, a text note sometimes indicates that development of a device has halted before production; usually, this means that a better device has supplanted it. Third, equipment for which there is only a serious proposal but not even a laboratory prototype shall be included in Class I.

USEFUL TO - A statement of whether the equipment is primarily useful to the Inspector or to the Operator of the Plant or is significant to both.

FACILITIES - A list of the facilities in the nuclear fuel cycle for which the equipment would be useful. "Fuel Storage" in some entires in the Equipment File refers to either fresh or irradiated nuclear material.

CAPITAL COST - The cost of purchasing and possibly installing the equipment (in early 1981 U.S. dollars). For seals, this is often the cost of the verification device. Qualifications may appear in the DESCRIPTION. For example, not all equipment prices include the cost of electronic packages used in several instruments.

MAINTENANCE COST - Annual repair costs, film costs, battery costs, or other operating costs. For seals, this is the cost of the seal it-

self. Note that a commonly used rule of thumb for estimating annual maintenance costs is to take 15% of an item's capital costs. This rule has not been applied in this CATALOG.

REPLACEMENT COST - The cost of replacing the equipment without paying again the structural installation costs.

LIFETIME - The useful lifetime in years due generally to obsolescence or breakdown. Another factor bearing on the lifetime of certain devices is the decay of radioactive sources.

SOURCE1,2 - A brief descriptive term referring to a complete listing in the Source File, Section IX. This would be either a commercial supplier of the equipment or a laboratory or contractor developing it.

REFERENCE1,2 - A brief descriptive term referring to a listing in the Reference File, Section VIII.

REFERENCE DETAIL - If REFERENCEi,2 is not a dedicated report, then this item gives additional bibliographic information--always the authors and possibly a page number, a volume number, an issue number, and a year of publication. This will always refer to REFERENCE1 unless tw items of detail are numbered, referring to REFERENCE1 and REFERENCE2 respectively.

C. Improvements

Since the contents of this entire document are stored in a computer data base, it is straightforward to design other report styles, make immediate queries about the information in the data base, and keep the information current. Indeed, if additional equipment or additional information about equip-

ment already included warrants, future editions of this CATALOG will be issued. Readers can aid in this effort by continuing to contribute research reports, critical commentary, and new product or price data.

D. Background and Acknowledgements

Original references for this work are letters sent to Guy Inman of the Department of Energy's Office of Safeguards and Security by Roddy B. Walton of Los Alamos National Laboratory, Ivan G. Waddoups of Sandia National Laboratories, and Martin S. Zucker of Brookhaven National Laboratory. Two very recent references that were especially valuable in the preparation of this document are the CONTAINMENT AND SURVEILLANCE COMPENDIUM, compiled by Frederick O. Luetters of Sandia, and the book, THE DETECTION OF FISSIONABLE MATERIALS BY NONDESTRUCTIVE MEANS, by Rudolph Sher and Samual Untermyer II. Both contain valuable conceptual remarks regarding safeguards equipment that go beyond the brief descriptions found in this document. Another book with great detail on the physics of active NDA instrumentation is ACTIVE NONDESTRUCTIVE ASSAY OF NUCLEAR MATERIALS, by Tsahi Gozani.

The information presented has been obtained from available literature and from numerous conversations with technical staff members of U.S. Government and foreign national laboratories engaged in safeguards research and development, with contractor personnel, and with representatives of commercial organizations.

Regarding literature, reliance has been on secondary sources, primarily proceedings of recent safeguards conferences, in compiling the information contained herein. An attempt has been made to provide an entree to the liter-

ature--not an exhaustive bibliography.

Those individuals who have contributed extensively to this document deserve mention and thanks. Many very valuable suggestions were provided by William A. Higinbotham of Brookhaven who, at the time of the work on the CATALOG, was engaged in a study for the International Atomic Energy Agency to estimate future safeguards instrumentation requirements. He also read and criticized drafts of the manuscript very carefully. The follcwing people, often with help from their colleagues, responded graciously to the initial queries for information or to the call for comments on the first draft: H. Kight, Allied-General Nuclear Services; R. Smith, Atomic Energy of Canada Limited; R. Perry, Argonne National Laboratory; C. Averbach, A.M. Bieber, Jr., I. Gordon, L. Green, J. Lemley, J. Skalyo, S. Suda, E. Weinstock, and M.S. Zucker, Brookhaven National Laboratory; M. Walker, Central Electricity Generating Board (United Kingdom); J. Perolat, Commissariat a l'Energie Atomique (France); C. Johnson, Exxon Nuclear Idaho, Inc.; K. Alvar, IRT Corporation; P. Filss, Kernforschungsanlage Julich (Federal Republic of Germany); P. Fehlau, R. Marshall, H. Menlove, and J. Shipley, Los Alamos National Laboratory; D. Camp and R. Gunnink, Lawrence Livermore National Laboratory; L. Welsh, National Nuclear Corporation; J. Scarborough, New Brunswick Laboratory; R. Sorenson, Pacific Northwest Laboratory; M. Bleck, F. Leutters, D. Poli, and I. Waddoups, Sandia National Laboratories; and P. DeRegge and F. Ven, Studiecentrum voor kernenergie (Belgium). Others, too numerous to mention, cheerfully answered specific questions. Tony Fainberg of Brookhaven examined the final manuscript.

Finally, of great value have been Dave Kirby of Brookhaven, who programmed

the computer data base and report procedures, and Bonnie Biittner of Brookhaven, who typed all of the information into the data base.

Errors or omissions in the document are the responsibility of the authors.

GLOSSARY

Am	Americium
AWCC	Active Well Coincidence Counter
Ba	Barium
Be	Beryllium
BF3	Boron trifluoride
BWR	Boiling Water Reactor
C	degrees Celsius
CANDU	Canadian Deuterium Uranium (Reactor)
cc	cubic centimeter
CCTV	Closed-Circuit Television
CdTe	Cadmium Telluride
Ce	Cerium
Cf	Californium
Ci	Curie
cm	centimeter
Co	Cobalt
CRT	Cathode-Ray Tube
Cs	Cesium
DT	Deuterium-Tritium
EURATOM	European Atomic Energy Community
g	gram
gal	gallon
Ge	Germanium
He	Helium
HEU	Highly-Enriched Uranium
HLNCC	High-Level Neutron Coincidence Counter

GLOSSARY

I	Iodine
IAEA	International Atomic Energy Agency
in	inch
ISAF	Isotopic Source Assay Fissometer
ISAS	Isotopic Source Assay System
JRC	Joint Research Centre
KeV	Kilo electron-volts
kg	kilogram
l	liter
Li	Lithium
LEU	Low-Enriched Uranium
LWR	Light-Water Reactor
m	meter
mg	milligram
min	minute
ml	milliliter
mm	millimeter
MeV	Mega electron-volts
mph	miles per hour
n	neutron
Na	Sodium
nCi	nano Curie
NBS	National Bureau of Standards
NDA	Nondestructive Assay
NRC	Nuclear Regulatory Commission
pCi	pico Curie

GLOSSARY

PNL	Pacific Northwest Laboratories
Pr	Praseodymium
Pu	Plutonium
PuO2	Plutonium Dioxide
PWR	Pressurized-Water Reactor
R	Roentgen
s	second
Sb	Antimony
Se	Selenium
SNM	Special Nuclear Material
Th	Thorium
THTR	Thorium High-Temperature Reactor
U	Uranium
UF6	Uranium Hexafluoride
UO2	Uranium Dioxide
Z	Atomic (Element) Number
Zr	Zicronium

Page in Sec VII	EQUIPMENT NAME	GENERAL TYPE	USE CAT.
1	Ball Valves with Valve-Position Indicators	Activity Monitor	PM
2	Laser Spent-Fuel Cover	Activity Monitor	CS
3	Secure Crane-Load Sensor	Activity Monitor	CS
4	Ultrasonic Surveillance System	Activity Monitor	CS
5	Valve Tamper Device	Activity Monitor	PM
6	CANDU Core Input Monitor	Bundle Counter	MCA
7	Pebble Counter	Bundle Counter	MCA
8	Spent-Fuel-Bundle (CANDU) Gamma-Ray Verifier	Bundle Counter	IU
9	Spent-Fuel-Bundle Counter (CANDU)	Bundle Counter	MCA
10	Spent-Fuel-Bundle Counter (Sandia)	Bundle Counter	MCA
11	Spent-Fuel-Element Monitor	Bundle Counter	PM
12	Computerized Material-Control & Accounting System	Communication	MCA
13	DYMAC	Communication	MCA
14	Integrated Process & Safeguards Monitoring Systems	Communication	PM
15	Plutonium Product-Area Monitor	Communication	PM
16	RECOVER Monitoring Unit	Communication	CS
17	RECOVER On-Site Multiplexer	Communication	CS
18	RECOVER Portable Verification Unit	Communication	IU
19	RECOVER Resident Verification Unit (RVU)	Communication	CS
20	RECOVER System	Communication	CS
21	High-Precision Level and Densit. Sensor Box	Density Measurement	PM
22	Vibrating Tube (Anton-Parr) Densimeter	Density Measurement	PM
23	Bar Coding	Identification	CS
24	Fuel-Assembly Ident. Device (FAID Eddy-Current)	Identification	CS
25	Fuel-Assembly Ident. System (Magnetic-Inclusion)	Identification	CS
26	Atomic-Emission Spectroscopy	Isotope Measurement	MCA
27	Mass Spectrometer (On-Line Gas-Phase)	Isotope Measurement	PM
28	Mass Spectrometer (Thermal-Emission)	Isotope Measurement	PM
29	Mass Spectrometer (Transportable Quadrupole)	Isotope Measurement	MCA
30	Balances (Electronic)	Mass Measurement	PM
31	Load Cells	Mass Measurement	MCA
32	Semi-Portable Cylinder Load Cell	Mass Measurement	IU
33	Uranium-Hexafluoride-Cylinder Weight Standards	Mass Measurement	MCA
34	Conductivity-Level Device	Material Monitor	PM
35	Electromagnetic Flowmeter	Material Monitor	MCA
36	Fuel-Pellet Inspection System	Material Monitor	PM
37	Gyroscopic-Coriolis Mass Flowmeter	Material Monitor	MCA
38	Optical Liquid In-Line Sensor	Material Monitor	PM
39	Orifice Flowmeter	Material Monitor	MCA
40	Pressure Switches	Material Monitor	PM
41	Thermal Flow Sensor	Material Monitor	PM
42	Thermal Flowmeter with Low-Flow Alarm	Material Monitor	PM
43	Transfer-Jet Monitor	Material Monitor	PM
44	Tubing Block	Material Monitor	CS
45	Ultrasonic Flowmeter	Material Monitor	MCA
46	Ultrasonic Level Detector with High Alarm	Material Monitor	PM
47	Ultrasonic Liquid In-Line Sensor	Material Monitor	PM
48	Vortex-Shedding Flowmeter	Material Monitor	MCA
49	Gamma Absorptiometer	NDA: Active Gamma	MCA
50	Gamma Absorptiometer (Dual-Energy)	NDA: Active Gamma	MCA
51	In-Line Gas-Phase Enrichment Meter	NDA: Active Gamma	PM
52	K- or L-Edge Densitometer	NDA: Active Gamma	MCA
53	Segmented Gamma Scanner	NDA: Active Gamma	MCA
54	X-Ray Fluorescence (Portable)	NDA: Active Gamma	IU
55	X-Ray Fluorescence Analysis (Energy Dispersive)	NDA: Active Gamma	PM
56	Active Well Coincidence Counter (AWCC)	NDA: Active Neutron	MCA

Page in Sec VII	EQUIPMENT NAME	GENERAL TYPE		USE CAT.
57	DENIS (Time-Delayed Neutrons)	NDA:	Active Neutron	MCA
58	Differential Die-Away System for Waste Assay	NDA:	Active Neutron	MCA
59	Fuel-Rod Scanner	NDA:	Active Neutron	PM
60	Fuel-Rod Scanner Standard Fuel Rods	NDA:	Active Neutron	MCA
61	Fuel-Subassembly Assayer	NDA:	Active Neutron	MCA
62	Isotopic Source Assay System & Fissometer	NDA:	Active Neutron	MCA
63	Lead Slowing-Down Spectrometer	NDA:	Active Neutron	MCA
64	Neutron Collar	NDA:	Active Neutron	IU
65	Random Driver	NDA:	Active Neutron	MCA
66	Resonance-Neutron Radiography	NDA:	Active Neutron	MCA
67	SIGMA	NDA:	Active Neutron	MCA
68	Sb-Be Photoneutron Interrogation System	NDA:	Active Neutron	MCA
69	Shuffler (Californium-252)	NDA:	Active Neutron	MCA
70	Small Sample Assay System	NDA:	Active Neutron	MCA
71	Calorimeter	NDA:	Heat	MCA
72	Infrared Detector	NDA:	Heat	CS
73	On-Line Alpha Monitor	NDA:	Passive Alpha	PM
74	Autoradiography	NDA:	Passive Gamma	IU
75	Hand-Held Enrichment Monitor	NDA:	Passive Gamma	IU
76	High-Resolution Gamma-Ray Spectrometer	NDA:	Passive Gamma	MCA
77	Leached-Hull Monitor	NDA:	Passive Gamma	PM
78	NDA Reference Materials for Scrap and Waste	NDA:	Passive Gamma	MCA
79	Portable Microprocessor	NDA:	Passive Gamma	IU
80	Rocky Flats Assay Meter	NDA:	Passive Gamma	IU
81	Stabilized Assay Meter (SAM-II)	NDA:	Passive Gamma	IU
82	Threshold Detector for Gamma Spectrometry	NDA:	Passive Gamma	IU
83	Brookhaven Survey Assay Meter (BSAM)	NDA:	Passive N&G	IU
84	Fuel-Drawer Scanner	NDA:	Passive N&G	MCA
85	In-Line Liquid-Phase Enrichment Monitor	NDA:	Passive N&G	PM
86	Multi-Energy Gamma Assay System (MEGAS) II	NDA:	Passive N&G	MCA
87	Multichannel Analyzer (Portable)	NDA:	Passive N&G	MCA
88	Multichannel Analyzer (Stationary)	NDA:	Passive N&G	MCA
89	Spent-Fuel Multielement Detectors	NDA:	Passive N&G	IU
90	Ultrasonic Gauge	NDA:	Sound	MCA
91	Channel Coincidence Counter	NDA:	Passive Neutron	MCA
92	Dual-Range Thermal-Neutron Coincidence Counter	NDA:	Passive Neutron	MCA
93	High-Level Neutron Coincidence Counter (HLNCC)	NDA:	Passive Neutron	MCA
94	In-Line Thermal-Neutron Coincidence Counter	NDA:	Passive Neutron	MCA
95	Large Omnidirectional Neutron Detection System	NDA:	Passive Neutron	MCA
96	Neutron Well Coincidence Counter	NDA:	Passive Neutron	MCA
97	Portable Neutron Coincidence Counter	NDA:	Passive Neutron	IU
98	Reactor Power Monitor (New)	NDA:	Passive Neutron	IU
99	Reactor-Power Monitor (Old)	NDA:	Passive Neutron	IU
100	Reactor-Power Track-Etch Monitor	NDA:	Passive Neutron	IU
101	Shielded Neutron Assay Probe (SNAP)	NDA:	Passive Neutron	IU
102	Spectral-Index Core Monitor	NDA:	Passive Neutron	IU
103	Trap-Material Enrichment Meter	NDA:	Passive Neutron	MCA
104	Advanced Television Surveillance System (CCTV)	Optical Surveillance		CS
105	CANDU Closed-Circuit Television System	Optical Surveillance		CS
106	CANDU Film Camera System	Optical Surveillance		CS
107	Cerenkov Viewing (Night-Vision) Device	Optical Surveillance		IU
108	Computer-Controlled CCTV Alarm Assessment System	Optical Surveillance		CS
109	Deep-Drawn Container	Optical Surveillance		CS
110	Digital Timer (PI-200)	Optical Surveillance		CS
111	EURATOM TV System	Optical Surveillance		CS
112	Environment-Resistant CCTV Camera	Optical Surveillance		CS

Page in Sec VII	EQUIPMENT NAME	GENERAL TYPE	USE CAT.
113	Flight Research Camera	Optical Surveillance	CS
114	Fuel Verification Periscope	Optical Surveillance	CS
115	IAEA TV Transmission Security System	Optical Surveillance	CS
116	KFK Eumig Camera System	Optical Surveillance	CS
117	Kodak Analyst Camera	Optical Surveillance	CS
118	Minolta Surveillance Camera	Optical Surveillance	CS
119	NBS Surveillance Camera System	Optical Surveillance	CS
120	Polavision Cameras	Optical Surveillance	CS
121	Portable Television Surveillance System	Optical Surveillance	CS
122	Psychotronic Surveillance System	Optical Surveillance	CS
123	Robot Film Camera	Optical Surveillance	CS
124	Semi-Automatic Super-8 Movie Film Scanner	Optical Surveillance	CS
125	Semi-Automatic TV T pe Scanner	Optical Surveillance	CS
126	Spent-Fuel-Bundle (CANDU) Cerenkov Verifier	Optical Surveillance	IU
127	Television Surveillance System (NBS)	Optical Surveillance	CS
128	Television Surveillance System (SNL)	Optical Surveillance	CS
129	Zeiss Contarex Camera System	Optical Surveillance	CS
130	Gamma Walk-Through Doorway Monitor	Portal Monitor	CS
131	Personnel Doorway Monitor	Portal Monitor	CS
132	Portal Monitor (Booth-Type)	Portal Monitor	CS
133	Portal Monitor (Rotor-Type)	Portal Monitor	CS
134	Portal Neutron Monitor	Portal Monitor	CS
135	Portal Radiation Monitor	Portal Monitor	CS
136	Secure Counter Panel	Portal Monitor	CS
137	Unattended Personnel Portal Monitor	Portal Monitor	CS
138	Vehicle (Large) Portal Monitor	Portal Monitor	CS
139	Vehicle Gate (Sodium Iodide) Monitor	Portal Monitor	CS
140	Vehicle Gateside (Organic) Monitor	Portal Monitor	CS
141	Vehicle Portal Monitor (Liquid Scintillator)	Portal Monitor	CS
142	Vehicle Portal Monitor (Modular, He-3 Based)	Portal Monitor	CS
143	Vehicle Roadbed Monitor	Portal Monitor	CS
144	(Yes/No) Electronic Dosimeter	SNM Monitor	CS
145	(Yes/No) Radio-Luminescent Dosimeter	SNM Monitor	CS
146	Hand-Held Monitor	SNM Monitor	CS
147	Mechanical Cell Monitor	SNM Monitor	CS
148	Plutonium-Vault Neutron Monitoring System	SNM Monitor	CS
149	Radiation Monitor with High Alarm	SNM Monitor	PM
150	Shelf Monitor System	SNM Monitor	CS
151	Spent-Fuel Integrated Monitoring System	SNM Monitor	CS
152	Spent-Fuel Monitor (Scintillator)	SNM Monitor	IU
153	Thermoluminescent Dosimeter (TLD)	SNM Monitor	CS
154	Unattended Loading-Dock Monitor	SNM Monitor	CS
155	Unattended Material or Equipment Pass-Through	SNM Monitor	CS
156	Cup-and-Wire Seal (Improved Type E)	Seal	CS
157	Cup-and-Wire Seal (Type E)	Seal	CS
158	Fiber-Optic (Active) Seal	Seal	CS
159	Fiber-Optic (Digital) Seal	Seal	CS
160	Fiber-Optic (Passive) Seal (I)	Seal	CS
161	Fiber-Optic (Passive) Seal (II)	Seal	CS
162	Fuel-Assembly Ident. Device (BWR FAID Ultrasonic)	Seal	CS
163	Fuel-Assembly Ident. Device (MTR FAID Ultrasonic)	Seal	CS
164	Label (Adhesive) Seal	Seal	CS
165	Shrink-Tubing Seal for UF-6 Cylinder Valves	Seal	CS
166	Ultrasonic Cap Seal and Secure Rod	Seal	CS
167	Ultrasonic Cup-and-Wire Seal	Seal	CS
168	Ltwt Air-Trans. Accident-Resist. Container (LAARC)	Transportation	IU

Page in Sec VII	EQUIPMENT NAME	GENERAL TYPE	USE CAT.
169	Mobile Safeguards Van	Transportation	IU
170	Tight Shipping Container for Pu Oxide	Transportation	MCA
171	Digital Pressure Transducer	Volume Measurement	MCA
172	Pulsed Sonar Sounding Device	Volume Measurement	MCA
173	Quartz Bourdon-Tube Electromanometer	Volume Measurement	MCA
174	Time-Domain Reflectometer	Volume Measurement	MCA
175	Turbine-Flowmeter Automated Tank Calibrator	Volume Measurement	MCA

EQUIPMENT NAME : Ball Valves with Valve-Position Indicators
USE CATEGORY : Process Monitoring
GENERAL TYPE : Activity Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 185
SOURCE 1 : Jamesbury
REFERENCE 1 : AGNS35900-2.2-24

DESCRIPTION :
These valves (Model No. A36-TT) have limit switches which will indicate at a remote location whether the valves are open or closed.

EQUIPMENT NAME	:	Laser Spent-Fuel Cover
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Activity Monitor
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class I : Laboratory Device
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; 29. 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 the LSFC system generates 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 intrude. 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 not only is focused on the most appropriate region but also is free of distraction from events other than those with which the inspector is concerned with.

A model system has operated.

EQUIPMENT NAME : Secure Crane-Load Sensor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Activity Monitor
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 5,000
SOURCE 1 : SNL
SOURCE 2 : Toho
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : IWGRPS
REFERENCE DETAIL : Sellers; V. 2, 565.

DESCRIPTION :

The SNL device can detect heavy crane loads which are significant to safeguards. The monitor is intended to be installed on a 7.5-ton crane in a fuel-storage bay. A tamper-indicating container encloses the load cell electronics package and counter. A load cell rated at 4.5 tons is mechanically attached to the crane. The monitor divides the full-load range of the crane into six adjustable load-sensitivity zones to discriminate different classes of bundles and containers. Counters record the number of events in each load range. The dynamic range of the monitor is 100 to 10,000 pounds. No cost is available for this inactive system, which has been superseded by the "Spent-Fuel Integrated Monitoring System."

The Toho system is designed to record when the girder of the cask-handling crane travels with a load higher than some threshhold value. The motion is recorded on a paper disk with a 16-day capacity and battery power is available. This method is widely used for recording machine-tool usage. The cost for this system (TASTEX Task A) is given above, but its performance must be improved for safeguards purposes.

EQUIPMENT NAME	:	Ultrasonic Surveillance System
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Activity Monitor
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class II : Development Prototype
USEFUL TO	:	Inspector
FACILITIES	:	Fuel Storage
CAPITAL COST	:	25,000
SOURCE 1	:	Nukem
REFERENCE 1	:	1979 ESARDA
REFERENCE 2	:	1978 IAEA
REFERENCE DETAIL	:	1. Crutzen; 89. 2. Crutzen & Dennys; V. 1, 583.

DESCRIPTION :

This is, in effect, a Sonar system which senses the location of fuel assemblies, and other objects in a part of a spent-fuel storage pool or in a whole pool. The system may be used to record that individual assemblies have been moved or to record the history of motions of objects within the field of view.

The capital cost is for the ultrasonic interrogator.

EQUIPMENT NAME : Valve Tamper Device
USE CATEGORY : Process Monitoring
GENERAL TYPE : Activity Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 5
SOURCE 1 : Mercoid
REFERENCE 1 : AGNS35900-2.2-24

DESCRIPTION :

These mercury switches are attached to the handles of ball valves and set off an alarm whenever a handle is moved. (Model No. DA-961.)

EQUIPMENT NAME	:	CANDU Core Input Monitor
USE CATEGORY	:	Materials Accountancy
GENERAL TYPE	:	Bundle Counter
MATERIAL TYPE	:	Fresh Fuel
STATUS	:	Class III : Field Evaluation Unit
USEFUL TO	:	Inspector
FACILITIES	:	Reactor
CAPITAL COST	:	4,300
MAINTENANCE COST	:	640
REPLACEMENT COST	:	2,600
LIFETIME	:	5 Years
SOURCE 1	:	AECL White
REFERENCE 1	:	1978 IAEA
REFERENCE 2	:	IAEA-STR-90
REFERENCE DETAIL	:	Tolchenkov, Honami, Jung, Smith, Vodrazka & Head; V. 1, 407.

DESCRIPTION :

The core input monitor is designed to record forward and reverse movements of fresh fuel during on-line fueling of CANDU reactors. The instrument will monitor time, number of bundles moved, and will perform self-reliability checks and record unusual incidents. It is designed to be repairable by inspectors that have minimal maintenance background. The instrument is housed in a tamper-resistant containment and has its own internal power supply.

This monitor 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, a lower limit.

EQUIPMENT NAME : Pebble Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : Reactor
CAPITAL COST : 300,000
SOURCE 1 : KFA
REFERENCE 1 : 1978 IAEA
REFERENCE DETAIL : Buker & Engelhardt; V. 2, 507.

DESCRIPTION :

The fuel for the thorium high-temperature pebble-bed (THTR) reactor consists of spherical elements 6 cm in diameter containing thorium and U-235. The core of a prototype will contain 675,000 such pebbles, and item counting is the method adopted for keeping track of the fuel flow and for safeguard material accounting.

A total of 36 counters reside in the reactor fuel stream, making possible the definition of several different material-accounting areas. Signals from the counters can be processed by the operator and, independently, by the safeguard inspectorate.

EQUIPMENT NAME : Spent-Fuel-Bundle (CANDU) Gamma-Ray Verifier
USE CATEGORY : Inspector Use
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 70,000
REPLACEMENT COST : 26,000
SOURCE 1 : AECL Chalk
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.

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	:	Spent-Fuel-Bundle Counter (CANDU)
USE CATEGORY	:	Materials Accountancy
GENERAL TYPE	:	Bundle Counter
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class IV : Production Model
USEFUL TO	:	Inspector
FACILITIES	:	Reactor
CAPITAL COST	:	21,300
MAINTENANCE COST	:	850
REPLACEMENT COST	:	21,300
LIFETIME	:	15 Years
SOURCE 1	:	AECL Chalk
REFERENCE 1	:	AECL-6209
REFERENCE 2	:	Nuc. Mat.
REFERENCE DETAIL	:	Zarecki, Smith, Head & Duncan; V. IX, No. 2, 49 (1980).

DESCRIPTION :

Irradiated fuel bundles from CANDU reactors 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, even when transferred in groups. 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 Counter (Sandia)
USE CATEGORY	:	Materials Accountancy
GENERAL TYPE	:	Bundle Counter
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class III : Field Evaluation Unit
USEFUL TO	:	Inspector
FACILITIES	:	Reactor
CAPITAL COST	:	71,000
REPLACEMENT COST	:	51,000
SOURCE 1	:	SNL
REFERENCE 1	:	1976 IAEA
REFERENCE 2	:	SAND 80-0002
REFERENCE DETAIL	:	Sinden, Hodgkinson, Campbell & Kosanke; 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.

The system has operated at the Pickering CANDU reactor station since 1976. Newer CANDU reactors will use the "CANDU Spent Fuel-Bundle Counter."

EQUIPMENT NAME : Spent-Fuel-Element Monitor
USE CATEGORY : Process Monitoring
GENERAL TYPE : Bundle Counter
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 2,000
LIFETIME : 10 Years
SOURCE 1 : CEGB
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Walker; 461.

DESCRIPTION :

This device records the passage of irradiated fuel elements from a reactor with on-load fuelling. Two Geiger-Mueller tubes with a logarithmic response circuit are able to measure a gamma flux range of (1-10,000) R/hr. A prototype instrument is in operation at a British magnox reactor. The discharged fuel elements, when measured, give an estimated minimum flux of 150 R/hr.

EQUIPMENT NAME : Computerized Material-Control & Accounting System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Communication
MATERIAL TYPE : Plutonium
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 2,400,000
SOURCE 1 : DEC
SOURCE 2 : AGNS
REFERENCE 1 : AGNS35900-2.3-76

DESCRIPTION :

The system provides near-real-time capability for controlling and accounting for nuclear materials for the Barnwell Nuclear Fuel Plant (a 5 ton/day reprocessing plant). It is intended to satisfy regulatory needs and provide information for materials management in the facility. Most of the component parts and subsystem would find application in other types of facilities.

The capital cost shown includes some optional equipment, spare parts and installation but not all measurement instruments or electrical lines from them that were included in the facility design originally. The measurement systems included in the cost take about $500,000. Local area processors (five) are PDP 11/44 systems. The central area processor is a PDP 11/70. Also included are a number of input-output terminals, graphics displays, instrument packages and interfaces and other peripherals (for data storage, for example). The cost for development of software for the system at Barnwell is estimated at approximately $4,000,000. The following major areas were covered: fuel reprocessing and storage, separations, Pu nitrate storage, UF-6 plant, Pu product plant, hot and cold laboratory, waste and storage.

EQUIPMENT NAME : DYMAC
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Communication
MATERIAL TYPE : Plutonium
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
SOURCE 1 : LANL
REFERENCE 1 : Nuc. Mat.
REFERENCE 2 : Anal. Chem.
REFERENCE DETAIL : 1. Malanify, Bearse & Christensen; V. IX, No. 4, 30 (1980). 2. Marshall; 305.

DESCRIPTION :

An accountancy system based on the Dynamic Materials Accountability (DYMAC) System has been in operation at the Plutonium Processing Facility at the Los Alamos National Laboratory since January 1978. This system has enhanced nuclear material accountability and process control at the facility. The nondestructive assay instruments and the central computer system are operating accurately and reliably. As anticipated, several uses of the system have developed in addition to safeguards, notably scrap control and quality control.

The system incorporates a Data General Eclipse C330 computer connected to 15 electronic balances and 23 remote terminals. Data about Pu transactions in the facility based on reprocessing steps are inserted into the computer via the terminals. There are, in addition, 21 other electronic balances, 3 solution assay instruments for Pu and Am measurements, 2 segmented gamma scanners for measuring Pu in scrap, and 18 thermal neutron coincidence counters for measuring Pu in bulk.

EQUIPMENT NAME	: Integrated Process & Safeguards Monitoring Systems
USE CATEGORY	: Process Monitoring
GENERAL TYPE	: Communication
MATERIAL TYPE	: Plutonium
STATUS	: Class III : Field Evaluation Unit
USEFUL TO	: Operator and Inspector
FACILITIES	: Reprocessing
SOURCE 1	: AGNS
SOURCE 2	: ENICO
REFERENCE 1	: ENICO
REFERENCE 2	: AGNS35900-2.2-24
REFERENCE DETAIL	: Cartan & Johnson.

DESCRIPTION :

This computer-controlled and operated system is designed to monitor key process variables and to notify the operators if any preset limiting values are exceeded. The system makes use of several kinds of transducers that are commercially available and indicate high liquid levels, low flows, high radiation levels, electrolyte concentrations, valve activation, increasing or decreasing pressures, and valve positions. (Some of these devices are described elsewhere in this document.) In addition to process monitoring, the system is usable for indicating diversion or tampering involving out-of-cell lines with access to, for example, product solutions. Such a system has been demonstrated on a portion of the Barnwell reprocessing plant.

A similar system at the Idaho Chemical Processing Plant includes indicators of portal and perimeter monitors and radiation alarms and provides the safeguards officer with the ability to examine system inputs in light of their historical values.

EQUIPMENT NAME : Plutonium Product-Area Monitor
USE CATEGORY : Process Monitoring
GENERAL TYPE : Communication
MATERIAL TYPE : Miscellaneous
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 100,000
SOURCE 1 : ENICO
REFERENCE 1 : TASTEX
REFERENCE 2 : 1979 INMM
REFERENCE DETAIL : 1. Task I.
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. Sensors in the system, as installed at the Power Reactor and Nuclear Fuel Development Corporation (PNC) plant (Tokai-mura, Japan) include high-precision pneumatic bubbler-probe signals, plant precision level and density signals, thermocouples, load-cell signals, valve status signals, and assorted signals from pumps and other monitors. There are approximately 200 signals. The computer is equipped with flexible disc drives and other accessories include interface equipment, multiplexers, etc. Presently, further development effort is underway largely concerned with data analysis and performance evaluation. The capital cost shown is an estimate for the computer and interfacing equipment only and does not include the sensors as these are usually in a plant of this type already.

EQUIPMENT NAME	: RECOVER Monitoring Unit
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Communication
MATERIAL TYPE	: Miscellaneous
STATUS	: Class II : Development Prototype
USEFUL TO	: Inspector
FACILITIES	: All
CAPITAL COST	: 100
REPLACEMENT COST	: 100
LIFETIME	: 6 Years
SOURCE 1	: TRW
REFERENCE 1	: Recover Cost
REFERENCE 2	: ARC 54-5699

DESCRIPTION :

The RECOVER Monitoring Unit is the device which links one piece of safeguards equipment at a facility to the RECOVER network. It encrypts status information for relay to the electronic network and is physically part of the safeguards equipment.

The capital cost assumes production of between one and five thousand devices, but it does not include profit for the manufacturer. This unit is discarded upon failure.

EQUIPMENT NAME	: RECOVER On-Site Multiplexer
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Communication
MATERIAL TYPE	: Miscellaneous
STATUS	: Class II : Development Prototype
USEFUL TO	: Inspector
FACILITIES	: All
CAPITAL COST	: 1,850
REPLACEMENT COST	: 1,850
LIFETIME	: 2 Years
SOURCE 1	: TRW
REFERENCE 1	: Recover Cost
REFERENCE 2	: ARC 54-5699

DESCRIPTION :

The RECOVER On-Site Multiplexer integrates encrypted signals from safeguards equipment at a facility for phone transmission to Vienna or for interrogation at the facility by a portable verifier. It can temporarily store the interrogation data, provide immediate notice of the monitors' status, allow local programming of the monitors, and sustain itself by battery power through a short power failure.

The capital cost assumes production of at least 200 units and does not include manufacturer profit. Though not all parts would require maintenance, the simplest assumption is that replacement occurs upon failure.

EQUIPMENT NAME	:	RECOVER Portable Verification Unit
USE CATEGORY	:	Inspector Use
GENERAL TYPE	:	Communication
MATERIAL TYPE	:	Miscellaneous
STATUS	:	Class I : Laboratory Device
USEFUL TO	:	Inspector
FACILITIES	:	All
CAPITAL COST	:	3,000
REPLACEMENT COST	:	3,000
LIFETIME	:	2 Years
SOURCE 1	:	TRW
REFERENCE 1	:	Recover Cost
REFERENCE 2	:	ARC 54-5699

DESCRIPTION :

The RECOVER Portable Verification Unit is used by inspectors to service the RECOVER communications components in facility safeguards equipment. Approximately one unit would be required for each eight facilities.

The capital cost is based on production of at least 200 units, but does not include manufacturer's profit. The simplest maintenance assumption is replacement upon failure.

It is likely that this unit will be superseded by two units, a computer terminal resident at the facility and able to transmit alphanumeric information and a small portable device for setting the encryption code.

EQUIPMENT NAME : RECOVER Resident Verification Unit (RVU)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Communication
MATERIAL TYPE : Miscellaneous
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 40,000
LIFETIME : 15 Years
SOURCE 1 : TRW
REFERENCE 1 : ARC 54-5699
REFERENCE 2 : Recover Cost

DESCRIPTION :

The RVU is the central control point of the RECOVER system. It is an automated data logger and telephone dialer, capable of monitoring all monitoring units in the system. It provides for automatic (unattended) polling of up to ninety on-site multiplexers (OSM). The unit also provides for notification of key personnel in case of alarm conditions. Direct interrogation of individual OSMs is possible manually (via system console) or automatically (via programming). All communications between RVU and OSM, as well as those communications between RVU and key personnel, are logged and stored in the system memory or provided in tabular form as hard copy, or both.

The RVU consists of a microcomputer, disk memory, a console with keyboard and cathode-ray-tube display, a printer, a universal programmer for programmable read-only memories, a clock, a telephone data set, and an audible status code generator and access code interpreter.

The capital cost covers these items.

EQUIPMENT NAME : RECOVER System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Communication
MATERIAL TYPE : Miscellaneous
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : All
MAINTENANCE COST : 250,000
LIFETIME : 15 Years
SOURCE 1 : TRW
REFERENCE 1 : ARC 54-5699
REFERENCE 2 : Recover Cost

DESCRIPTION :

RECOVER (REmote COntinual VERification) is an advanced system for determining the status of safeguards equipment at nuclear facilities by telephone communications from the IAEA in Vienna. Component sub-systems, aside from the actual safeguards equipment, include thousands of Monitoring Units, one On-Site Multiplexer per facility, one Portable Verification Unit per each eight facilities, and one Resident Verification Unit (RVU) in Vienna. The system itself is designed to be secure and tamper-indicating.

The maintenance cost includes telephone costs, maintenance contracts, and spare parts for the RVU for one year, but not costs for maintaining the remote and portable units. This annual operational cost is based on a network of 200 facilities around the world called once per week.

EQUIPMENT NAME : High-Precision Level and Density Sensor Box
USE CATEGORY : Process Monitoring
GENERAL TYPE : Density Measurement
MATERIAL TYPE : Liquids
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 10,000
SOURCE 1 : ENICO
SOURCE 2 : Parosci
REFERENCE 1 : ENICO
REFERENCE DETAIL : Boland & Deveraux.

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, as a diversion monitor, can detect very small changes in tank volumes.

The High-Precision Level and Density Sensor Box contains two Paroscientific "Digiquartz" 0-15 pounds per square inch (differential) pressure transducers and a pneumatic multiplexer. 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 operation by computer and for use and maintenance in the difficult environment of a chemical processing plant. The box also provide for on-line calibration checks for the two 0.015% pressure transducers.

EQUIPMENT NAME : Vibrating Tube (Anton-Parr) Densimeter
USE CATEGORY : Process Monitoring
GENERAL TYPE : Density Measurement
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 6,000
SOURCE 1 : Mettler
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : AGNS35900-2.4163
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 and 0.000001 g/cc for the DMA-60.

EQUIPMENT NAME	: Bar Coding
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Identification
MATERIAL TYPE	: Miscellaneous
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: All
CAPITAL COST	: 10,700
LIFETIME	: 25 Years
SOURCE 1	: Motorola
SOURCE 2	: Intermec
REFERENCE 1	: TSO
REFERENCE 2	: Kiawah
REFERENCE DETAIL	: 1. A. Bieber; June, 1980. 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 supermarkets. A printer for $6000, a portable reader with memory for $1700, and a multiplexer that can handle results from 10 readers for $3000 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.

The equipment is commercially available, but the safeguards applications are under development.

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

EQUIPMENT NAME	:	Fuel-Assembly Ident. Device (FAID Eddy-Current)
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Identification
MATERIAL TYPE	:	Fuel
STATUS	:	Class II : Development Prototype
USEFUL TO	:	Inspector
FACILITIES	:	Reactor Fabrication Reprocessing Fuel Storage
CAPITAL COST	:	3,000
MAINTENANCE COST	:	10
SOURCE 1	:	SNL
SOURCE 2	:	Westinghse
REFERENCE 1	:	1980 ESARDA
REFERENCE 2	:	SAND 80-0002
REFERENCE DETAIL	:	McKenzie, Deveney, Sheldon, Sellers, Miller, Oaks & Denero; 458.

DESCRIPTION :

In some cases it may be possible to verify integrity of a container by employing nondestructive testing techniques. In order to remove and replace fuel rods in a PWR fuel assembly it is necessary to replace a "thimble tube" on top of the fuel nozzle plate. The several welds in a thimble tube have unique positions and features which it would be difficult to reproduce exactly. This technique employs electromagnetic coils, precisely located, to derive a unique eddy-current pattern from the thimble-tube welds.

The capital cost is for the verifier and the maintenance cost, for the seal itself.

EQUIPMENT NAME : Fuel-Assembly Ident. System (Magnetic-Inclusion)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Identification
MATERIAL TYPE : Fuel
STATUS : Class I : Laboratory Device
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 :

Magnetic (iron) inclusions in the uranium dioxide fuel of light-water reactors produce measurable signals when scanned with an inductance measuring system. Research indicates that such nondestructive measurements might be usable for rapid fuel-assembly identification by nonnuclear methods since the magnitude and frequency, but not the location, of the inclusions can be controlled during fuel-assembly manufacture. It is not yet known whether the method will work for irradiated fuel.

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	: Inspector
FACILITIES	: Reprocessing
	Enrichment
CAPITAL COST	: 200,000
REPLACEMENT COST	: 100,000
SOURCE 1	: Ames
REFERENCE 1	: 1981 ESARDA
REFERENCE DETAIL	: Edelson & Fassel; p. 17.

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 are presented along with high-resolution spectra of simulated dissolver (spent-fuel) solutions.

The inductively coupled plasma offers the potential for near-real-time, on-line analysis of the dissolver solutions at a nuclear fuel reprocessing facility. These analyses, which can be performed accurately and rapidly, when combined with isotopic correlation techniques, 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 materials balance of the facility.

The capital cost estimate covers spectroscopic and plasma-generating equipment, a small computer, and installation; the estimate is rough because of the early stage of the work.

EQUIPMENT NAME	: Mass Spectrometer (On-Line Gas-Phase)
USE CATEGORY	: Process Monitoring
GENERAL TYPE	: Isotope Measurement
MATERIAL TYPE	: Uranium Hexafluoride
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: Enrichment
CAPITAL COST	: 430,000
MAINTENANCE COST	: 10,000
SOURCE 1	: MAT
SOURCE 2	: VG Isotope
REFERENCE 1	: 1978 IAEA
REFERENCE 2	: 1981 ESARDA
REFERENCE DETAIL	: 1. Minato; V. 1, 219. 2. Merren, Cantle & Welch; 19.

DESCRIPTION :

An on-line gas-phase mass spectrometer is a general analytical tool specially installed to determine the U-235 enrichment of the process uranium-hexaflouride gas in an enrichment plant. The use of a gas-phase instrument eliminates several of the biases caused by chemical procedures required for sample preparation for thermal-emission mass spectrometry.

The costs given are for a representative machine.

EQUIPMENT NAME	: Mass Spectrometer (Thermal-Emission)
USE CATEGORY	: Process Monitoring
GENERAL TYPE	: Isotope Measurement
MATERIAL TYPE	: Laboratory Samples
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: Fabrication Enrichment Reprocessing
CAPITAL COST	: 290,000
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. Consider, e.g., reprocessing.

Three recent developments, when combined, have the potential for greatly improving accountability measurements in the nuclear fuel cycle. The techniques are particularly valuable when measuring the contents of vessels difficult to calibrate by weight or volume. Input dissolver accountability measurements, in particular, benefit from the application of these techniques: (1) the capability for isotopic analysis of U and Pu samples at the nanogram level with an accuracy of 0.1 relative %; (2) the capability of preparing mixed, solid metal U and Pu spikes with an accuracy of better than 0.1 relative %; and (3) the 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 and laboratories supply thermal-emission mass spectrometers, though highly sensitive, multi-stage devices tend to be custom built.

The costs given are for one representative machine.

EQUIPMENT NAME : Mass Spectrometer (Transportable Quadrupole)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Isotope Measurement
MATERIAL TYPE : Laboratory Samples
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Enrichment
Fabrication
Reprocessing
CAPITAL COST : 215,000
SOURCE 1 : Balzers
SOURCE 2 : ENICO
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : ENICO
REFERENCE DETAIL : 1. Facchetti, Federico, Guzzi, Huber & Rettinghaus; 149.
2. Echo.

DESCRIPTION :

A commercially available, quadrupole mass spectrometer installed in a truck has served as a field laboratory for the analysis of gaseous uranium hexaflouride 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 less than 10 parts per million. The instrument is therefore capable of measuring the minor-isotope ratios reasonably pecisely as well as the major-isotope ratio more precisely. These comments suggest the applications for enrichment and fabrication plants. Other applications exist for reprocessing plants.

The capital cost is for a fully automated and computer-controlled instrument. A similar system using a Hewlett-Packard spectrometer modified by ENICO would cost about $100,000.

EQUIPMENT NAME : Balances (Electronic)
USE CATEGORY : Process Monitoring
GENERAL TYPE : Mass Measurement
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 5,000
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 facilitate processing monitoring and materials-accountancy measurements in reprocessing plants, where crucial measurements of reactor Pu production are made and such Pu purified.

A precision balance can increase the precision of mass measurements 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 3 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 (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. The Sartorius electronic balances employ the electromagnetic-force-compensation system for weighing.

The cost given is for a 60 kg top-loading Sartorius balance. An analytical balance for gram samples would cost about the same. Calibrated stainless-steel weight sets for such balances cost about $1000.

EQUIPMENT NAME : Load Cells
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Mass Measurement
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 15,000
SOURCE 1 : Kyowa
SOURCE 2 : BLH
REFERENCE 1 : TASTEX
REFERENCE DETAIL : Task D

DESCRIPTION :

Load cells based on strain gauges are produced by a number of manufacturers. They are capable of giving weights directly for large process or storage vessels provided. Such vessels are not rigidly connected to other parts of the system. A typical installation at Tokai in Japan uses special radiation-resistant, precision-grade load cells manufactured by Kyowa.

EQUIPMENT NAME	:	Semi-Portable Cylinder Load Cell
USE CATEGORY	:	Inspector Use
GENERAL TYPE	:	Mass Measurement
MATERIAL TYPE	:	Uranium Hexafluoride
STATUS	:	Class II : Development Prototype
USEFUL TO	:	Inspector
FACILITIES	:	Fabrication
		Enrichment
CAPITAL COST	:	20,000
MAINTENANCE COST	:	3,000
SOURCE 1	:	BLH
SOURCE 2	:	NBS
REFERENCE 1	:	POTAS
REFERENCE 2		1981 INMM
REFERENCE DETAIL		1. Task A.40, 69.
		2. Suda, Pontius & Schoonover, 39

DESCRIPTION

Two systems for weighing cylinders are under consideration. The first is a semi-portable load-cell-based system designed for weighing 2.5 metric ton uranium hexafluoride shipping cylinders. The system, which includes a digital display, accurately weighs checkweights to within one-half kg. It also can be disassembled and assembled in about twenty minutes. The cost is 3/4 for the weighing system and 1/4 for a hoist. Infrequent calibration would cost about $500

The second system is bulkier but involves a load cell under continual stress, thereby improving weighing accuracy.

The load cells themselves are commercial devices. It is the specific portable weighing systems that are under development.

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
USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
Fabrication
CAPITAL COST : 90,000
SOURCE 1 : Paducah
REFERENCE 1 : ORO-651

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 fulfilled, two each of 2.5-ton, 10-ton, and 14-ton UF6 cylinders were made as pressure vessels. One of each size was cut open and filled with lead and concrete to mimic the weight of filled cylinders. Their 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. They are intended 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 1000 pound block

EQUIPMENT NAME : Conductivity-Level Device
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 300
SOURCE 1 : L&N
SOURCE 2 : Honeywell
REFERENCE 1 : AGNS35900-2.2-24
REFERENCE 2 : ORNL TM-7340

DESCRIPTION :

Conductivity-level devices are low-cost instruments for accurate, continuous monitoring of electrolytic conductivity. They are used to determine if liquids are present in process lines normally filled with air.

Though rugged, these devices require intrusive installation in piping.

EQUIPMENT NAME : Electromagnetic Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 2,000
SOURCE 1 : F&P
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. The meter can be operated in a radioactive environment and has been used at U.S. Government reprocessing plants for several years. Precision and accuracy of 1% or better are possible. The meter can be used in pipes as small as 0.25 cm, at a cost proportional to pipe diameter.

The cost given is for the F&P model 10D1419, capable of measuring flows from 40 cc per minute to 700,000 gallons per minute. The cost is from the April, 1981 issue of MEASUREMENTS & CONTROL.

EQUIPMENT NAME	: Fuel-Pellet Inspection System
USE CATEGORY	Process Monitoring
GENERAL TYPE	: Material Monitor
MATERIAL TYPE	: Fresh Fuel
STATUS	: Class II : Development Prototype
USEFUL TO	: Operator
FACILITIES	: Fabrication
CAPITAL COST	: 425,000
SOURCE 1	: HEDL
REFERENCE 1	: Kiawah
REFERENCE DETAIL	: McLemore & Nyman, 342

DESCRIPTION :

A major operation in the fuel-fabrication process is the inspection of fuel pellets for dimensions (length and diameter), surface flaws, and weight, traditionally done on a sampling basis. To minimize sampling limitations due to economics and personnel exposure and to provide enhanced quality assurance information and improved SNM accountability, an automated gaging system has been designed and fabricated that measures these attributes on fuel pellets at a rate of one pellet per second.

The pellet gaging system is divided into two parts: (1) mechanical and (2) electronic. The mechanical portion consists of a pellet handling system; inspection stations for measuring length, diameter, weight, and surface flaws; a glovebox-like containment which isolates SNM; and associated hardware from the surrounding environment. The length, diameter, and surface flaw inspections utilize laser optical systems with solid-state detection devices. A standard scale statistically samples pellets to determine pellet densities.

The electronic portion of the gaging system consists of a process control system, a small dedicated minicomputer, and a supevisory computer system. The dedicated computer system is used to control the operation of the mechanical handling system, synchronize data inputs and outputs with the handling cycle, process data, and sort the fuel pellets into one of three categories: acceptable, rejectable, and hold (oversize diameter for centerless grinding).

EQUIPMENT NAME	: Gyroscopic-Coriolis Mass Flowmeter
USE CATEGORY	: Materials Accountancy
GENERAL TYPE	: Material Monitor
MATERIAL TYPE	: Liquids
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: Reprocessing
CAPITAL COST	: 4,000
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 gryoscopic-coriolis mass flowmeter is a patented device. The angular deflection of a U-shaped pipe is measured optically as the pipe is subjected to oscillation. Four sizes of meter are available, covering mass flow rates from 2 to 230 kg/min. Continuous computer-operated data recording is possible. The instrument has been shown by Allied-General Nuclear Services to provide an accuracy of 0.5% in measuring mass flow of process streams.

The cost is $1500-4000 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 : Optical Liquid In-Line Sensor
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 100
SOURCE 1 : Hi-G
SOURCE 2 : Sens. Tech
REFERENCE 1 : ORNL TM-7340

DESCRIPTION :

Optical devices may be used to detect the presence of liquid in a small-diameter, horizontal line that is partially (about 25%) full of liquid. The Hi-G device uses a light-transmitting probe with a commercial tip which acts as a prism, normally (no liquid present) reflecting most of the light back to a sensor. In contact with a liquid (index of refraction greater than air's), the probe's light is refracted away and not returned to the sensor. It operates from -32 deg. C to 121 deg. C. Although intrusive it is rugged and reliable and also "fails-safe" (i.e., alarms on failures).

The Sens. Tech. device employs a light-emitting diode and a photon-sensing transistor. An alarm sounds when the light path is interrupted by a liquid. It operates from -40 deg. C to 85 deg. C but is intrusive.

EQUIPMENT NAME	:	Orifice Flowmeter
USE CATEGORY	:	Materials Accountancy
GENERAL TYPE	:	Material Monitor
MATERIAL TYPE	:	Liquids
STATUS	:	Class IV : Production Model
USEFUL TO	:	Operator and Inspector
FACILITIES	:	Reprocessing
CAPITAL COST	:	1,000
SOURCE 1	:	
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. Orifice meters are used for process control in U.S. Government reprocessing plants and are incorporated in several areas of the Allied-General Nuclear Services plant at Barnwell, South Carolina.

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	: Pressure Switches
USE CATEGORY	: Process Monitoring
GENERAL TYPE	: Material Monitor
MATERIAL TYPE	: Gases or Liquids
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: Reprocessing
CAPITAL COST	: 70
LIFETIME	: 10 Years
SOURCE 1	: Mercoid
SOURCE 2	: SOR
REFERENCE 1	: ENICO
REFERENCE 2	: AGNS35900-2.2-24

DESCRIPTION :

Pressure switches will detect a pressure increase or decrease which is more than the preset range. The Mercoid one (Model DA-521-3) is used to monitor the pressure in an air purge pipe to ensure that abnormal values and possible illicit liquid Pu flows are detected.

The SOR one can be used to monitor operation of pneumatic valves, samplers, and transfer jets or to detect vacuum in instrument lines or overpressure in storage vessels. The switch withstands 1500 pounds per square inch over its designated range, steam temperatures, and is available in a stainless steel housing.

EQUIPMENT NAME : Thermal Flow Sensor
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Gases or Liquids
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Enrichment
Fabrication
CAPITAL COST : 100
SOURCE 1 : ENICO
REFERENCE 1 : ENICO
REFERENCE DETAIL : Bentzen.

DESCRIPTION :

The thermal sensor detects small flows of liquids or gases in process or instrument lines. It will be 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. The sensor is nonintrusive. 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.

EQUIPMENT NAME : Thermal Flowmeter with Low-Flow Alarm
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Gases or Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Conversion
Enrichment
Fabrication
CAPITAL COST : 730
SOURCE 1 : FCI
SOURCE 2 : Celesco
REFERENCE 1 : AGNS35900-2.2-24

DESCRIPTION :

These devices detect variations in flow velocity by sensing changes in the heat transfer properties of the flowing liquid. The FCI sensor consists of three thermowelds, which contain a matched pair of resistive temperature sensors (one active and one reference), and a low-powered heating element. The heater is located so that it will always heat the active temperature sensor. This creates a temperature difference between the active and reference sensors which can be converted to flow rate. Of Model 12-64-4 or Model FR-70-4, the former is less sensitive and the price is given above; the latter costs $1000.

Detection in the Celesco sensor is achieved by a sensing thermoresistor, a reference thermoresistor, and a heater. The heater is located in the flow stream so that during flow the heat is carried away from both sensors. When the flow stops, convection currents heat one sensor above the temperature of the other, signaling a flow stoppage.

Extremely stable in operation, this unit is virtually unaffected by line voltage fluctuations and wide temperature changes in fluids or ambient conditions. The Celesco Model No. MF-10 costs $575.

The flowmeter is used to detect the presence of liquid in a process line designed for air.

EQUIPMENT NAME : Transfer-Jet Monitor
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 100
SOURCE 1 : ENICO
REFERENCE 1 : ENICO
REFERENCE DETAIL : Deveraux & Wagner.

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 or resistance-temperature detector 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 includes an estimate for installation.

EQUIPMENT NAME : Tubing Block
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Gases or Liquids
STATUS : Class II : Development Prototype
USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 100
SOURCE 1 : ENICO
REFERENCE 1 : ENICO
REFERENCE DETAIL : E.P. Wagner.

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 : Ultrasonic Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,830
SOURCE 1 : L&N
SOURCE 2 : ENICO
REFERENCE 1 : LA-8042
REFERENCE 2 : ENICO-1027
REFERENCE DETAIL : 1. Hakkila, Ostenak, & Thomas, Jr.; V. III, App. L.
2. Piper; 16.

DESCRIPTION :

There are three types of flowmeters employing ultrasonic techniques. The first is based on the charge 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 is a bubble-transit flowmeter based on the use of ultrasonic sensors to measure the passage of injected or random bubbles in the flowing fluid. The ultrasonic detectors are mounted exterior to process lines and are designed primarily for low flow rates. The flowmeter is being developed and evaluated at the Idaho Chemical Processing Plant (ICPP). Periodic recalibration is not required except to reduce systematic errors, and the instrument is not susceptible to plugging or corrosion. Accuracy of 0.5% has been demonstrated. The third 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 also 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. The cost is from the October, 1980 issue of MEASUREMENTS & CONTROL.

EQUIPMENT NAME : Ultrasonic Level Detector with High Alarm
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 310
SOURCE 1 : Nat. Son.
SOURCE 2 : Sensor
REFERENCE 1 : AGNS35900-2.2-24
REFERENCE 2 : ORNL TM-7340

DESCRIPTION :

This unit uses an ultrasonic signal that can be transmitted through the walls of a pipe or vessel filled with liquid but will not transmit when the vessel is filled with a gas, which is the normal condition for air purge lines.

Ultrasonic detection is unaffected by variations in temperature, pressure, reflected light, liquid conductivity, or vibration. A particular advantage is that the ultrasonic sensor can be attached nonintrusively to existing piping. Disadvantages are that very low levels or flows through plastic tubes within the main pipe or flows through very narrow pipes (less than 1.4 cm in outer diameter, and 0.93 cm in inner diameter) are not reliably detected.

The Nat. Son. detector (Model No. 621S-16) can also have a high-level alarm. The cost is for a detector without a control unit.

EQUIPMENT NAME : Ultrasonic Liquid In-Line Sensor
USE CATEGORY : Process Monitoring
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Liquids
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 3,000
SOURCE 1 : ENICO
REFERENCE 1 : ENICO 1071

DESCRIPTION :

This 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 : Vortex-Shedding Flowmeter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Material Monitor
MATERIAL TYPE : Gases or Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,000
SOURCE 1 : F&P
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. A vortex-shedding meter that measures the rate of vortex formation by using a heated thermistor will be evaluated at Los Alamos National Laboratory and at Oak Ridge National Laboratory. An accuracy of 0.5% is claimed for the meter, but this claim has not been evaluated under reprocessing plant conditions.

Another vortex-shedding flowmeter uses a piezoelectric sensor to monitor liquids or gases, including superheated steam. In this flowmeter, vortex-induced deformations of a stainless steel bar placed in a fluid stream are detected by a piezoelectric sensor within the bar. The flowmeter electronics translate these deformations into frequency, which is directly proportional to flow rate. Advantages of the sensor used in this flowmeter include (1) no fluid contact, (2) higher temperature limits, (3) reduced corrosion problems, and (4) no moving parts.

The cost is from the June 1980 issue of MEASUREMENTS & CONTROL for the F&P model 10LV2000, with a flow range of 3 to 150 gallons per minute.

EQUIPMENT NAME : Gamma Absorptiometer
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 : Conversion
SOURCE 1 : CEA
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Raymond & Neuilly; 382.

DESCRIPTION :

This device consists of an Americium-241 source (which emits 59.6-KeV gamma rays), a measuring cell through which a solution of uranyl nitrate passes, a sodium iodide detector, and electronics. The attenuation of the gamma rays is a measure of concentration. The system has been used on the input to a 20 kg U/hour conversion unit (nitrate to oxide). It is used in conjunction with a turbine flowmeter and an electronic scale (on the output). The three on-line measurements are fed to a programmable calculator.

EQUIPMENT NAME	: Gamma Absorptiometer (Dual-Energy)
USE CATEGORY	: Materials Accountancy
GENERAL TYPE	: NDA: Active Gamma
MATERIAL TYPE	: SNM in Solutions
STATUS	: Class II : Development Prototype
USEFUL TO	: Operator
FACILITIES	: Reprocessing Fabrication
CAPITAL COST	: 20,000
SOURCE 1	: ENICO
REFERENCE 1	: ENICO
REFERENCE DETAIL	: Cartan.

DESCRIPTION :

This in-line instrument measures concentrations of uranium or plutonium solutions in plant product or final-separations areas. It was designed for a concentration range of 0-300 g/l of either plutonium or uranium in nitric-acid solution. The instrument is not element-specific. It corrects for solution radioactivity and for variations in the nitric-acid concentration.

The instrument consists of two sources, Am-241 (59.6 KeV) and Cs-137 (622. KeV), each mounted colinearly with collimators and sodium iodide gamma detectors. Each radiation beam can be remotely shuttered and arranged to measure the count rate of the sources through either a sample flow cell or a standard absorber. The ratio of the count rates is a function of the concentration of the solution. The instrument is operated by a small computer. A version of this instrument is installed in the Italian processing plant near Saluggia.

EQUIPMENT NAME : In-Line Gas-Phase Enrichment Meter
USE CATEGORY : Process Monitoring
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
SOURCE 1 : LANL
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : LA-8657-MS
REFERENCE DETAIL : Strittmatter & Tape; 127.

DESCRIPTION :

A laboratory prototype for a gas-phase UF6 enrichment meter was tested at UF6 pressues of 10 to 680 torr and 27 degrees C. The enrichment is determined by a count rate of 186-keV gamma rays from U-235 and a measurement of the transmission through the UF6 gas by 60-keV gamma rays from an Am-241 source. The pressure range covers most of the range encountered in existing enrichment plants.

The prototype system consists of a sample chamber, a sodium iodide detector, and the source. The sample chamber is instrumented with thermocouples and a precision capacitive manometer for temperature and pressure measurements.

Enrichments are expected to be determined with a relative precision of 1%.

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
USEFUL TO	: Operator
FACILITIES	: Fabrication Reprocessing
CAPITAL COST	: 250,000
SOURCE 1	: LANL
REFERENCE 1	: 1980 INMM
REFERENCE DETAIL	: Russo, Hsue, Langer & Sprinkle, Jr.; 730.

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 make 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	:	Segmented Gamma Scanner
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	:	94,250
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 bottles or cans).

The 414-KeV Pu-239 gamma activity, the 765-KeV Pu-238 gamma activity, or the 186-KeV U-235 gamma activity is measured with a collimated Ge(Li) gamma detector. A suitable isotopic 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 absorption 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 present in the sample.

The data from the multichannel analyzer 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 minute after the scanning is completed.

The Jomar model scans with a stepping motor and has a different control procedure from that of the Canberra model, for which the price applies.

EQUIPMENT NAME : X-Ray Fluorescence (Portable)
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Active Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 55,000
SOURCE 1 : CEA
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Perolat, Monier, Sanson & Orloff; 368.

DESCRIPTION :

The technique is based on the emission and detection of K-x-rays resulting from gamma-ray excitation of uranium and plutonium in solution. The technique is employed in a portable inspection instrument. The excitation source is Iridium-192 which is collimated and filtered. The sample chamber has a volume of 30 cc. The detector is high-purity Ge with collimation. The output is fed to a multichannel analyzer and a calculator. K-x-rays from uranium (94.7 KeV) and plutonium (103.7 KeV) are most free of interference. Analysis of U-Th solutions having a concentration of 15 mg/cc yield an uncertainty (2-sigma) of approximately .06 mg/cc.

Under development is use of the technique for determination of the Pu/U ratio in the pellets and pins of fast-neutron reactor fuel.

EQUIPMENT NAME	: X-Ray Fluorescence Analysis (Energy Dispersive)
USE CATEGORY	: Process Monitoring
GENERAL TYPE	: NDA: Active Gamma
MATERIAL TYPE	: SNM in Solutions
STATUS	: Class III : Field Evaluation Unit
USEFUL TO	: Operator and Inspector
FACILITIES	: Reprocessing
CAPITAL COST	: 50,000
SOURCE 1	: LLNL
REFERENCE 1	: Kiawah
REFERENCE 2	: UCRL-52616
REFERENCE DETAIL	: Hudgens & Craft; 547; and Camp & Ruhter; 584.

DESCRIPTION :

Energy dispersive x-ray fluorescence analysis (EDXRFA) can be used to monitor actinide concentrations and to obtain product accountability information at reprocessing plants. EDXRFA can be used either off-line or on-line to measure accurately, rapidly and nondestructively pure or mixed thorium, uranium, and plutonium concentrations over a wide dynamic range (0.1-500 g/l). Suitably collimated 122-keV gamma radiation from Co-57 excites the actinide K x-rays. By using a shutter to eclipse the exciting radiation, passive counts of the solution radioactivity can be taken; hence plutonium isotopic or uranium enrichment information can be deduced. 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 multichannel-analyzer system allows real-time concentration information to be obtained.

Measurement times depend on concentration and purpose. For process control where several percent accuracy is sufficient, measurement times vary from 10 s for relatively concentrated solutions to 500 s for waste solutions. Accountability measurements (sub 1% accuracy) require more time; and for solutions containing plutonium, a passive spectrum must be taken and subtracted from the excited spectrum to remove the effects of variable isotopics. Concentrations in single- and dual-element solutions have been determined to an accuracy of better than 0.5% after calibration of the system.

EQUIPMENT NAME : Active Well Coincidence Counter (AWCC)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Uranium
STATUS : Class III : Field Evaluation Unit
USEFUL TO FACILITIES : Operator and Inspector
Reactor
Fabrication
CAPITAL COST : 60,000
SOURCE 1 : LANL
REFERENCE 1 : LA-7823-M

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 also related to a High-Level Neutron Coincidence Counter (HLNCC) with neutron sources; the former possesses superior counting efficiency, but both use the same electronics system. Of course the AWCC can also be used passively.

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.

The capital cost covers the detector, two AmLi sources, and associated electronics; the electronics package is the same as for the HLNCC.

EQUIPMENT NAME : DENIS (Time-Delayed Neutrons)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Uranium
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reactor
Reprocessing
CAPITAL COST : 140,000
SOURCE 1 : KFA
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : Handbook
REFERENCE DETAIL : 1. Stein, Cloth, Filss & Heinzelmann; V. 2, 517.
2. Gozani; Chapter 6.

DESCRIPTION :

Nondestructive measurements of fissile material contents can be performed by detection of delayed neutrons after irradiation of the samples in a low energy neutron field. Somewhat different time behavior of these delayed neutrons in the case of U-235 and U-233 makes it possible to distinguish between the samples. This technique is being used in the uranium-thorium pebble-bed-reactor fuel cycle.

The measuring system consists of a target of the 14-MeV neutron generator surrounded by an iron cylinder followed by a layer of polyethylene as neutron moderator. The iron cylinder is the hollow axis of a wheel made of graphite. It bears a circle of 16 holes parallel to the axis, each capable of holding two pebbles. The wheel is rotated in order to work against inhomogeneous loading of fissile material and inhomogeneous efficiency of the detectors, which are at positions in the static part of the apparatus. This static part consists of a lead cylinder surrounding the rotating wheel and acting as a gamma-shield in the case of irradiated fuel. The lead cylinder is embedded in polyethylene block in which up to 16 boran triflouride or He-3 detectors can be inserted. The number of detectors can be increased considerably if necessary to increase counting efficiency.

The cost is the upper estimate for a similar system consisting of neutron generator, tailoring assemblies, slab detector, shielding and assembly.

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 II : Development Prototype
USEFUL TO	: Operator
FACILITIES	: Reprocessing
CAPITAL COST	: 100,000
SOURCE 1	: LANL
REFERENCE 1	: 1980 INMM
REFERENCE DETAIL	: Kunz, Atencio & Caldwell; 131.

DESCRIPTION :

This equipment consists of a pulsed thermal-neutron interrogation system with detection of prompt fission neutrons. It has been used to detect transuranics 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 detections on all sides is under construction. 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 electronics.

EQUIPMENT NAME	: Fuel-Rod Scanner
USE CATEGORY	: Process Monitoring
GENERAL TYPE	: NDA: Active Neutron
MATERIAL TYPE	: Fresh Fuel
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 2	: IRT
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 Californium-252 source. Fission-product gamma rays are detected. Measurements include uranium enrichment and the geometrical location of fissile material. It is important that a scanner function quickly and that it detect anomalous rods while only rarely making an unfounded rejection of one meeting specifications.

Much of the cost arises from the fuel conveyance system.

Standard fuel rods are needed to maintain the instrument's calibration.

EQUIPMENT NAME : Fuel-Rod Scanner Standard Fuel Rods
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fresh Fuel
STATUS : Class IV : Production Model
USEFUL TO : Operator
FACILITIES : Fabrication
CAPITAL COST : 30,000
SOURCE 1 : GE SanJose
REFERENCE 1 : None

DESCRIPTION :

Accurate results from nuclear instrumentation require the use of well-characterized standards as part of any measurement program. Use of the "Active Fuel Rod Scanner" thus requires standard fuel rods.

For BWR fuel, a suitable set of standard rods might consist of 16 rods spanning the enrichment range of 2.2% to 3.6% U-235, with two at each enrichment. Each would contain about 3 kg of total uranium.

The cost given includes the costs of the uranium, the enrichment service, the fuel fabrication, and the characterization of the isotopic content by the manufacturer. The cost is for 16 rods. Since fuel rods are not ordinarily ordered in such small lots, since the cost is usually split between several concerns (for uranium, enrichment, and fabrication), and since characterization by NBS, e.g., might be desired, the estimate given should be viewed with caution.

For plutonium fuel, radioactive decay would materially affect the characterization so that the date of fuel characterization is important.

EQUIPMENT NAME : Fuel-Subassembly Assayer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Fabrication
Reprocessing
SOURCE 1 : ORNL
REFERENCE 1 : 1979 INMM
REFERENCE DETAIL : Ragan, Ricker, Chiles, Ingersoll & Slaughter; 334.

DESCRIPTION :

Recent studies show that subassemblies (integral units of 217 rods, many of which constitute a complete core) containing various spent fuels could be assayed rapidly and accurately by a nondestructive assay system using active-neutron interrogation and prompt-neutron detection. Subassembly 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 have demonstrated the potential for assaying, with better than 5% accuracy, three spent plutonium-fueled subassemblies per hour. Calculations, validated by experiments, predict even better performance for fresh or uranium-fueled subassemblies. The total fissile content of an unknown subassembly is obtained by comparison of the measurement with that for a nearly identical standard reference subassembly.

EQUIPMENT NAME	: Isotopic Source Assay System & Fissometer
USE CATEGORY	: Materials Accountancy
GENERAL TYPE	: NDA: Active Neutron
MATERIAL TYPE	: SNM Samples
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: All
CAPITAL COST	: 100,000
SOURCE 1	: IRT
SOURCE 2	: NNC
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 : Lead Slowing-Down Spectrometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM Samples
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator
FACILITIES : Fabrication
Reprocessing
CAPITAL COST : 235,000
SOURCE 1 : RPI
REFERENCE 1 : Handbook
REFERENCE 2 : NUREG/CR-0602
REFERENCE DETAIL : Gozani; Chapter 6.

DESCRIPTION :

The lead slowing-down spectrometer is a large (1 to 8 meters) solid block of pure lead, into which a pulse of fast (e.g., 14-MeV or photoneutrons) neutrons is introduced. The average neutron energy of fast neutrons decreases rather slowly with time, and the energies of most of the neutrons do not deviate much from the average energy. Thus, at least to a first approximation, the neutrons slow down as a group. If a fissionable sample and a prompt neutron detector are placed in the block, the count-rate variation with time after the neutron pulse is introduced will depend on the fission cross-section variation with neutron energy. This dependence allows for both detection of the fissionable material and isotopic discrimination.

The cost is the upper estimate for a system consisting of pulsed-neutron source, lead block, instrumentation, and sample-handling hardware.

EQUIPMENT NAME : Neutron Collar
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fresh Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Fabrication
Reactor
CAPITAL COST : 15,000
SOURCE 1 : LANL
REFERENCE 1 : LA-7528-M

DESCRIPTION :

The portable, active-neutron interrogation system for light-water reactor (LWR) 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 polyethlene 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, which has a yield that is a function of the fissile mass in the fuel assembly and which has an average neutron energy higher than that from the moderated AmLi source. Two He-4 detectors are used and measure the relative fluence of the induced fission neutrons from the fuel assembly.

The capital cost covers sources and detectors. The electronics system is the same as for the HLNCC and AWCC.

EQUIPMENT NAME	: Random Driver
USE CATEGORY	: Materials Accountancy
GENERAL TYPE	: NDA: Active Neutron
MATERIAL TYPE	: Uranium
STATUS	: Class IV : Production Model
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 fission 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 a pair of fast-neutron 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 : Resonance-Neutron Radiography
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Spent Fuel
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing
CAPITAL COST : 500,000
SOURCE 1 : NBS
REFERENCE 1 : Kiawah
REFERENCE 2 : IEEE TNS
REFERENCE DETAIL : 1. Schrack, Behrens, Bowman & Carlson; 86. 2. Schrack, Behrens, Johnson & Bowman; V. NS28, 1640 (1981).

DESCRIPTION :

A resonance-neutron radiography system is being developed to provide, generally, a reference method for NDA measurements and, specifically, a method for determining the isotopic content of spent nuclear fuel.

Because of the measurement technique employed in resonance-neutron radiography, it is possible to provide an assay of an isotope in a mixture without interference from other materials. The method therefore promises a significant advantage in terms of isotopic and elemental discrimination over thermal-neutron radiography. Indeed, tests of the method on spent nuclear fuel show excellent resolution in measuring the inhomogeneities in isotopic distribution along the length of fuel assemblies.

The heart of the method is the production of neutrons by an electron linear accelerator. The neutrons, incident on a sample, are detected with time-of-flight discrimination to determine sample transmission as a function of neutron energy. Isotopes of interest, especially of SNM, produce valleys in the transmission spectrum.

The cost given is for a field installation in an existing building to examine spent-fuel assemblies. The main item is a Varian Linatron 3000 linear electron accelerator at $360,000.

EQUIPMENT NAME : SIGMA
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
SOURCE 1 : JRC
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : 1976 IAEA
REFERENCE DETAIL : 1. Berroit & Coppo; 317. 2. Cuypers, Van der Stricht, Boursier & Corbelini; V. 2, 521.

DESCRIPTION :

The Sigma system was designed to measure the U-235 content of THTR pebbles. Basically it is an automated device wherein each pebble is irradiated by a Cf-252 source and, after a suitable delay, neutrons emitted by the sample are counted. A microprocessor controls the entire measurement sequence and performs the required calculations. In addition, the operator is prompted through the operating procedure and all data are recorded on a cassette. There are calibration and diagnostic procedures built in as well. Up to 100 pebbles can be loaded in a magazine and an automatic sample changer transfers the pebbles through the sequence under control of the microprocessor. Data treatment includes background subtraction, normalization, and statistical error calculation.

EQUIPMENT NAME : Sb-Be Photoneutron Interrogation System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM Samples
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing
SOURCE 1 : JRC
SOURCE 2 : KFA
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : Nuc. Mat.
REFERENCE DETAIL : 1. Prosdocimi & Dell'Oro; 328; & Filss, Kirchuer & Merz; 331. 2. Filss; V. VIII, No. 2, 74 (1979).

DESCRIPTION :

This system utilizes selective measurement of fission neutrons produced by irradiation with thermal neutrons which are emitted from a Sb-Be source. At KFA Julich the detection limit was 7 mg of Pu or 15 mg of U-235 in mixed U-Pu or U-235 samples. The system is operable in the presence of high levels of radioactivity from fission products. A similar system called PHONID is under study at JRC (Ispra) but is less sensitiive.

EQUIPMENT NAME : Shuffler (Californium-252)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM Samples
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Critical
Fabrication
Conversion
Reprocessing
CAPITAL COST : 250,000
SOURCE 1 : IRT
REFERENCE 1 : LA-7315
REFERENCE 2 : S&U
REFERENCE DETAIL : Menlove, Ensillin, Krick & Hsue; A-8.

DESCRIPTION :

The Cf-252 Shuffler uses fast- or thermal-neutron interrogation, combined with delayed-neutron counting. The Cf-252 Shuffler repetitively transfers the neutron source from the interrogation position to a shielded position while the delayed neutrons are counted. The assay system includes a source shield tank, a polyethylene shield, and an irradiation tank. The assay sample is irradiated inside a high-efficiency neutron well counter used to count the delayed-fission neutrons. For samples containing Pu, this well counter also can be used in the passive coincidence mode to count the spontaneous-fission neutrons. The neutron detector consists of a polyethylene matrix filled with 25 He-3 tubes.

The Shuffler system has been evaluated for assay of fuel rods, inventory samples, scrap and waste, U ore, irradiated fuel, and Pu-U mixtures. For the Pu-U mixtures, the combination of passive-neutron coincidence counting and active-neutron interrogation can separate the U-235 and Pu components in the assay. The system can assay samples with fissile content from a few milligrams up to several kilograms, using thermal-neutron interrogation for the low-mass samples and fast-neutron interrogation for the high-mass samples.

EQUIPMENT NAME : Small Sample Assay System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Active Neutron
MATERIAL TYPE : SNM Samples
STATUS : Class IV : Production Model
USEFUL TO : Operator
FACILITIES : Fabrication
CAPITAL COST : 100,000
SOURCE 1 : IRT
REFERENCE 1 : IRT

DESCRIPTION :

The small sample assay system is an active-neutron, nondestructive system used to determine the content of fissile material in samples with a volume less than 7 cubic centimeters. In its usual operation, a Cf-252 neutron source irradiates samples containing U-235. The passive gamma-ray activity is measured prior to neutron irradiation and passive plus delayed (fission-product) gamma-ray activity after irradiation. The system can also be arranged to handle samples containing Pu.

The cost is for a complete system with automatic sample handling.

EQUIPMENT NAME	:	Calorimeter
USE CATEGORY	:	Materials Accountancy
GENERAL TYPE	:	NDA: Heat
MATERIAL TYPE	:	Plutonium
STATUS	:	Class IV : Production Model
USEFUL TO	:	Operator and Inspector
FACILITIES	:	Reprocessing Fabrication
CAPITAL COST	:	80,000
MAINTENANCE COST	:	1,000
REPLACEMENT COST	:	80,000
LIFETIME	:	10 Years
SOURCE 1	:	Mound
SOURCE 2	:	ANL
REFERENCE 1	:	Nuc. Mat.
REFERENCE 2	:	ANSI N15.22
REFERENCE DETAIL	:	Lemming, Rodenburg, Rakel, Duff & Jarvis; V. IX, No. 2, 109 (' ,0).

DESCRIPTION :

These assay Pu in solid form (metal, oxide, scrap, etc.) by measuring the heat output per unit mass. Calorimeters usually are tailored to sample mass and shape and to a given range of specific heat (heat output per unit mass). Three sizes are of interest: (i) a small sample calorimeter for individual pellets, small numbers of pellets, or small archival samples of oxide, 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 about 1 m long or 4 m long. The price of a calorimeter system depends on the sample size, the required precision, the data readout and if the units are transportable as opposed to stationary. The costs given are upper limits.

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

EQUIPMENT NAME : Infrared Detector
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : NDA: Heat
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Storage
CAPITAL COST : 100
SOURCE 1 : Dexter
REFERENCE 1 : SAND 79-1583
REFERENCE 2 : LA-8584-MS

DESCRIPTION :

Infrared-radiation (IR) sensing devices can make remote measurements of the temperature of items. As such, these devices can serve as crude calorimeterlike monitors of plutonium. In a physical-protection role, these devices can sense the presence of a human being.

IR sensing devices can be relatively simple thermocouples or thermopiles (thermocouples in series) or relatively complex photon detectors which often require cryogenic cooling.

The Dexter device, the Thermacon, weights 140 g and can be battery-powered. The package uses a thermopile IR detector and logic circuitry to detect temperature changes in its field-of-view and the unit is sensitive to IR radiation from objects in the room temperature range. Collimators are used to define the field-of-view and the T80 Model has logic circuits to detect increases or decreases in the mean temperature of the field-of-view. Thus, it can detect a human body entering the field or a piece of paper or shield obscuring the field-of-view. The unit as now sold would need additional circuitry, similar to dosimeter circuitry, for accumulation and display of alarm conditions. Thus, the capital cost given does not completely characterize a device suitable for safeguards applications.

EQUIPMENT NAME : On-Line Alpha Monitor
USE CATEGORY : Process Monitoring
GENERAL TYPE : NDA: Passive Alpha
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 22,100
SOURCE 1 : IRT
REFERENCE 1 : Nuc. Safe.
REFERENCE 2 : LA-8042
REFERENCE DETAIL : 1. Hufstetter, Tucker, Kemmerlin, Gray & Huff; 124.
2. Hakkila, Ostenak & Thomas, Jr.; V. III, App. L.

DESCRIPTION :

On-line alpha monitors are used in reprocessing plants for process control 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 at the Barnwell Nuclear Fuel Plant for continuous quantitative determination of plutonium in the concentration range from .001 to .1 g/l with relative standard deviation of 12%. Interference from beta activity to a 10000 ratio relative to alpha activity and to gamma radiation to 0.5 mCi/l is eliminated by electronic discrimination.

The cost is for a system complete with electronics.

EQUIPMENT NAME : Autoradiography
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Fuel
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reactor
Reprocessing
Critical
Fuel Storage
CAPITAL COST : 10,500
MAINTENANCE COST : 800
SOURCE 1 : ANL
SOURCE 2 : Kodak
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 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 $2000 and film at $400 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 : Hand-Held Enrichment Monitor
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Uranium
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 7,000
SOURCE 1 : NNC
REFERENCE 1 : POTAS
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Task A.11, 36.

DESCRIPTION :

The hand-held enrichment monitor (portable gamma spectrometer) is a portable NDA instrument used to make semi-quantitative measurements of nuclear materials in small quantities. The feature distinguishing this instrument from others of its kind is that it measures gamma rays in two channels. (One channel's counts are internally subtracted from the other's.) The complete system, a battery-operated single-channel analyzer, includes a detection device and an electronics package fitted into a single hand-held unit. Sodium iodide detectors have been used in the first design. Work on cadmium-telluride detectors may be applicable for use in this device.

EQUIPMENT NAME : High-Resolution Gamma-Ray Spectrometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM in Solutions
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 50,000
REPLACEMENT COST : 50,000
LIFETIME : 5 Years
SOURCE 1 : LLNL
SOURCE 2 : LANL
REFERENCE 1 : 1979 INMM
REFERENCE 2 : UCRL-52877
REFERENCE DETAIL : Gunnink, Prindle, Niday, Van Lehn & Asakura; 429.

DESCRIPTION :

The gamma-ray-spectrometry method is based on the fact that each of the isotopes of plutonium can be uniquely characterized by the energy and intensity pattern of the gamma rays it emits. When these radiations interact with a high-resolution germanium detector, an energy-related spectrum of pulses is produced that can be sorted, stored, and subsequently analyzed by the computer portion of the system.

The Livermore (LLNL) and Los Alamos (LANL) systems have been demonstrated in the reprocessing plant at Tokai-mura, Japan and is designed to provide analyses that can be easily monitored by an inspector. An analysis of a solution is performed by drawing a small, undiluted portion into a specially designed cell that contains a built-in monitor to correct accurately for small changes in the detection response. Complete analysis results can be obtained in times as short as 15 minutes. Similar systems have been developed and tested at the Barnwell Nuclear Fuels Reprocessing Plant. The LLNL system has been used at the DuPont Savannah River Plant since 1975. (See also the entry for "X-Ray Fluorescence Analysis (Energy Dispersive)".)

The capital cost covers the sample cell, detector, electronics, and computer system with peripheral devices. The five-year lifetime applies only to a Cadmium-109 reference source.

EQUIPMENT NAME : Leached-Hull Monitor
USE CATEGORY : Process Monitoring
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM in Waste
STATUS : Class II : Development Prototype
USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 100,000
SOURCE 1 : SNL
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This monitor is used to measure the Pu and U discharged with the hulls to waste storage. A sodium-iodide scintillator and two single-channel analyzers are used to detect the characteristic radiation from Pr-144. When a level is exceeded, an event counter increments. Other counters monitor the number of hull containers passing the detector (by sensing the broad-band gamma emissions from the hulls) and the number of power failures. The hull monitor assembly is a stand-alone system protected by a tamper-resistant enclosure.

Many earlier systems of this sort have been described and used in the United Kingdom and elsewhere. It is important to distinguish the 2.2 MeV gamma ray of Pr-144 from the intense 1.2, 1.3 MeV coincident gamma rays of Co-60. Pr-144 is the short-lived daughter of 285 day Ce-144. This method may not work on fuel that has aged 5 or more years.

Development of the system is not being pursued.

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
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing
SOURCE 1 : NBL
REFERENCE 1 : Kiawah
REFERENCE DETAIL : Voeks & Trahey; 25.

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 : Portable Microprocessor
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Plutonium
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reprocessing
Reactor
Storage
CAPITAL COST : 10,000
SOURCE 1 : LLNL
REFERENCE 1 : ISPO-134

DESCRIPTION :

A portable microprocessor unit has been developed that can be used by an inspector to analyze Pu gamma-ray spectra recorded by the IAEA Agency-type portable (Silena BS27 and BS27/N) multichannel analyzers. The connection can be direct or through magnetic tape. The unit incorporates a Digital Equipment Corporation 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 produces a permanent copy of the results. A simple numeric keypad is used for input. The software is resident on 16,000 words of memory.

The unit analyzes four to six peak groupings in the 110- to 210-KeV or the 110- to 400-KeV region of the gamma-ray spectrum. Gaussian and exponential tail terms are used to describe the peak shape. A relative efficiency curve is established from isotopically related peaks in the spectrum. The only input information required for spectrum analysis is the 148- and 208-KeV peak positions. Output from the unit includes plutonium isotopic ratios, U-235 to Pu-239 if it is present, and days since separation (growth of Am-241 from Pu-241). Results are available in 70-90 seconds after submission of the input parameters.

EQUIPMENT NAME : Rocky Flats Assay Meter
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 3,500
SOURCE 1 : Ludlum
SOURCE 2 : HP
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 modules 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 stock 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 Ludlum ratemeter interfaced to a Hewlett Packard 41-C continuous memory calculator.

EQUIPMENT NAME : Stabilized Assay Meter (SAM-II)
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : SNM Samples
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 3,300
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, the Compton 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.

EQUIPMENT NAME : Threshold Detector for Gamma Spectrometry
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Gamma
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Storage
Reprocessing
CAPITAL COST : 2,000
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(gamma,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 (gamma,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 = 285.4 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 provided by gross-gamma measurements.

The capital cost is for the detector without ancillary electronics or analyzers.

EQUIPMENT NAME : Brookhaven Survey Assay Meter (BSAM)
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : SNM Samples
STATUS : Class IV - Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 11,000
SOURCE 1 : BNL
SOURCE 2 : 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 fiberglass 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	: Fuel-Drawer Scanner
USE CATEGORY	: Materials Accountancy
GENERAL TYPE	: NDA: Passive N&G
MATERIAL TYPE	: Fuel
STATUS	: Class II : Development Prototype
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 1-in.-long Pu fuel plate in a drawer containing as much as 36 in. (total) of Pu fuel in one or more rows and a variety of coolant, structural, and fertile mockup materials also present in the drawer.

EQUIPMENT NAME : In-Line Liquid-Phase Enrichment Monitor
USE CATEGORY : Process Monitoring
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
CAPITAL COST : 35,000
MAINTENANCE COST : 4,000
LIFETIME : 8 Years
SOURCE 1 : Jomar
REFERENCE 1 : Nuc. Tech.
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Reilly, Martin, Parker, Speir & Walton; V. 23, 318 (1974).

DESCRIPTION :

This system was developed for use in process-enrichment control and criticality control, to assure that highly enriched, liquid uranium hexafluoride is not drawn into low-enrichment cylinders. In the same mode it can serve a safeguards role. Measurements are made on the liquid before the material is loaded into product cylinders. The U-235/U ratio is determined by measuring the 186 KeV U-235 gamma rays from a "thick" sample. The neutron detector measures the neutrons from alpha-neutron reactions and spontaneous fission. The U-234/U ratio can be computed from this neutron measurement. Gamma and neutron measurements are independent and may be used singly. If the computed enrichment, which for U-235 can be measured to an accuracy of 0.5% relative, goes above or below preset limits, the control unit issues an alarm.

The gamma-detection portion of this system has been redesigned and repackaged for use as an international safeguards device at the Gas Centrifuge Enrichment Plant. The functions are essentially as described above with the addition of a tamper-protecting enclosure and an encrypted data link to tamper-protect the data. A commercial prototype of this unit is being field-tested.

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
SOURCE 1 : LANL
REFERENCE 1 : IAEA Alpha
REFERENCE 2 : Kiawah
REFERENCE DETAIL : 1. Caldwell, Cates, Close, Crane, Kunz, Shunk, Umbarger & Franks; 515. 2. Harlan; 622.

DESCRIPTION :

MEGAS-II is a segmented scanner used for assaying low-density transuranic wastes (TRU) 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 at the three-sigma level above background for Am-241 is less than 5 pCi/g for a 500-s count for approximately 6 kg of low dnsity wastes in a 57-liter carton.

The presence of beta- and gamma-ray emitting fission products severely decreases the achievable TRU detection limit for even thin NaI detectors. However, the recent addition of a high-resolution hyperpure planar germanium detector, allows the assay of TRU isotopes even in the presence of considerble extraneous gamma and x-ray backgrounds. An estimate is that TRU assay at 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 polyethylene-moderated He-3 neutron detectors. The measured detectability limit for this neutron detection system is 10 mg of typical reactor-grade Pu oxide. This detection limit applies for a net signal 3-s above background for a 1000-s run time using the total neutron count.

EQUIPMENT NAME : Multichannel Analyzer (Portable)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : Radioactive Mat'l in Any Form
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 10,000
SOURCE 1 : Davidson
SOURCE 2 : ND
REFERENCE 1 : Davidson
REFERENCE 2 : ND

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.

The Davidson model described has 4096 channels and weighs 5.7 kg. It has its own cathode-ray-tube display and can also transmit channel information to peripheral display devices.

The ND model, to be available soon, has 2048 channels, weighs about 6 kg, includes its own batteries and power supplies, has a splash-proof case, has tape cassette mass storage, and is otherwise designed for rugged field use.

The cost is for the ND model; the Davidson model costs about $8000.

EQUIPMENT NAME : Multichannel Analyzer (Stationary)
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : Radioactive Mat'l in Any Form
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 9,700
SOURCE 1 : Silena
SOURCE 2 : Canberra
REFERENCE 1 : Canberra

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. Thousands of channels are available in advanced models, which also include display and analysis features. The IAEA has been using the Silena models BS27 and BS271N. Similar multichannel analyzers are sold by many companies around the world.

The capital cost given is for the Silena BS271N analyzer with printing, tape-cassette and other options. Advanced computing, printing, and memory devices could increase the cost of a system significantly.

EQUIPMENT NAME : Spent-Fuel Multielement Detectors
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive N&G
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 10,000
SOURCE 1 : LANL
REFERENCE 1 : Kiawah
REFERENCE 2 : LA-8590-PR
REFERENCE DETAIL : 1. Lee, Phillips, Halbig, Hsue, Lindquist, et al.; 426.
2. Halbig, Klosterbuer, Caine, Duran & Whitehill; 49.

DESCRIPTION :

Nondestructive techniques for characterizing irradiated LWR fuel assemblies have been developed. They encompass portable detection systems that measure the axial neutron yield and gamma yield.

Gross-gamma measurements are an alternative to gamma spectrometry. Although the measurement is not able to differentiate the presence of specific fission products, it does sense the high radiation field that must be present in a spent fuel assembly. The measurement is also relatively insensitive to the interior rods because of attentuation. Two aspects make passive neutron measurements particularly attractive for the measurement of spent fuel assemblies. First, neutrons are less subject to self-absorption in the fuel assembly than are gamma rays. Therefore the neutron measurement is more sensitive to all the interior pins in the fuel assembly than is the gamma-ray spectrometry measurement. Secondly, the passive neutron measurement requires very simple electronics and a neutron detector.

A ring detector with four ion chambers for gamma measurements and four fission chambers for neutron measurements would cost about $5000. A microprocessor-based portable electronic unit called the ION-1 complements the detector array and would also cost about $5000. Another detector employed in this system is the "Threshhold Detector for Gamma Spectrometry."

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 Heavy Water
CAPITAL COST	:	5,000
SOURCE 1	:	Branson
REFERENCE 1	:	1980 INMM
REFERENCE DETAIL	:	Ricci, Fields & Rushton; 720.

DESCRIPTION :

An ultrasonic thickness gauge may be used to measure the thickness of a metallic container (such as a UF6 cylinder) in order to provide attenuation corrections during gamma-ray assays. Such a device may also be useful for the determination of the heavy water content of a sealed container. The principle of operation is measurement of the sound travel time through a material and analysis of echoes from the material boundaries.

EQUIPMENT NAME : Channel Coincidence Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reprocessing
Fabrication
Critical
CAPITAL COST : 25,000
SOURCE 1 : LANL
REFERENCE 1 : LA-8373-PR
REFERENCE 2 : LA-8404-MS
REFERENCE DETAIL : Krick; 51.

DESCRIPTION :

Fast-critical-assembly (FCA) drawers are assayed with the HLNCC using a two-position measurement to provide uniform assay weight to the plutonium regardless of its axial position in the drawer. This measurement technique has four disadvantages: 1) the HLNCC must be reconfigured to perform the measurement; 2) the two-position measurement is inconvenient and time-consuming; 3) a slight positioning error can produce a 1-2% assay error; and 4) the open counting geometry reduces the coincidence counting efficiency of the HLNCC.

At the request of the IAEA a custom detector, called the channel coincidence counter, was designed to improve the assay of fuel rods and FCA fuel drawers. The principal feature of the detector is a 7- by 7- by 97-cm detector channel, which provides a uniform neutron detection efficiency (16% absolute) across the central 40 cm of the channel. The electronics system is the same as that used for the HLNCC.

The coincidence rate of the channel coincidence counter is about three times higher than that of the HLNCC, allowing an assay of the same statistical precision in one-third the time.

The cost is for the detector alone.

EQUIPMENT NAME	: Dual-Range Thermal-Neutron Coincidence Counter
USE CATEGORY	: Materials Accountancy
GENERAL TYPE	: NDA: Passive Neutron
MATERIAL TYPE	: Fuel
STATUS	: Class III : Field Evaluation Unit
USEFUL TO	: Operator and Inspector
FACILITIES	: Critical
CAPITAL COST	: 61,900
SOURCE 1	: LANL
SOURCE 2	: IRT
REFERENCE 1	: TANS
REFERENCE DETAIL	: Ensslin, Evans, Menlove, Sapir & Swansen; V. 27, 182.

DESCRIPTION :

Used for measurement of 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. By changing the internal configuration, the counter operates at either low (8%) counting efficiency for high neutron activities or high (20%) efficiency for low neutron activities.

The capital cost is for the counter without the electronics system, which is the same as for the HLNCC.

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
USEFUL TO : Inspector
FACILITIES : Fabrication
Reprocessing
Critical
CAPITAL COST : 43,000
SOURCE 1 : IRT
SOURCE 2 : LANL
REFERENCE 1 : 1978 IAEA
REFERENCE DETAIL : Krick, Evans, Ensslin, Hatcher, Menlove, Sapir, Swansen, DeCarolis & Ramalho; V. 2, 51.

DESCRIPTION :

The portable high-level neutron coincidence counter (HLNCC) was developed for the assay of Pu. The counter was designed to measure the effective Pu-240 mass in Pu samples which may have a high Pu content. The term "high-level" refers to the high neutron count rates produced by large (more than 500) Pu oxide or Pu metal samples. The counter measures coincident fission neutrons in the presence of a random neutron background with an efficiency of about 1%. Total Pu content is calculated from the Pu isotopic composition. Correction procedures for removing nonlinearities in the counter response due to multiplication effects in the samples are being developed for Pu 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 electronics package featuring shift-register coincidence counting electronics was designed for use with the detector. The electronics package is interfaced to a Hewlett-Packard HP-97 programmable calculator and to 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.

EQUIPMENT NAME : In-Line Thermal-Neutron Coincidence Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Plutonium
STATUS : Class I : Laboratory Device
USEFUL TO : Operator
FACILITIES : Reprocessing
CAPITAL COST : 55,000
SOURCE 1 : LANL
REFERENCE 1 : 1980 INMM
REFERENCE DETAIL : Marshall and Canada; 107.

DESCRIPTION :

An in-line assay technique for wet plutonium oxalate is required for accountability and process control purposes. A measurement technique has been developed using a thermal-neutron coincidence counter (TNC) equipped with two concentric rings of He-3 detectors surrounding the central counting well. The count rate between the two rings provides a parameter that is used to correct the observed coincidence neutron count rate for moisture-induced multiplication effects. An evaluation of the measurements made by process technicians on 26 batches of plutonium oxalate shows the in-line TNC measurements to have a slight bias of -0.7% and a one-sigma precision of 2.2%.

The cost is more than for the high-level neutron coincidence counter, e.g., mainly because of the larger number of He-3 detector tubes.

EQUIPMENT NAME : Large Omnidirectional Neutron Detection System
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM Neutron Emitters
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 150,000
LIFETIME : 15 Years
SOURCE 1 : LANL
REFERENCE 1 : IAEA Alpha

DESCRIPTION :

Self-contained modules (external dimensions 2.1 x 1.2 x .3 m) are stacked into an array yielding an assay chamber region of 1.2 x 1.2 x 2.1 m (or larger) in extent. Separate counting electronics are provided for each module and for selected arrangements of He-3 proportional counters contained within each module. Coincidence and passive total neutron counts are taken of large packages placed inside. Sensitivity is about 10 mg Pu (or equivalent other neutron source) for material anywhere within large packages up to 1.2 x 1.2 x 2.1 m in extent.

EQUIPMENT NAME : Neutron Well Coincidence Counter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM Neutron Emitters
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reactor
Fabrication
Reprocessing
Critical
CAPITAL COST : 80,000
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Zucker & Fainberg; 313.

DESCRIPTION :

For Pu primarily, this counter can also be used for U-238, hence LEU. It is basically a passive device detecting neutrons from spontaneous fission of the even isotopes. It has a cylindrical hollow in a moderator which has neutron-sensitive proportional counters, either BF3 or He-3 embedded in it, together with support electronics. The latter consists of a detector bias supply, preamplifiers, amplifiers, and "logic" circuitry for analyzing correlations in the pulse train from the counter. Generally a small computer of the desk type or even a pocket computer is included for data reduction. These counters are available at prices from $40,000. Some units with the design intent to be very flexible as to sample size may cost appreciably more.

EQUIPMENT NAME : Portable Neutron Coincidence Counter
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Plutonium
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reprocessing
Fabrication
CAPITAL COST : 20,000
SOURCE 1 : LANL
REFERENCE 1 : LA-8373-PR
REFERENCE DETAIL : Menlove; 55.

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 40% was determined using a calibrated Cf-252 source. A measurement precision of 0.5% can be obtained in a 1000-s measurement for 15 ml of solution containing 250 g Pu/l (20% 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.

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

EQUIPMENT NAME	:	Reactor Power Monitor (New)
USE CATEGORY	:	Inspector Use
GENERAL TYPE	:	NDA: Passive Neutron
MATERIAL TYPE	:	Reactor
STATUS	:	Class II : Development Prototype
USEFUL TO	:	Inspector
FACILITIES	:	Reactor
CAPITAL COST	:	5,000
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.

EQUIPMENT NAME : Reactor-Power Monitor (Old)
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Reactor
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
SOURCE 1 : SNL
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This monitor is operator-independent and utilizes a commercial ion chamber mounted in a stepped plug in the biological shield of the reactor. Neutron flux is monitored by the detector and is compared with plant records to confirm power-production data. Sixteen levels of output information are provided. Near normal power levels, small changes in power level can be detected accurately; but at low power, where continued operation is unlikely, the data are not as accurate. Readings are recorded at regular intervals (10 minutes) at a central recording station. The monitor can be used only where a penetration of the biological shield can be made.

The monitor was tested in Canada but is no longer under active development.

EQUIPMENT NAME	: Reactor-Power Track-Etch Monitor
USE CATEGORY	: Inspector Use
GENERAL TYPE	: NDA: Passive Neutron
MATERIAL TYPE	: Reactor
STATUS	: Class II : Development Prototype
USEFUL TO	: Inspector
FACILITIES	: Reactor
SOURCE 1	: GE Pleas.
REFERENCE 1	: 1978 IAEA
REFERENCE 2	: ISPO 143
REFERENCE DETAIL	: Pentenyi, Rohar, Dermendjiev, Hornsby & Poroykov; V. 1, 425.

DESCRIPTION :

Neutron flux is measured and recorded by this monitor to verify the power history of the reactor. When fission reactions occur in a thin layer of fissionable material, the fission fragments have sufficient kinetic energy to escape from the surface. In this device, source material is fissioned by the neutron flux of the reactor. The material is located close to a polyester plastic film and the fission fragments create tracks in the plastic, which are subsequntly made visible by etching. The plastic film is drawn slowly past a block containing these fissionable-material sources, resulting in a recorded track whose density is proportional to the incident neutron flux. This block also contains a Californium-252 spontaneous-fission source, which provides a reference track. Track density can be measured by automated counters or by manual counting using a microscope. To date, analysis methods have proven to be complex and costly and the mechanical operation of the monitor as presently designed is unreliable. Careful scheduling and adequate precautions for health and safety during installation and removal are required. Residual radioactivity from the monitor may be a problem after removal.

EQUIPMENT NAME : Shielded Neutron Assay Probe (SNAP)
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : SNM Neutron Emitters
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reprocessing
Fabrication
Enrichment
CAPITAL COST : 6,000
SOURCE 1 : NNC
REFERENCE 1 : LA-5291-PR
REFERENCE 2 : S&U
REFERENCE DETAIL : Walton & Atwell; 14.

DESCRIPTION :

The shielded neutron assay probe (SNAP) is a portable device designed to be used with commercial electronic amplifiers and counters. The probe consists of one or two helium-3 counters with a polyethelene cylinder open on one side to make the probe directional.

A passive detector, SNAP is designed to be especially sensitive to neutrons having energies of (1-2) MeV, which arise from alpha-neutron reactions from plutonium and uranium and from spontaneous fission of Pu-240 or Pu-242.

The cost is for an advanced SNAP-II system without electronics; simpler systems could cost as little as $3000.

EQUIPMENT NAME : Spectral-Index Core Monitor
USE CATEGORY : Inspector Use
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Reactor
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Critical
Reactor
CAPITAL COST : 450
SOURCE 1 : RX
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : ANL-80-13
REFERENCE DETAIL : Gryazev, Gadzhiev, Nigmatullin, Demidov & Yakovleva; 509.

DESCRIPTION :

Metal foils can be used to measure crudely the neutron energy spectrum of a nuclear reaction. This permits an assessment of the overall condition of the reacting mass and is a means for detecting removal of special nuclear material from reacting cores.

Natural indium foils provide a good detector for cores of fast critical facilities (or reactors) because different gamma rays result from low and high energy neutrons, the dividing energy being about 1 MeV. The half-lives are 4.5 and .9 hours respectively, so immediate gamma-counting measurements would be required at an inspection.

What is under development is the technique for determining the sensitivity of the foils to removal of material. The foils themselves have been used for many years.

The capital cost is for special combination kits of foils to measure neutron flux, dosage, and spectra. Depending upon the material, foils are sold in boxes of ten for between $100 and $200.

EQUIPMENT NAME : Trap-Material Enrichment Meter
USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : Enrichment
CAPITAL COST : 80,000
SOURCE 1 : LANL
REFERENCE 1 : 1979 INMM
REFERENCE DETAIL : Tape, Baker, Strittmatter, Jain & Evans; 719.

DESCRIPTION :

This device is designed to detect HEU production indirectly by screening outgoing alumina trap-material for enrichments greater than the declared top product of the facility. It can also possibly provide information on the U-235 content of the trap material for material-balance purposes.

Compounds of uranium and fluorine emit neutrons from two sources; spontaneous fission neutrons and reactions in which an alpha particle from the decay of a uranium nucleus interacts with a fluorine-19 nucleus and emits a neutron. Since neutrons from fission are emitted simultaneously, coincidence counting techniques may be used to distinguish between neutrons produced from alpha-neutron reactions and those resulting from spontaneous fission. The measurement of the ratio of the total neutron counting rate to the coincident neutron counting rate from a uranium-fluorine compound can then yield an approximate determination of the uranium enrichment.

A thermal-neutron coincidence (well) counter with a shift-register electronics package can be used to screen the enrichment of trap-material samples as large as 55-gal drums. Such a device has been successfully tested on an experimental basis for enrichments from 0.2 to 17% with concentrations of uranium from 1 to 4% in 14 to 15 kg of alumina.

EQUIPMENT NAME : Advanced Television Surveillance System (CCTV)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 35,000
MAINTENANCE COST : 4,000
LIFETIME : 7 Years
SOURCE 1 : Fernseh
SOURCE 2 : SNL
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This system consists of two cameras and a central control console. The control console includes a support base containing auxiliary batteries; an electronics console containing video tape recorders, control functions and a viewing monitor; and an auxiliary video recorder chassis which can be serviced without allowing access to the electronics console. Signals from the two cameras are combined into a single video signal for recording. Tamper indication, motion detection and video analysis are included.

EQUIPMENT NAME	:	CANDU Closed-Circuit Television System
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Optical Surveillance
MATERIAL TYPE	:	Fuel
STATUS	:	Class IV : Production Model
USEFUL TO	:	Inspector
FACILITIES	:	Reactor
CAPITAL COST	:	230,000
MAINTENANCE COST	:	40,000
REPLACEMENT COST	:	230,000
LIFETIME	:	10 Years
SOURCE 1	:	AECEC
REFERENCE 1	:	Nuc. Mat.
REFERENCE 2	:	IAEA-STR-90
REFERENCE DETAIL	:	Zarecki, Smith, Head & Duncan; V. IX, No. 2, 49 (1980).

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.

High 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.

EQUIPMENT NAME	:	CANDU Film Camera System
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Optical Surveillance
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class IV : Production Model
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	:	AECEC
REFERENCE 1	:	Nuc. Mat.
REFERENCE 2	:	IAEA-STR-90
REFERENCE DETAIL	:	Zarecki, Smith, Head & Duncan; V. IX, No. 2,49 (1980).

DESCRIPTION :

The system is designed to detect any attempt to divert irradiated fuel through the fresh-fuel loading area of a CANDU reactor or from the spent-fuel storage pools. It 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.

Sandia contributed to the early development of this system.

EQUIPMENT NAME : Cerenkov Viewing (Night-Vision) Device
USE CATEGORY : Inspector Use
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 4,000
SOURCE 1 : Javelin
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Dowdy, Nicholson & Caldwell; 353.

DESCRIPTION :

This device can be used to obtain qualitative information from the Cerenkov glow from spent fuel assemblies. What it does is intensify 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 lightweight and easy to use.

Development is proceeding to combine the night-vision device with either a film camera or a television camera to yield quantitative information on declared exposure and cooling time of assemblies. Microdensitometry of film negatives and intensity measurements of video recordings would provide the data. A realization of this development is the "Spent-Fuel-Bundle (CANDU) Cerenkov Verifier."

The cost is for the night-vision device alone.

EQUIPMENT NAME : Computer-Controlled CCTV Alarm Assessment System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator
FACILITIES : All
SOURCE 1 : DEC
SOURCE 2 : AGNS
REFERENCE 1 : AGNS35900-2.1-78
REFERENCE 2 : AGNS35900-2.3-50

DESCRIPTION :

This is a computer-controlled closed-circuit television (CCTV) system that, through switching and alarm devices, reduces human observation to only a few monitors at once. As installed at the Barnwell Nuclear Fuel Reprocessing Plant, area surveillance and alarm detection are under control in a manner that automatically and rapidly permits CCTV's to view alarm points when they are activated. Six such areas are currently under control by this system, which includes color graphics displays of the areas and of alarm listings. Four-second delays are encountered between sensor disturbance and alarm display. Manual CCTV switching capabilities are included in the system.

Required equipment includes a computer (DEC PDP 11/34A) and associated multiplexers, video terminals, and interface.

EQUIPMENT NAME : Deep-Drawn Container
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 800
LIFETIME : 20 Years
SOURCE 1 : Zero
REFERENCE 1 : Sandia Int. CS

DESCRIPTION :

This aluminum deep-drawn container for photographic cameras is tamper-indicating because its anodized surface is difficult to repair nondetectably.

EQUIPMENT NAME : Digital Timer (PI-200)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : SNL
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This system was designed to provide triggering pulses to existing IAEA still cameras. The crystal-generated timing allows triggering intervals between ten and ninety minutes. New systems developed in Europe have superseded this one.

EQUIPMENT NAME : EURATOM TV System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : Multilock
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Haas; 106.

DESCRIPTION :

An assembly recorder is the heart of the EURATOM system. In its present version, two full frames are added to the record for each event triggered. In this way about 40,000 events can be recorded per cassette. The important features of the recorder are absolute flicker-free fast scan, a variable slow-speed scan, and still picture. These features permit normal playback (2 hours of real time per second, assuming a 10-min interval between frame recording) and close inspection of the record. The basic components are a date-time generator, four-corner-insert logic to combine the images of two video-cameras, a monitor, and a battery-buffered power supply. The system operates on 12 volts. The two video cameras are controlled by the console. The system is equipped with a security interface which monitors possible intrusion attempts to the console compartments, cables, and cameras and which detects system malfunctions.

The system will have to be redesigned to meet IAEA requirements.

EQUIPMENT NAME : Environment-Resistant CCTV Camera
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 6,000
MAINTENANCE COST : 100
LIFETIME : 8 Years
SOURCE 1 : Fernseh
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This camera uses a charge-coupled-diode chip for optical pickup. It operates on low voltage (nominally 12 volts) and can be configured to require only a single cable connection to the control console. All timing signals, video signals, and camera power are transmitted over this cable. In addition, a multiplexing system is used for tamper-indication in the cable. Alternatively, separate cables can be used if the camera is to be connected to an existing control console. Tamper-safing features have not yet been specified.

This basic camera is intended for use with the "Portable Television Surveillance System" and with advanced CCTV systems.

EQUIPMENT NAME : Flight Research Camera
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : IAEA
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This system consists of a 16-mm movie camera with a very large capacity (about 10,000 frames). There are no tamper-safing features. Only a small number of these systems were procured. A major problem is the requirement for line power.

EQUIPMENT NAME : Fuel Verification Periscope
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Fuel
STATUS : Class IV : Production Model
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 when packed 24 kg and 80 kg respectively.

Final testing is now (1980) in progress.

EQUIPMENT NAME : IAEA TV Transmission Security System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 23,400
SOURCE 1 : Hitachi
SOURCE 2 : Col. Vid.
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : SAND 79-1780
REFERENCE DETAIL : Konnov & Lengsteiner; 146.

DESCRIPTION :

The basic system consists of two television cameras and an electronics console. The cameras are located in surveillance areas, and the console is placed in a convenient central location. The video pictures from the two cameras are combined into a single video frame for recording on a single video recorder. The recording interval is adjustable. The transmission security system was to be added to an existing "Psychotronic Surveillance System." However, since an existing system was unavailable, breadboard hardware was constructed to simulate the system. The video signal is encrypted, transmitted over the line from the camera to the console, decrypted at the console, and verified. Tamper indication is assured by generating an encoded signal which is added tothe video signal at the camera and checked at the console.

Though the IAEA system is inactive, similar equipment is available commercially through, e.g., Colorado Video, for which the cost applies. That equipment would consist of a digital, slow-scan receiver and transmitter (2 units). A pair of modems at about $600 each and encryptors at about $1100 each would be needed along with a narrow-band communications line; the price is included above. The transmission time per picture could be about 2.5 minutes.

A similar system investigated at SNL was called the "Spent-Fuel Monitoring System."

EQUIPMENT NAME : KFK Eumig Camera System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 12,000
SOURCE 1 : KFK
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Brueckner & Pfeffer; 109.

DESCRIPTION :

The system uses modified Eumig 880 PMA Super-8 cameras. They are equipped with an automatic control device of aperture and exposure time up to one minute, so that satisfactory pictures can be received under light conditions from 0.04 lux to 1,000 lux. Each camera is coupled with its own auxiliary timer and battery pack. The time settings are adjustable from 1 to 60 min. Other time settings can be arranged. The entire camera-timer system can be tested at 4 frames/minute by pushing a button. 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 3600 frames with normal film, 7200 frames with MFX film in normal cassettes, and 14,400 frames (61-m cassettes). The battery capacity allows exposure of one 61-m cassette.

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

EQUIPMENT NAME : Kodak Analyst Camera
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 :
REFERENCE 1 : IAEA-174
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Part E, Chapter 10.

DESCRIPTION :

This system uses a Kodak Super-8 Movie camera operating in a single-frame mode. A separate timer provides triggering at preset intervals. Tamper-safing is accomplished by installing the camera inside a stressed-glass container. Only two to four of these systems were built. It is not known if all have been retired.

EQUIPMENT NAME	: Minolta Surveillance Camera
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Optical Surveillance
MATERIAL TYPE	: Spent Fuel
STATUS	: Class IV : Production Model
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," has been deployed at a large number of field locations. This basic system is being replaced with the Minolta XL-401. There are currently problems with operation in dim light and with recording the date and time.

The capital cost applies to the system under development (two cameras in a sealed container) and the lifetime is the mean time to a failure that prevents operation.

EQUIPMENT NAME : NBS Surveillance Camera System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : NBS
REFERENCE 1 : IAEA-174
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Part E, Chapter 10.

DESCRIPTION :

This system uses a Bolex 16-mm movie camera in a secure, tamper-indicating container. The camera records a scene when triggered either by an adjustable timer or by a light-sensitive motion detector. A digital clock records time on each frame. The NBS camera has a 4000 frame capacity.

Two systems were built, but the system is no longer in use.

EQUIPMENT NAME : Polavision Cameras
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class I : Laboratory Device
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 12,000
SOURCE 1 : Aerodyne
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Prokoski, Caulfield & Quilty; 468.

DESCRIPTION :

This system consists of a movie camera which uses the newly developed "Polavision" instant movie film. The film is exposed normally and developed automatically during the first playback. The system will include features to adapt the camera to a safeguards environment, including possible communication of status indicators to a remote location. A tamper-indicating housing would include two cameras, a controller, batteries and diagnostic interface.

Film storage capability is small, so the system could probably only be useful for short-term surveillance.

The capital cost covers a complete housing unit and a playback system.

EQUIPMENT NAME	:	Portable Television Surveillance System
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Optical Surveillance
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class II : Development Prototype
USEFUL TO	:	Inspector
FACILITIES	:	Reactor Fuel Storage Reprocessing
CAPITAL COST	:	13,000
MAINTENANCE COST	:	1,300
LIFETIME	:	8 Years
SOURCE 1	:	SNL
REFERENCE 1	:	1978 IAEA
REFERENCE 2	:	SAND 80-0002
REFERENCE DETAIL	:	Campbell, Johnson & Stieff; V. 1, 625.

DESCRIPTION :

The battery-operated system is designed to be set up and placed into operation quickly. The system provides an inspector with the capability of monitoring an activity at selectable time periods between one and 15 minutes (in one-minute increments) for a duration of 24 hours. At each interval, the controller for the battery-operated system turns on the tape recorder and records for approximately one second. The controller also places the time of recording and the day number into the video picture. The case containing the controller and recorder receives the video signal from the sealed tamper-indicating camera housing via a fiber-optic cable (or a standard coaxial cable). The use of this type of cable makes attempts to tamper with the video quite difficult. If the power line (used directly to operate a built-in battery charger) to the camera housing is interrupted or shorted, the system will detect the loss of power and automatically record a tamper indication in the video picture. If the video cable is broken, then a second tamper indication will appear in the video recording. A third tamper indicator prevents undetected opening of the case with the video recorder.

The development status of the system is more precisely that the IAEA is using one and evaluating it for possible implementation of more.

EQUIPMENT NAME	: Psychotronic Surveillance System
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Optical Surveillance
MATERIAL TYPE	: Spent Fuel
STATUS	: Class IV : Production Model
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. Rechargable 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 : Robot Film Camera
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : IAEA
REFERENCE 1 : IAEA-174
REFERENCE 2 : SAND 80-0002

DESCRIPTION :

This system uses a 35-mm still photographic camera and includes a film magazine, clock, control unit, and instrument panel contained in a metal box with a glass window. A timer provides triggering at preset intervals which can range from 3 sec to 3 hr. The date and time are recorded on each frame from the battery-operated clock. The container provides some tamper resistance.

This was the first optical surveillance system to be placed in use by the IAEA. Only a small number of these were built and only one or two are still in use. A problem is the requirement for main line power. The system is also rather bulky and costly.

EQUIPMENT NAME	:	Semi-Automatic Super-8 Movie Film Scanner
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Optical Surveillance
MATERIAL TYPE	:	Miscellaneous
STATUS	:	Class III : Field Evaluation Unit
USEFUL TO	:	Inspector
FACILITIES	:	Reactor Fuel Storage Reprocessing
CAPITAL COST	:	75,000
MAINTENANCE COST	:	8,000
LIFETIME	:	5 Years
SOURCE 1	:	SNL
REFERENCE 1	:	SAND 80-2069
REFERENCE 2	:	SAND 80-0002

DESCRIPTION :

Developed Super-8 surveillance movie film is converted to an electronic video signal through a standard "film chain." The resulting video signal is then inspected automatically for changes in scene. Pictures which indicate a change are recorded on a video disc recorder for playback at variable speeds. Date and time are calculated from the picture-taking frequency and the start time (input by the user). These, plus frame count, are included in the video picture. Motion is detected by integrating the signal strength in two spots of variable size and position. The sensitivity is adjustable.

The development status is more precisely that the IAEA is routinely using one system to evaluate it. The system is not very useful when many frames display activities.

EQUIPMENT NAME : Semi-Automatic TV Tape Scanner
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Miscellaneous
STATUS : Class I : Laboratory Device
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : Fairchild
REFERENCE 1 : ISPO-70
REFERENCE 2 : SAND 80-0002

DESCRIPTION :

The TV tape scanner operates on the same basic system as the "IAEA TV Transmission Security System." However, since the basic system was unavailable for testing, breadboarded hardware was constructed to simulate the system.

Automatic video analysis is performed on the recorded data to reduce the number of pictures that must be viewed by an inspector. An audible and visual signal is generated on any frame which contains an alarm condition. The video tape recorder is also stopped on that frame during replay. The alarm condition is based on an edge-detection technique. Thus, light level variations should have little effect on the system detection capability.

This system has not turned out to be very useful because most tapes show too much motion.

EQUIPMENT NAME	:	Spent-Fuel-Bundle (CANDU) Cerenkov Verifier
USE CATEGORY	:	Inspector Use
GENERAL TYPE	:	Optical Surveillance
MATERIAL TYPE	:	Spent Fuel
STATUS	:	Class III : Field Evaluation Unit
USEFUL TO	:	Inspector
FACILITIES	:	Reactor
CAPITAL COST	:	8,500
MAINTENANCE COST	:	1,300
REPLACEMENT COST	:	8,500
SOURCE 1	:	AECL White
REFERENCE 1	:	IAEA-STR-90

DESCRIPTION :

This device uses a light intensifier attached to a light pipe or periscope to view Cerenkov radiation emanating from an irradiated fuel bundle. A camera may also be attached to the light intensifier to photograph the Cerenkov radiation coming from the fuel bundles for record purposes.

It is intended that this device shall be capable of viewing Cerenkov radiation emanating from the end of any individual fuel bundle contained in a stack of spent CANDU fuel.

This system is built around the "Cerenkov Viewing (Night-Vision) Device" as its basic element.

EQUIPMENT NAME : Television Surveillance System (NBS)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
SOURCE 1 : NBS
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

A standard closed-circuit television system is used to provide surveillance of portions of a CANDU reactor. The picture is encoded by shifting the grey scales in a variable pattern. The encoded data is transmitted by wire to a decoding monitor in a secure instrumentation container. At predetermined time intervals, or when triggered by a gamma-level detector or an auxiliary-motion detector, the encoding for the picture is changed, and a photographic camera is triggered to record the displayed video. The encoding technique and the container for the decoding monitor provide tamper protection.

This system received limited field testing at a CANDU reactor.

EQUIPMENT NAME	: Television Surveillance System (SNL)
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Optical Surveillance
MATERIAL TYPE	: Spent Fuel
STATUS	: Class I : Laboratory Device
USEFUL TO	: Inspector
FACILITIES	: Reactor
	Fuel Storage
SOURCE 1	: SNL
REFERENCE 1	: 1970 IAEA
REFERENCE 2	: SAND 80-0002
REFERENCE DETAIL	: McManus & Engel, Jr.; V. 1, 73.

DESCRIPTION :

A slow-scan closed-circuit television camera was developed for application in a CANDU reactor to detect fuel handling with other-than-normal fueling machines, to detect the introduction of decoy fuel elements, and to confirm operator fuel-handling records. Pictures are triggered by a timer, gamma-level detector or motion detector. The gamma-level and motion detectors are hardware systems separate from the television system. The camera is enclosed in a stressed-glass, tamper-resistant, tamper-detecting container. Data is protected by scanning the picture in a random pattern before transmitting. The receiving system then unscrambles the picture. Recording is on an audio recorder. (The slow-scan television signal is low enough in frequency for this to be practical.) The equipment that would be required here is described in more detail for the "IAEA TV Transmission Security System," except that no encryption is included in this now dormant system.

EQUIPMENT NAME : Zeiss Contarex Camera System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Optical Surveillance
MATERIAL TYPE : Spent Fuel
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
SOURCE 1 : IAEA
REFERENCE 1 : IAEA-174
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Part E, Chapter 10.

DESCRIPTION :

The system uses a 35-mm camera with a wide-angle lens and operates on battery power. The main system components are the camera with film magazine, a tele-sensor attachment for automatic exposure control, a timer, motor drive, electronic interface, and battery packs. Pictures are taken at a preset fixed rate using the timer. Tamper-safing features are not included, but the main disadvantage of the system is the limited film capacity of 450 frames.

EQUIPMENT NAME : Gamma Walk-Through Doorway Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 30,000
SOURCE 1 : UKAEA
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Williams; 118.

DESCRIPTION :

The system, designed for domestic physical protection, contains four sodium iodide gamma counters, a metal detector, and an ultrasonic-doppler occupancy detector. The system is controlled by a microprocessor.

The monitor can detect less than 0.5 g of Pu shielded by 3 mm of brass at the 90% confidence limit with a false alarm rate of no more than 0.1%, or 3 g of U-235 enriched to 90% at the 50% confidence limit with a false alarm rate of no more than 0.1%.

EQUIPMENT NAME : Personnel Doorway Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 20,000
SOURCE 1 : LANL
SOURCE 2 : UKAEA
REFERENCE 1 : 1976 IAEA
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Chambers & Ney; 297.

DESCRIPTION :

This system consists of an enclosure containing a detector array, signal-conditioning electronics, power supplies, alarm logic circuits, a microwave occupancy monitor, an alarm recording camera, irreversible electro-mechanical counters, and a tamper-indicating enclosure. The system was developed to detect unauthorized movements of materials. Characteristic gamma radiation from U-235 or Pu-241 is detected by four sodium iodide scintillators. Electronics packages process the count-rate data to measure background rates and to provide selectable detection levels of background rates. The monitor is designed to detect one gram of Pu or 50 grams of U-235 with a probability of detection of 50%. This system is currently inactive.

A similar system at the Harwell Laboratory very sensitive to gamma radiation costs about $30,000.

EQUIPMENT NAME : Portal Monitor (Booth-Type)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : All
SOURCE 1 : KFK
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Jourdan, Moennich, Scheuerpflug & Sellinschegg; 115.

DESCRIPTION :

The system includes sodium iodide gamma detectors, door controls, and an occupancy detector. The doors are pneumatically operated. The system is controlled by an electronic control unit.

The booth monitor detects 1.5 g of uranium (90% enriched U-235) or 0.045 g of plutonium (90% Pu-239) shielded with 3 mm of brass, at a false alarm rate of less than 0.1% and a detection probability of 90%.

This portal was designed for domestic physical protection and is limited to the passage of two persons per minute.

EQUIPMENT NAME : Portal Monitor (Rotor-Type)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : All
SOURCE 1 : KFK
REFERENCE 1 : 1979 ESARDA
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Jourdan, Moennich, Scheurpflug & Sellinschegg; 115.

DESCRIPTION :

The main feature of this monitor, designed for domestic physical protection, is a pneumatically operated rotor. The gamma-detection system is located in the center and at one side of the rotor. The rotor can be triggered by an individual or can be operated continuously. Gamma rays are detected with two liquid scintillators.

This monitor can detect less than 0.5 g of Pu shielded by 3 mm of brass at the 90% confidence limit with a false alarm rate no more than 0.1%, or 3 g of U-235 enriched to 90% at the 50% confidence limit with a false alarm rate of no more than 0.1%.

EQUIPMENT NAME	:	Portal Neutron Monitor
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Portal Monitor
MATERIAL TYPE	:	SNM Neutron Emitters
STATUS	:	Class IV : Production Model
USEFUL TO	:	Operator and Inspector
FACILITIES	:	All
CAPITAL COST	:	62,400
SOURCE 1	:	IRT
SOURCE 2	:	Jomar
REFERENCE 1	:	IRT

DESCRIPTION :

The IRT monitor contains three neutron-sensitive detectors on each side. Its commercial availability is imminent at this writing.

The Jomar monitor uses liquid scintillators and pulse-shape analysis to detect neutrons and gammas as well, with a low false-alarm rate. The capital cost given is for this Jomar detector as designed for international applications, i.e., with tamper-safing features and public-key encryption of its signals.

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 : 18,100
SOURCE 1 : IRT
SOURCE 2 : NNC
REFERENCE 1 : LA-7646
REFERENCE 2 : LA-5681

DESCRIPTION :

The IRT portal monitor is sensitive to gram quantities of U-235 and Pu-239 and to 1 microcurie amounts of Ba-133, Cs-137, and Co-60. Capable of checking about fifty persons per minute, this unit employs liquid scintillators for radiation detection, constantly monitors background radiation, and monitors 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. Savings accrue from the use of a multiple detector control unit for more than four portals.

Similar monitors available from TSA and NNC at equal or lower cost perform the same functions as the IRT monitor.

EQUIPMENT NAME : Secure Counter Panel
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Miscellaneous
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : All
SOURCE 1 : SNL
REFERENCE 1 : Kiawah
REFERENCE DETAIL : Smathers; 257.

DESCRIPTION :

The Secure Counter Panel (SCP) is intended to be located within a locked equipment enclosure with the safeguards instruments to be protected. The present design is part of an "Unattended Personnel Portal Monitor." It notes tamper attempts and other selected operating data that cannot be erased without leaving obvious physical evidence of tampering. The SCP includes backup power and continues to monitor tamper attempts and instrument activities during a power outage. The data recorded in the SCP are recovered by visually inspecting or photographing the front panel during periodic visits by an inspector.

Several design features minimize the possiblity of tampering with the SCP without leaving physical evidence. The color-anodized finish on the deep-drawn welded aluminum box makes penetration very difficult without leaving surface flaws. A stressed-glass window covers 14 electro-mechanical data counters and will shatter if scratched or cut. Unstressed glass covers the stressed glass, and the glass can only be replaced by removing the cover, which itself is sealed with a fiber-optic seal.

EQUIPMENT NAME : Unattended Personnel Portal Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Radioactive Mat'l in Any Form
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : All
SOURCE 1 : SNL
SOURCE 2 : LANL
REFERENCE 1 : 1979 INMM
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Mangan; 674.

DESCRIPTION :

The system contains gamma and neutron coun rs, a metal detector, door controls, and tamper-safing features. The inspector interface is a secure panel on which safeguards alerts and operating warnings are recorded. A portal log (tape cassette), a log-tape analyzer, and a status panel are included with the system.

Gamma rays are measured by three plastic scintillators in each side wall. Neutrons are detected with 12 He-3 proportional tubes in the floor and ceiling. The metal detector is an active electromagnetic system with coils in the walls, floor, and ceiling to detect stationary metal objects in three orthagonal directions. The gamma and neutron systems are designed to detect a specific unshielded (or shielded with 11 kg of lead) fuel plate containing 32 g of Pu (including 1.4 g of Pu-240) with a probability of 100% and a false alarm rate of 0.1%.

Tamper-safing is provided by the special design of the outer and inner walls, strategically placed microswitches, a microprocessor for control of portal functions, and a Secure Counter Panel, which records abnormal portal functions, alerts, warnings, tamper attempts, and loss of power.

EQUIPMENT NAME	: Vehicle (Large) Portal Monitor
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Portal Monitor
MATERIAL TYPE	: SNM Neutron Emitters
STATUS	: Class I : Laboratory Device
USEFUL TO	: Operator and Inspector
FACILITIES	: Enrichment
CAPITAL COST	: 5,000,000
SOURCE 1	: LANL
REFERENCE 1	: 1979 INMM
REFERENCE 2	: SAND 80-0002
REFERENCE DETAIL	: Fehlau, Atwater, Caldwell & Shunk; 681.

DESCRIPTION :

The large-vehicle portal monitor is a tunnel neutron detector. The conceptual design has concrete floor, walls, and ceiling large enough to accommodate the largest vehicle requiring inspection (approximately 6.1 m high, 6.1 m wide, and 18.3 m long). The structure is shielded with about 5 m of dirt overburden. The inside walls and ceiling are lined with polyethylene and the end doors are entirely constructed of polyethylene. A grid of He-3 filled proportional counters is placed on the enclosure walls and ceiling.

A vehicle, presumably with feed for or product or tails from an enrichment plant, is counted when it is driven into the enclosure. The polyethylene serves as a neutron moderator and reflector. Thermal neutrons are repeatedly scattered by the liner until they are captured by the proportional counters, the polyethylene or the concrete. The presence or absence of nuclear material within the vehicle is determined by a comparison of the proportional counter readings with the normal background readings.

This shielded, nonintrusive, vehicle portal monitor is expected to be capable of detecting 0.1 g of typical reactor-grade plutonium oxide or about 0.6 kg of uranium hexafluoride for an inspection time of 200 s.

EQUIPMENT NAME : Vehicle Gate (Sodium Iodide) 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 : 20,000
SOURCE 1 : Scurry
REFERENCE 1 : 1974 INMM
REFERENCE DETAIL : Martinez & Cunningham; 416.

DESCRIPTION :

The detection system consists of four small sodium iodide detectors. These detectors are mounted to the gate posts, two on each side facing toward the center of the gate and oriented at right angles to vehicular traffic flow. The electronics compares the instantaneous count from a passing vehicle to a stored background count. The gate width is 24 feet.

A minimally shielded 50 g plutonium source can be reliably detected when placed inside a 1.5-ton truck or a passenger car traveling through the gate at speeds up to 15 mph. Tests with the same source placed inside a rubbish container show similar sensitivities provided the vehicle speed is less than 7 mph. Alternatively, the minimum times to detect 25 g of encapsulated Pu as oxide and 1 kg of highly enriched uranium, both unshielded but inside a stationary vehicle, are 6 and 20 seconds respectively.

EQUIPMENT NAME	: Vehicle Gateside (Organic) Monitor
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Portal Monitor
MATERIAL TYPE	: Gamma Emitters
STATUS	: Class III : Field Evaluation Unit
USEFUL TO	: Operator and Inspector
FACILITIES	: All
CAPITAL COST	: 20,000
SOURCE 1	: LANL
REFERENCE 1	: 1979 INMM
REFERENCE DETAIL	: Fehlau, Atwater, Caldwell & Shunk; 681.

DESCRIPTION :

This prototype gateside monitor is constructed from components of a personnel doorway monitor that utilize plastic scintillators. This unit has four 5.08 cm diameter by 91 cm long organic scintillators, with two on each side of the gate. These gateside monitors were used to carry out static count rate measurements on a source-containing vehicle at gate where the separation between detectors is 7.3 m.

The minimum times required to detect 25 g of encapsulated Pu as oxide and 1 kg of highly enriched uranium metal (both unshielded but inside a vehicle) are 15 and 7.7 seconds respectively.

EQUIPMENT NAME : Vehicle Portal Monitor (Liquid Scintillator)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : SNM Neutron Emitters
STATUS : Class I : Laboratory Device
USEFUL TO : Inspector
FACILITIES : Enrichment
CAPITAL COST : 200,000
SOURCE 1 : SNL
SOURCE 2 : BNL
REFERENCE 1 : TSO
REFERENCE DETAIL : Fainberg; Dec. 30, 1980.

DESCRIPTION :

Four planar tanks of liquid scintillator would surround a portal. The plan would be for a truck to stop for 10 seconds at several points along its length. The detectors could be sensitive to either fast or thermal neutrons, or some tanks could be sensitive to one and some to the other. Sensitivity is 1 kg of unshielded uranium hexaflouride.

EQUIPMENT NAME	: Vehicle Portal Monitor (Modular, He-3 Based)
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: Portal Monitor
MATERIAL TYPE	: Uranium Hexafluoride
STATUS	: Class III : Field Evaluation Unit
USEFUL TO	: Operator and Inspector
FACILITIES	: Enrichment Reprocessing
CAPITAL COST	: 100,000
LIFETIME	: 15 Years
SOURCE 1	: LANL
REFERENCE 1	: 1979 ESARDA
REFERENCE DETAIL	: Caldwell, Atwater, Bernard, Bieri & Shunk; 122.

DESCRIPTION :

Self-contained modules of polyethylene-moderated and reflected He-3 proportional counters are placed on both sides of a vehicle portal. Neutrons from uranium spontaneous fission and alpha-neutron reactions (characteristic of an enrichment plant) are detected in the modules. Neutron detections are recorded in an integrated data processing system which provides detector status, updated background, vehicle status and alarm-level functions. The vehicle is constrained to stay in one location for a count period of approximately 10 sec. The unshielded uranium hexaflouride sensitivity is about 1 kg.

The basic module is a rectangular-cross-section box constructed from 1.2- and 2.5-cm-thick polyethylene in which are placed seven He-3 proportional counters 5 cm in diameter and 1.82 m long with two-atmosphere fill pressure. External module dimensions are 2.1 m x 0.3 m. Modules are self-contained, self-supporting, and may be grouped together in any desired configuration. Four modules are required (two on each side) for a standard vehicle portal monitor with 10 sec. vehicle count time.

EQUIPMENT NAME : Vehicle Roadbed Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Portal Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 80,000
SOURCE 1 : LANL
REFERENCE 1 : 1979 INMM
REFERENCE DETAIL : Fehlau, Atwater, Caldwell & Shunk; 681.

DESCRIPTION :

The motive in constructing a roadbed monitor is to minimize the separation between the detectors and the vehicle without obstructing traffic. This roadbed monitor utilizes a pit to house its array of eight sodium iodide 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. Occupancy and traffic direction data, microwave vehicle identification data, and all of the detector counting data are transmitted by overhead lines to an adjoining building and input to a minicomputer serving all logic and control functions for the monitor. Also on top of the adjoining building is a background monitor. The roadbed monitor detector pit also contains an array of 48 boron triflouride proportional counters to make neutron measurements for comparative purposes.

The minimum times required to detect 25 g of encapsulated Pu as oxide and 1 kg of highly enriched uranium metal (both unshielded but inside a vehicle) are 3.5 and 160 seconds respectively for the sodium iodide and 50 seconds (Pu only) for the proportional counters.

EQUIPMENT NAME : (Yes/No) Electronic Dosimeter
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Radioactive Mat'l in Any Form
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 RMD device is an advanced CdTe chirper sensitive to dose rate but without any memory. The XETEX device is an integrating dosimeter with GM detector and built-in display.

Recent developments and future plans are such that it will be possible to sense and display both total dose and dose rate in one package, making small dosimeters of greater yes/no use than existing personnel or environmental dosimeters. 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 : Spent Fuel
STATUS : Class IV : Production Model
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 are not normally removed. 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 passed the location.

These dosimeters are used at CANDU reactors and the costs reflect their use there as expressed in Reference 2. (The general statements made here come from the reference SAND 80-0002.)

EQUIPMENT NAME	: Hand-Held Monitor
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: SNM Monitor
MATERIAL TYPE	: Gamma Emitters
STATUS	: Class IV : Production Model
USEFUL TO	: Operator and Inspector
FACILITIES	: All
CAPITAL COST	: 1,350
SOURCE 1	: NNC
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. A newer 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 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 : Mechanical Cell Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : SNL
REFERENCE 1 : SAND 80-0002

DESCRIPTION :

This device is a spent-fuel-bundle counter with the added capability of detecting high-level waste containers. Two xenon ionization chambers in each of two instrumented shielded plugs sense gamma radiation from irradiated fuel being transferred from the storage basin to the mechanical cell. The plugs, separated approximately 1.5 m, are inserted through the biological shield. Electronic circuits are used to process the outputs from the ionization chamber to drive five electro-mechanical counters. The system stands alone but is not tamper-safe.

Designed for the General Electric plant in Morris, Illinois about 1971, this system would require complete redesign for any other reprocessing plant.

EQUIPMENT NAME : Plutonium-Vault Neutron Monitoring System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Plutonium
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Fabrication
Reprocessing
Critical
Fuel Storage
CAPITAL COST : 50,000
MAINTENANCE COST : 1,000
LIFETIME : 15 Years
SOURCE 1 : LANL
REFERENCE 1 : LA-8373-PR
REFERENCE DETAIL : Pratt, Caldwell, Hastings, France, Shunk, Bieri & Kuckertz; 26.

DESCRIPTION :

A set (typically 25) of bare He-3 proportional counters placed in a grid near the ceiling of a plutonium storage vault is used to continuously monitor the thermal-neutron flux produced by stored plutonium. Each proportional counter is monitored separately and the neutron flux distribution in the vault is determined after each count cycle. Removal or addition of plutonium to the vault is signaled by changes in the thermal-neutron flux distribution near the ceiling.

This system has been demonstrated in a large plutonium storage vault and a removal or addition sensitivity of about 1 kg in a vault total of about 2000 kg has been obtained. Long term stablility of 0.04% in total count rate has been obtained. The system can be used to obtain crude (at the 0.04% level) on-line real-time plutonium accountancy. Such a level is crude because no loss is expected in a vault, wherein no processing occurs.

EQUIPMENT NAME : Radiation Monitor with High Alarm
USE CATEGORY : Process Monitoring
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Radioactive Mat'l in Any Form
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : All
CAPITAL COST : 1,000
SOURCE 1 : Baird
REFERENCE 1 : AGNS35900-2.2-24

DESCRIPTION :

This monitor presents visual and audible indications of radioactivity. A front panel red alarm flashes when the preset alarm value is reached. Simultaneously, an optional remote alarm is triggered. The monitor is adjustable from 10% to 100% full scale. This particular one (Model 904-443) uses either Geiger-Mueller, scintillation, or gas detectors.

EQUIPMENT NAME	: Shelf Monitor System
USE CATEGORY	: Containment-Surveillance
GENERAL TYPE	: SNM Monitors
MATERIAL TYPE	: Gamma Emitters
STATUS	: Class II Development Prototype
USEFUL TO	: Operator and Inspector
FACILITIES	: Fabrication Reprocessing Fuel Storage Critical
CAPITAL COST	: 150,000
SOURCE 1	: LANL
SOURCE 2	: SNL
REFERENCE 1	: 1980 INMM
REFERENCE 2	: DSS News
REFERENCE DETAIL	: 1. Nicholson, Kuckertz & Ethridge; 649. 2. No. 1 (May, 1981), 7.

DESCRIPTION :

Periodic inventory of large quantities of Pu, in cans on shelves in a vault, results in personnel exposure when conventional methods are used. This system provides continuous surveillance of such stored Pu. (Though radiation exposure is not significant for highly enriched uranium, the real-time monitoring feature would be useful for it too.) It consists of a shelf monitor designed with a single-component microcomputer to collect data from a Geiger Mueller tube that monitors gamma emissions and a scale that monitors the total weight of the special nuclear material and its container. Because the weight sensor depends on the capacitance of the container, merely touching the container would change the weight reading; thus the weight sensor is inherently tamper-indicating.

A network of these shelf monitors can report their acquired data to a minicomputer for analysis and storage. Because a large number of these monitors is likely to be needed in most storage facilities, a low-cost but reliable monitor is needed.

The capital cost given is for a system capable of monitoring 1000 items but it is expandable to 16000 at $100/item.

A similar system built by Sandia for Hanford is expected to cost $20,000 for the processor and $50 for each shelf position.

EQUIPMENT NAME : Spent-Fuel Integrated Monitoring System
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Spent Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Operator and Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
SOURCE 1 : SNL
REFERENCE 1 : IWGRPS
REFERENCE 2 : POTAS
REFERENCE DETAIL : 1. Supplement, Appendix III.
2. Task E.45, 180.

DESCRIPTION :

This system employs an array of radiation detectors, a set of strain gauges attached to the rails of the cask-handling crane, and a triggered 8mm film camera for monitoring a spent-fuel transport portal and unloading area. The radiation detectors monitor the total spectrum of gamma radiation emerging from a spent-fuel cask. The data from the radiation detectors are processed in near-real time to determine the position of a loaded spent-fuel cask. The strain gauges monitor the weight and direction of motion of the crane. These systems provide independent indication of spent-fuel movement. The camera takes pictures of the area when a potential diversionary activity is sensed by the radiation and crane monitors.

Extensive tamper-indicating features have been included in the system. Accumulated information on fuel movements and tamper status is available to the inspector through an Inspector Display Module. A prototype system has been successfully demonstrated to the IAEA. (This is an improved version of the "Secure Crane-Load Sensor.")

EQUIPMENT NAME : Spent-Fuel Monitor (Scintillator)
USE CATEGORY : Inspector Use
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Spent Fuel
STATUS : Class I : Laboratory Device
USEFUL TO : Inspector
FACILITIES : Reactor
Fuel Storage
Reprocessing
CAPITAL COST : 20,000
SOURCE 1 : LANL
REFERENCE 1 : 1980 INMM
REFERENCE 2 : LA-8447
REFERENCE DETAIL : Moss, Nixon & Bernard; 214.

DESCRIPTION :

A monitor for rapidly measuring the gross gamma-ray flux immediately above spent fuel assemblies in underwater storage racks has been developed. It consists of a plastic scintillator, photomultiplier, collimator, underwater cables, support ropes, and a small battery-powered electronics package.

The relative gross gamma-ray measurements have been correlated with the declared irradiation histories and cooling times of selected fuel assemblies. If this information is provided by the operator or is measured independently, calculations can then be made on the expected counting rate in the scintillator. This relationship has been demonstrated on irradiated PWR fuel assemblies with a precision of 22%. The crosstalk from an isolated fuel assembly to an adjacent void is only about 2%.

The scintillator detector is simple and easy to operate. It requires only a small electronic package and is highly portable. The scintillator detector system can be used to measure rapidly (1 per minute) the gamma-ray signatures of irradiated fuel assemblies in vertical underwater storage racks. It can be easily adapted to various underwater handling devices; for example, it could be incorporated in an underwater telescope used for reading serial numbers of fuel assemblies. This would permit the measurement of an assembly while performing an item counting inventory.

EQUIPMENT NAME : Thermoluminescent Dosimeter (TLD)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Radioactive Mat'l in Any Form
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 8,000
MAINTENANCE COST : 70
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.

TLDs possess a very large dynamic range, are physically small, and are readable over an integrated dose rate that extends from 10 mR to 100,000 R. Exposure times could be made as short as 1 min. The light output is approximately linear over very broad ranges of integrated dose rates.

An added advantage is that 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 could be very simple and inexpensive because little more than a heater and photodiode would be required. Operationally, the use of TLDs could cause some problems because some type of closed underwater positioning system would be required to send the TLD packet down to the spent fuel and to retrieve it for readout. TLDs can be recycled almost indefinitely, thus limiting the required inventory. Because the apparatus required to do a pond fuel-assembly inventory could be cumbersome and would become contaminated, it should be installed permanently at each facility.

The capital cost covers an analyzer and about 100 dosimeters and the maintenance cost, enough LiF TLD powder for one charge of each dosimeter.

EQUIPMENT NAME : Unattended Loading-Dock Monitor
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : Gamma Emitters
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : Conversion
Fabrication
Enrichment
SOURCE 1 : LANL
SOURCE 2 : SNL
REFERENCE 1 : 1976 IAEA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Chambers & Ney; V. 2, 297.

DESCRIPTION :

This device detects large masses of material, such as unenriched feed materials that are moved in multi-thousand kilogram quantities. A gamma-ray scintillator and an electronics package fit within a tamper-resistant cylindrical container. The monitor is installed adjacent to a standard shipping-dock doorway. Background radiation is measured. If the monitor is incapcitated by external shielding of radiation, an 8-mm movie camera records activities on the dock.

The system is not being developed further.

EQUIPMENT NAME : Unattended Material or Equipment Pass-Through
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : SNM Monitor
MATERIAL TYPE : SNM Samples
STATUS : Class I : Laboratory Device
USEFUL TO : Operator and Inspector
FACILITIES : All
SOURCE 1 : SNL
SOURCE 2 : LANL
REFERENCE 1 : Kiawah
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Smith & Rice, III; 372.

DESCRIPTION :

A 400x480x760-mm enclosure contains a pulsed neutron source and proportional counters to detect removal of shielded or unshielded nuclear material. The system contains a microprocessor to provide the inspector with a log of the system operation. The system can be made tamper-safe, and it contains radiation shielding to protect personnel from the neutron source.

Each fission (epithermal) neutron detector is an array of He-3 filled proportional counter tubes stacked between polyethylene sheets and encased in a cadmium cover. Thermal neutrons are detected with unshielded proportional counters. The sensitivity is being evaluated. The system is designed with tamper-resistant features, such as wire grid in the exterior walls to sense penetration, microswitches to detect removal of exterior panels, and a self-contained microprocessor controller; but most of these features are not installed on the prototype unit.

EQUIPMENT NAME : Cup-and-Wire Seal (Improved Type E)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : All
MAINTENANCE COST : 25
SOURCE 1 : SNL
REFERENCE 1 : SAND 80-2699

DESCRIPTION :

The Type X seal is a new design considered for replacement of the Type E seal. It is a stainless steel cup-and-wire design with special spring fingers to hold it together. It is fingerprinted with scribed lines on the inside of the case as is the Type E seal. Of all other designs tested, the Type X is the most durable and tamper-resistant, though also the most expensive.

Another new design under consideration is the Type DC seal. It is a double-cap variation of the Type E seal having better tamper resistance than than the Type E seal but only moderately more costly.

The actual costs for the Type X and DC seals are $6 and $1.50 respectively. The actual use costs would be about $25 and $20.

EQUIPMENT NAME : Cup-and-Wire Seal (Type E)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
MAINTENANCE COST : 20
LIFETIME : 10 Years
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 developed and has improved the procedures for the unique marking, verification, etc. In quantities, the two-cup sets cost about $.75. The $20.00 maintenance cost includes the additional handling at headquarters.

EQUIPMENT NAME	:	Fiber-Optic (Active) Seal
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Seal
MATERIAL TYPE	:	Containments
STATUS	:	Class III : Field Evaluation Unit
USEFUL TO	:	Inspector
FACILITIES	:	All
CAPITAL COST	:	5,000
MAINTENANCE COST	:	1,000
LIFETIME	:	1 Year
SOURCE 1	:	KFA
SOURCE 2	:	SNL
REFERENCE 1	:	1978 IAEA
REFERENCE 2	:	SAND 80-0499
REFERENCE DETAIL	:	Kennepohl, Maekelburg & Stein; V. 1, 617.

DESCRIPTION :

These are the first versions of active fiber-optic seals, which have an internal (battery) power source and which continually verify the integrity of the fiber-optic loop and display its status, in situ or possibly remotely. The U.S. (Sandia) and West German (KFA) approaches are similar. (The German seal system is known as VACOSS.) A semiconductor light-emitting diode is pulsed repeatedly and photodiodes detect the pulses unless the fiber-optic bundle is broken or damaged. The present designs generate a series of pseudo-random numbers as a function of time so long as the photodiodes and the light pipe are not interrupted. The specific random-number series for each seal is imposed on the internal programmer by a programmer-verifier instrument and recorded. An inspector provided with this code can verify secure operation by comparing the pseudorandom number on the display of the seal with the number assigned in his book for that seal at that time. Though expensive the units can be reused, with new light pipes. They are not only verifiable in situ, but could easily be adapted for remote verification.

The capital cost is that for the programmer-verifier unit and the maintenance cost, for the seal itself; these apply to the Sandia system. The lifetime derives from the battery lifetime.

EQUIPMENT NAME : Fiber-Optic (Digital) Seal
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class I : Laboratory Device
USEFUL TO : Inspector
FACILITIES : All
SOURCE 1 : ARC
REFERENCE 1 : SAND 80-0002
REFERENCE 2 : SAND 78-0400

DESCRIPTION :

This is one of several schemes which have been proposed or have been demonstrated in a laboratory to obtain direct, e.g. digital, data from a fiber-optic type of seal, thus eliminating the need to take photographs and to compare them. (This particular system is also known as LASS, for Linear Array Seal System.) The basic idea is to use the fiber bundle to thread the containment object and to create a unique random pattern by obstructing some light-guides and by scrambling all of them. A unique digital signature may be obtained, e.g., by illuminating one end of the fiber bundle and viewing the other end by means of photodiodes.

Such a system could yield cheap and easy-to-install seals and "loops", be easy to record, and be easy to verify in situ. It is conceivable that such seals might, with additional interrogators, be remotely verifiable. The costs, reliability and usefulness remain to be determined.

EQUIPMENT NAME : Fiber-Optic (Passive) Seal (I)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 5,000
MAINTENANCE COST : 35
SOURCE 1 : Fiber-Lock
SOURCE 2 : HDL
REFERENCE 1 : SAND 80-0002
REFERENCE 2 : SAND 78-0400

DESCRIPTION :

A fiber-optic seal has the advantage that the loop which threads the containment object is verifiable. In the case of passive fiber-optic seals, such as this, some strands in the fiber-optic bundle are randomly blocked to give a unique pattern that would be very difficult to reproduce. The first such seal was developed by Harry Diamond Lab. under contract to the US Arms Control and Disarmament Agency. The fiber-optic bundle is threaded through holes in the containment object. The two ends are glued into a plastic block in such a way that some strands conduct light, others don't, and the individual light-pipes are randomly oriented. The seal is attached and a picture recorded through a low-power microscope. The seal can be verified in situ by repeating this process and comparing the photographs. Practical difficulties were encountered in applying, recording and verifying the earlier versions. Evaluation of improved designs continues.

The capital cost is that of the identifier and the maintenance cost, that of the seal itself.

EQUIPMENT NAME : Fiber-Optic (Passive) Seal (II)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 10,000
MAINTENANCE COST : 10
SOURCE 1 : ARC
REFERENCE 1 : SAND 78-0400

DESCRIPTION :

The fiber-optic bundle is threaded through holes in the containment. The two ends are pushed through holes in a metal fixture which is then squeezed together, cutting some of the fiber light pipes. The protruding ends are cut off flush with the face of the fixture. The reader, or verifier, consists of microscope optics, a Polaroid camera, and a "coherent" light pipe to make connection to the two exposed ends of the fiber-optic bundle at the face of the fixture. The picture of the seal, after installation, is a unique pattern which may be compared to in situ photographs taken later. Verification is accomplished by comparing the in situ produced photography with a negative transparency of the seal signature which was produced from the seal positive at installation time.

The field-portable system weighs about 5 kg. It is self-powered and contains sufficient material to install 20 seals. A shipping case provides additional parts and film for an additional 80 assemblies.

The capital cost is for the verifier and the maintenance cost, for the seal itself.

EQUIPMENT NAME	:	Fuel-Assembly Ident. Device (BWR FAID Ultrasonic)
USE CATEGORY	:	Containment-Surveillance
GENERAL TYPE	:	Seal
MATERIAL TYPE	:	Fuel
STATUS	:	Class II : Development Prototype
USEFUL TO	:	Inspector
FACILITIES	:	Fabrication Reactor Reprocessing Fuel Storage
CAPITAL COST	:	3,000
MAINTENANCE COST	:	100
LIFETIME	:	5 Years
SOURCE 1	:	Exxon
SOURCE 2	:	SNL
REFERENCE 1	:	1980 ESARDA
REFERENCE 2	:	SAND 80-0002
REFERENCE DETAIL	:	McKenzie, Deveney, Sheldon, Sellers, Nilson, Patterson, Fanton, Snyder & Crutzen; 455.

DESCRIPTION :

The ultrasonic seal snaps onto one of the tie rods which hold the top and bottom frames that hold the fuel rods together. The tie rod must be notched for the seal snap-on ring. The seal contains a random distribution of acoustic discontinuities. The ultrasonic signature can be read accurately by placing the transducer in contact with the seal. The unique signature is obtained by pulsing the ultrasonic transudcer and recording the pattern of reflections as a function of time. The reflections are due to the discontinuities in the seal itself and to the attachment to the tie rod.

The seal was originally designed at Ispra. It has been applied to BWR fuel assemblies which have been exposed to typical exposures (burnups) in BWR's. The seals were not appreciably degraded. However, variations in transducers and problems in precisely attaching the transducers to the seals underwater in spent fuel storage pools have, so far, not been entirely overcome.

The capital cost is for the ultrasonic verifier and the maintenance cost, for the BWR FAID.

EQUIPMENT NAME : Fuel-Assembly Ident. Device (MTR FAID Ultrasonic)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 25,000
MAINTENANCE COST : 100
LIFETIME : 5 Years
SOURCE 1 : Nukem
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Crutzen, Vinche, Burgers & Combet; V. 1, 561.

DESCRIPTION :

The basic principles are the same as those described for the BWR FAID. An MTR (materials-testing reactor) assembly consists of a number of long, thin plates enclosed in a box to facilitate efficient water cooling. The ultrasonic seal is in the form of a rivet that is swaged into a hole strategically located at one end of the box and placement structure. These seals were developed at JRC Ispra and have been applied to MTR fuel assemblies which were exposed to high burnup in a research reactor. The seals were not too damaged by the exposure. Some problems regarding transducers and feasible readout for post-irradiation verification remain to be solved.

The capital cost is for the identifier and the maintenance cost, for the seal.

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 maintenance cost is for the seal itself.

EQUIPMENT NAME : Shrink-Tubing Seal for UF-6 Cylinder Valves
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Uranium Hexafluoride
STATUS : Class I : Laboratory Device
USEFUL TO : Inspector
FACILITIES : Enrichment
Fabrication
Conversion
MAINTENANCE COST : 20
SOURCE 1 : BNL
SOURCE 2 : SNL
REFERENCE 1 : TSO
REFERENCE DETAIL : Fiarman; 9 April 1980.

DESCRIPTION :

Because of the present design of uranium hexafluoride cylinders (containers), there is no reliable way to attach the available Type-E or similar seals to the spigot and valves which permit UF-6 to be fed to or withdrawn from these safeguards-important containers.

A new development, under investigation, employs "shrink-tubing", i.e. plastic tubing which shrinks to half size when moderately heated. The idea that is proposed would be to use two pieces of shrink tubing. The first is prepared with randomly distributed, differently colored inclusions and is placed over and, by heating, shrunk onto the valve and nozzle. The second piece of tubing would be marked with a labelled grid of X-Y coordinates. It would be placed over and heat-shrunk onto the former. An inspector would select a few identified segments of the latter grid and record the number (possibly color) of the dots on the inner shrunken tube within that sector.

In view of the design of UF-6 cylinders, it is not clear that this would provide the degree of assurance that the IAEA needs. There is no experience to indicate how easy or difficult it might be for inspectors to use this technique.

EQUIPMENT NAME : Ultrasonic Cap Seal and Secure Rod
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Spent Fuel
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Inspector
FACILITIES : Storage
Reactor
Fuel Storage
CAPITAL COST : 25,000
MAINTENANCE COST : 1,150
SOURCE 1 : AECEC
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : Nuc. Mat.
REFERENCE DETAIL : 1.Crutzen & Dennys; V. 1, 583.
2.Zarecki, Smith, Head & Duncan; V. IX, No. 2, 49(1980).

DESCRIPTION :

Spent CANDU fuel bundles (assemblies) are placed in trays (12 to 24 per tray). After some cooling time in the spent-fuel storage pool, the trays are stacked (20-30) on top of each other in a basket at one end of the pool or in an auxiliary pool. A tie rod of special design is passed through plates at the bottom and top of the cage that contains the stack of trays. An ultrasonic seal is snapped onto the top of the tie rod. The "cap-seal" contains a random distribution of acoustic discontinuities. The acoustic signature can be recorded upon installation and recovered later by accurately locating an ultrasonic transducer in contact with the top of the seal underwater. The acoustic signal contains information on the seal itself and on the status of the tie rod. Integrity of the cage must be examined optically using underwater optical or TV equipment. The seal and reader design are based on ISPRA developments. AECEC modified the seal and reader designs for this purpose and designed the cages, plates and the tie rod, which contains a hollow glass tube with a gas under high pressure. Tampering with the rod would change the acoustic echo pattern.

The capital cost is for the ultrasonic verifier and the maintenance cost for the rod and seal combination.

EQUIPMENT NAME : Ultrasonic Cup-and-Wire Seal
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Containments
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : All
CAPITAL COST : 25,000
MAINTENANCE COST : 5
SOURCE 1 : Nukem
REFERENCE 1 : 1978 IAEA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : Crutzen, Vinche, Burgers & Combet; V. 1, 561.

DESCRIPTION :

The seals consists of two cups and a wire which passes through holes in the containment and through holes in one cup. The wire ends are tied and the knot is enclosed by snapping the two cups together. One or both cups contain randomly spaced acoustical discontinuities. The unique acoustical pattern is read before use and after removal by placing the seal in a holder equipped with ultrasonic transducers employing the sonar echo-ranging technique. The identifier unit is portable, so that the seals may be characterized and verified on-site, but not in situ.

This is one of a variety of seals employing ultrasonic signatures and verification developed at the Euratom Ispra Research Institute during the last ten years. The cup seal has been independently assessed for vulnerability and improved as a result of this. Several hundreds of these seals have been used by Euratom inspectors.

The capital cost describes the identifier and the maintenance cost, the seal itself.

EQUIPMENT NAME	:	Ltwt Air-Trans. Accident-Resist. Container (LAARC)
USE CATEGORY	:	Inspector Use
GENERAL TYPE	:	Transportation
MATERIAL TYPE	:	Plutonium
STATUS	:	Class III : Field Evaluation Unit
USEFUL TO	:	Inspector
FACILITIES	:	Fabrication Reprocessing
CAPITAL COST	:	13,000
SOURCE 1	:	SNL
REFERENCE 1	:	OSS News
REFERENCE DETAIL	:	No. 1 (May 1981), 6.

DESCRIPTION :

A shipping container designed for air transport of safeguards samples containing gram quantities of plutonium for international and domestic use has been developed and successfully tested. The LAARC consists of three basic parts: (1) a spherical containment vessel; (2) a protective overpack assembly of redwood and maplewood for heat and shock absorption and a stainless-steel cylindrical drum; and (3) a stainless-steel capsule within the containment vessel. The LAARC is aproximately 15 inches in diameter, 14 inches high and weighs approximately 70 pounds. NRC license approval and Department of Transportation certification are underway.

EQUIPMENT NAME	: Mobile Safeguards Van
USE CATEGORY	: Inspector Use
GENERAL TYPE	: Transportation
MATERIAL TYPE	: SNM Samples
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, a neutron well counter (with interchangeable end plugs and reflectors for active or passive assay), and two random drivers (one large and one small).

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 : Tight Shipping Container for Pu Oxide
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Transportation
MATERIAL TYPE : Plutonium
STATUS : Class II : Development Prototype
USEFUL TO : Operator
FACILITIES : Reprocessing
Fabrication
SOURCE 1 : NBL
SOURCE 2 : IAEA
REFERENCE 1 : 1980 ESARDA
REFERENCE DETAIL : Pietri, Malone, Weiss & Kuhn; 404.

DESCRIPTION :

To circumvent the problem of dealing with hygroscopic Pu oxide when shipment of analytical samples is required, this design employs a modified low-pressure dissolution flask with a leakproof closure. This enables weighing of the sample before shipment and dissolution of the preweighed sample for analysis purposes, when it is received, directly in the container with little or no loss or weight-change problems. Complete recovery of the sample has been demonstrated. Preweighing of three samples is to be done in the presence of the receiver's witness followed by sealing and shipping. Shipper and receiver then each may analyze one sample and the third sample is held for a referee laboratory if necessary.

EQUIPMENT NAME : Digital Pressure Transducer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 4,000
SOURCE 1 : Parosci
REFERENCE 1 : ENICO
REFERENCE DETAIL : Cartan.

DESCRIPTION :

This 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. It consists of a pair of opposed bellows (exposed to high and low pressures in a differential mode), which, through a lever arm, applies stress to a quartz crystal. This applied stress alters the resonant frequency of the crystal, thus yielding a measure of the differential pressure. Typically, full scale is said to be 15 pounds per square inch differential (other models are available) with a claimed resolution of .005% of full scale and a claimed accuracy of .015% of full scale. The device is small and weighs only 138 grams.

The capital cost shown includes one transducer and a readout device. The latter is capable of handling more than one transducer (transducers are approximately $2000 each).

EQUIPMENT NAME : Pulsed Sonar Sounding Device
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : Liquids
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 3,000
MAINTENANCE COST : 150
LIFETIME : 10 Years
SOURCE 1 : MOL
SOURCE 2 : Bartex
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : OSS News
REFERENCE DETAIL : 1. Ven & DeRegge; 335.
2. No. 1 (May, 1981), 4.

DESCRIPTION :

The principle of the technique is based on the echoing of sound waves. At one end of a tube a loudspeaker is mounted; it emits a short sound wave. This sound wave propagates along the tube and is reflected at the other end of the tube. The loudspeaker also generates an electrical signal if a pressure pulse (reflected sound wave) is received. The tube contains two fixed restrictions acting as internal calibration and reference points to correct for variations in sound speed along the tube due to temperature or gas-composition differences. By measuring the time lag between the generation of the sound wave and the arrival of the reflected pulses, a measure of the distance between the reference point along the tube and the liquid surface is obtained. The liquid level is converted to volume by means of a calibration chart. For liquid level, a precision of 0.35 mm and accuracies of 1 to 2.5 mm are observed with a temperature sensitivity of 1.7 mm per degree. Conversion to volume adds additional uncertainties.

The Bartex device, known as the Aquatrak, has been tested at Rocky Flats with promising results. A more expensive model at $10,000 has digital output and is ten times more accurate but has not yet been tested in a reprocessing plant.

EQUIPMENT NAME : Quartz Bourdon-Tube Electromanometer
USE CATEGORY : Materi-ls Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 5,000
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 electromanometer serves as a pressure-measuring device for such a system.

This electromanometer 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 a few hundredths of tenths of a pascal. 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 $30-70,000.

EQUIPMENT NAME : Time-Domain Reflectometer
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : Liquids
STATUS : Class III : Field Evaluation Unit
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
SOURCE 1 : IAEA
REFERENCE 1 : IAEA-174
REFERENCE 2 : US-ESARDA CS
REFERENCE DETAIL : Part E, 32.

DESCRIPTION :

The monitor functions on the principle of time-domain reflectometry (TDR). 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 system 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. The system can be designed with measuring probes in ten different tanks to monitor the level in each tank. A coaxial switching unit is used for the multiple tank system. Tampering with the cable or the tank sensor would alter the measurement signature.

EQUIPMENT NAME : Turbine-Flowmeter Automated Tank Calibrator
USE CATEGORY : Materials Accountancy
GENERAL TYPE : Volume Measurement
MATERIAL TYPE : Liquids
STATUS : Class IV : Production Model
USEFUL TO : Operator and Inspector
FACILITIES : Reprocessing
CAPITAL COST : 1,000
SOURCE 1 : Flow Tech.
SOURCE 2 : Bearingles
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 nonrepeatability of the turbine meters. Confidence in the uncertainty figure is retained by measuring the ratio of the 2 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. The cost, from the February, 1981 issue of the magazine MEASUREMENTS & CONTROL, is the "starting price" for a Bearingless E100 flowmeter limited to 32 l/min.

REFERENCE : 1970 IAEA
TITLE :
Safeguards Techniques
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1970
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : 1971 INMM
TITLE :
Proceedings of the Twelfth Annual Meeting of the INMM
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1971
PUBLISHER : Inst. of Nuc. Mat'ls. Mngement
CITY : Reston
STATE OR COUNTRY : VA

REFERENCE : 1974 INMM
TITLE :
Nuclear Materials Management: Proceedings, 15th Annual Meeting
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1974
PUBLISHER : Inst. of Nuc. Mat'ls. Mngement
CITY : Reston
STATE OR COUNTRY : VA

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)
AUTHORS :
E.R. Johnson Assoc., Inc. (Editorial Staff)
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1979
PUBLISHER : Inst. of Nucl. Mat'ls Managemt
CITY : Reston
STATE OR COUNTRY : VA

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 Nuclear Mat'ls Mngemt
CITY : Reston
STATE OR COUNTRY : VA

REFERENCE : 1981 ESARDA
TITLE :
3rd Annual Symp. on Safeguards and Nuclear Materials Management (Abstracts)
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 : Reston
STATE OR COUNTRY : VA

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 : Chalk River Nuclear Labs
CITY : Chalk R,Ontario
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 : AGNS35900-2.1-78
TITLE :
Computer-Controlled CCTV Alarm-Assessment System Development
AUTHORS :
A. Moultrie, Jr.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
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 : AGNS35900-2.3-50
TITLE :
Safeguards Coordination Center
AUTHORS :
L. Barnes, G. Collert & R. King
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Allied-General Nucl. Services
CITY : Barnwell
STATE OR COUNTRY : SC

REFERENCE : AGNS35900-2.3-76
TITLE :
Scope, Sched. & Cost Est. for Implemen. of a Computerized Nucl. MC&A System...
AUTHORS :
J. Ellis & C. Joseph
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
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 : 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-80-13
TITLE :
Fast Critical Assembly Safeguards, Volume I
AUTHORS :
S. Brumbach, C. Roche, R. Perry & P. Amundson
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
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
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 N15.22
TITLE :
ANS Calibration Techniques for the Calorimetric Assay of Pu-Bearing Solids...
AUTHORS :
Secretariat, Institute of Nuclear Materials Management
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1975
PUBLISHER : Amer. Nat'l Standards Inst.
CITY : N_w York
STATE OR COUNTRY : NY

REFERENCE : ARC 54-5699
TITLE :
RECOVER - Remote Continual Verification
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : Atlantic Research Corporation
CITY : Alexandria
STATE OR COUNTRY : VA

REFERENCE : Anal. Chem.
TITLE :
Analytical Chemistry in Nuclear Fuel Reprocessing
AUTHORS :
W.S. Lyon, Ed.
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1978
PUBLISHER : Science Press
CITY : Princeton
STATE OR COUNTRY : NJ

REFERENCE : BNL-17165
TITLE :
Catalog of Nuclear Material Safeguards Instruments
AUTHORS :
L.A. Kull
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1972
PUBLISHER : Brookhaven National Laboratory
CITY : Upton
STATE OR COUNTRY : N.Y.

REFERENCE : Canberra
TITLE :
Canberra 79-80 (Catalog)
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : Canberra Industries, Inc.
CITY : Meriden
STATE OR COUNTRY : CT

REFERENCE : Davidson
TITLE :
Instruction Manual: Pulse Height Analyzer
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1978
PUBLISHER : D.S. Davidson Company
CITY : North Haven
STATE OR COUNTRY : CT

REFERENCE : ENICO
TITLE :
Private Communication
AUTHORS :
C. Johnson, H. Deveraux, F. Cartan, T. Piper, F. Bentzen & T. Boland
TYPE OF REFERENCE :
COPYRIGHT DATE : 1981
PUBLISHER : Exxon Nuclear Idaho Co., Inc.
CITY : Idaho Falls
STATE OR COUNTRY : ID

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-1027
TITLE :
Final Report for FY79: Advanced Sfgds Systems Devel for Chem Processing Plants
AUTHORS :
C.E. Johnson, Ed.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Exxon Nuclear Idaho Co., Inc.
CITY : Idaho Falls
STATE OR COUNTRY : ID

REFERENCE : ESARDA SAFEGUARD
TITLE :
Practical Applications of R&D in the Field of Safeguards
AUTHORS :
European Safeguards Research and Development Association
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1974
PUBLISHER : Nat. Comm. for Nuclear Energy
CITY : Rome
STATE OR COUNTRY : Italy

REFERENCE : Handbook
TITLE :
Handbook of Nuclear Safeguards Measurement Methods
AUTHORS :
D. Rogers, Ed.
TYPE OF REFERENCE : Draft Report
PUBLISHER : Monsanto Research Company
CITY : Miamisburg
STATE OR COUNTRY : OH

REFERENCE : IAEA Alpha
TITLE :
Management of Alpha-Contaminated Wastes
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1981
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

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 : IRT
TITLE :
Catalog
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : IRT Corporation
CITY : San Diego
STATE OR COUNTRY : CA

REFERENCE : ISPO-134
TITLE :
Development Report for Portable Data Reduction Microprocessor Unit
AUTHORS :
W.D. Ruhter & D.C. Camp
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Lawrence Livermore Laboratory
CITY : Livermore
STATE OR COUNTRY : CA

REFERENCE : ISPO-143
TITLE :
The Track-Etch Technique Evaluation and Field Test of a Reactor Power Monitor
AUTHORS :
B.S. Carpenter
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : National Bureau of Standards
CITY : Washington
STATE OR COUNTRY : D.C.

REFERENCE : ISPO-70
TITLE :
Semi-Automatic TV Tape Scanner
AUTHORS :
Fairchild Imaging Systems
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1979
PUBLISHER : Fairchild Camera & Instrument
CITY : Syosset
STATE OR COUNTRY : NY

REFERENCE : IWGRPS
TITLE :
Containment and Surveillance Devices
AUTHORS :
International Working Group on Reprocessing Plants Safeguards (Subgroup 1)
TYPE OF REFERENCE : Draft Report
COPYRIGHT DATE : 1979
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

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-4705-MS
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-5291-PR
TITLE :
Nuclear Analysis Research and Development.
AUTHORS :
G.R. Keepin, Group Leader
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1973
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-5651-M
TITLE :
Fundamentals of Passive Nondestructive Assay of Fissionable Material
AUTHORS :
R.H. Augustson & T.D. Reilly
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1974
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-5681
TITLE :
Portal Monitor for Diversion Safeguards
AUTHORS :
W. Chambers, H. Atwater, P. Fehlau, R. Hastings, C. Henry, (cont'd below)
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1974
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-5681+
TITLE :
Portal Monitor for Diversion Safeguards
AUTHORS :
W. Kunz, T. Sampson, T. Whittlesey & G. Worth
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-6574
TITLE :
Measurement Reliability for Nuclear Material Assay
AUTHORS :
T. Reilly & M. Evans
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1977
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-7699
TITLE :
Irradiated Fuel Monitors
AUTHORS :
E.J. Dowdy & J.T. Caldwell
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 :
H. Menlove
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, D. Cobb, H. Dayem, R. Dietz, E. Kern, J. Markin, (cont'd below)
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
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 :
J. Shipley, J. Barnes, L. Scheinman, et al.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-8373-PR
TITLE :
Nuclear Safeguards Research and Development
AUTHORS :
G. Robert Keepin, Ed.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-8404-MS
TITLE :
Channel Coincidence Counter: Version I
AUTHORS :
M.S. Krick & H.O. Menlove
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Los Alamos Scientific Lab.
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-8447
TITLE :
Gross Gamma-Ray Measure. of LWR Spent-Fuel Assem. in Underwater Storage Arrays
AUTHORS :
C. Moss & D. Lee
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-8603-MS
TITLE :
Plutonium Isotopic Composition by Gamma-Ray Spectroscopy
AUTHORS :
S. Hsue, T. Sampson, J. Parker, S. Johnson & D. Bowersox
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Los Alamos Scientific Lab
CITY : Los Alamos
STATE OR COUNTRY : NM

REFERENCE : LA-8657-MS
TITLE :
Concept. Design for Field Test & Eval of the Gas-Phase UF6 Enrichment Meter
AUTHORS :
R. Strittmatter, J. Leavitt & R. Slice
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Los Alamos Scientific Lab.
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 : M&C
TITLE :
Measurements & Control
TYPE OF REFERENCE : Journal Article
PUBLISHER : Measurements & Control Society
CITY : Pittsburgh
STATE OR COUNTRY : PA

REFERENCE : Mettler
TITLE :
Balance Catalog
TYPE OF REFERENCE : Technical Report
PUBLISHER : Mettler Instrument Corporation
CITY : Hightstown
STATE OR COUNTRY : NJ

REFERENCE : ND
TITLE :
Promotional Letter
AUTHORS :
K. Thompson
TYPE OF REFERENCE : Technical Report
PUBLISHER : Nuclear Data, Inc.
CITY : Schaumburg
STATE OR COUNTRY : IL

REFERENCE : NUREG/CR-0602
TITLE :
Active Nondestructive Assay of Nuclear Materials
AUTHORS :
Tsahi Gozani
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : U.S. Nuclear Regulatory Comm.
CITY : Washington
STATE OR COUNTRY : D.C.

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

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
PUBLISHER : Amer. (& European) Nucl. Soc.
CITY : LaGrange Park
STATE OR COUNTRY : IL

REFERENCE : Nuclear Power
TITLE :
Nuclear Power and its Fuel Cycle
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1977
PUBLISHER : Inter. Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : ORNL TM-7340
TITLE :
Selection & Testing of Liq. Sensing Devices for Application in the Sfgds...
AUTHORS :
E. Blakeman, L. Ottinger & D. Swindle, Jr.
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Oak Ridge National Laboratory
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : ORO-651
TITLE :
Uranium Hexafluoride: Handling Procedures and Container Criteria
AUTHORS :
Oak Ridge Operations Office
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1977
PUBLISHER : U.S. ERDA
CITY : Oak Ridge
STATE OR COUNTRY : TN

REFERENCE : OSS News
TITLE :
Safeguards and Security Technology Transfer
AUTHORS :
Division of Safeguards Systems Development and Implementation
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1981
PUBLISHER : Off. Safegds & Security, USDOE
CITY : Washington
STATE OR COUNTRY : D.C.

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 : Recover Cost
TITLE :
Recover Cost Projections
AUTHORS :
G. Baird & F. Hinke
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : TRW Systems Group
CITY : McLean
STATE OR COUNTRY : VA

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 79-1583
TITLE :
Status Monitoring (Alternate to Optical Surveillance)
AUTHORS :
W. Ream, H. Arlowe, D. Miyoshi & A. Binder
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : SAND 79-1780
TITLE :
A Study of Narrow Bandwidth Transmission Techniques for Video Images
AUTHORS :
C.S. Johnson
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

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 80-0499
TITLE :
Electronic Fiber-Optics Seal Mod. 1 Operations Manual
AUTHORS :
E. Johnson, J. Todd & J. Campbell
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

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
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque
STATE OR COUNTRY : NM

REFERENCE : SAND 80-2069
TITLE :
Semi-Automatic Video Scanner for Analysis of Super 8mm Surveillance Films
AUTHORS :
M.R. Heiser
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
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F. Leutters, J. Martin, D. McGovern, & G. Harvey
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Transactions of the American Nuclear Society
TYPE OF REFERENCE : Journal Article
PUBLISHER : American Nuclear Society
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International Safeguards Project Office
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TSO Personnel
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Nondestructive EDXRFA of Product Stream Concen. from Reprocessed LWR Fuels
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Determination of Pu Isotopic Abundances by Gamma-Ray Spectrometry
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R. Gunnink with J. Niday, A. Pringle, W. Ruhter & D. Camp
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