JNMM

Journal of Nuclear Materials Management

Published by the Institute of Nuclear Materials Management ■ Volume XXVII, Number 3 ■ Spring 1999

JNMM (ISSN 0893-6188) is published four times a year by the Institute of Nuclear Materials Management Inc., a not-for-profit membership organization with the purpose of advancing and promoting efficient management and safeguards of nuclear materials.

SUBSCRIPTION RATES: Annual (United States, Canada, and Mexico) $100.00; annual (other countries) $135.00 (shipped via air mail printed matter); single copy regular issues (United States and other countries) $25.00; single copy of the proceedings of the Annual Meeting (United States and other countries) $250.00. Mail subscription requests to *JNMM*, 60 Revere Drive, Suite 500, Northbrook, IL 60062 U.S.A. Make checks payable to INMM.

ADVERTISING, distribution, and delivery inquiries should be directed to *JNMM*, 60 Revere Drive, Suite 500, Northbrook, IL 60062 U.S.A., or contact Angie Leondedis at 847/480-9573; fax, 847/480-9282; or e-mail, inmm@inmm.org. Allow eight weeks for a change of address to be implemented.

CONTENTS

Volume XXVII, Number 3 • Spring 1999

PAPERS

EDITORIALS

INMM NEWS

ANNOUNCEMENT AND NEWS

Institute's Holistic Approach Answers Global Challenges

In recent weeks, there have been a significant number of disruptions to world peace and stability. Many of the events have drawn media attention to our profession. As we approach the year 2000, we will be facing even greater challenges in the area of proliferation of nuclear weapons worldwide and other aspects of nuclear materials management. One of the strengths of the nuclear materials management community and our professional society is our holistic approach to solving problems. We emphasize the importance of the whole system, while recognizing the interdependence of its parts. The reality of our nonproliferation goals is greater than the simple sum of individual parts, our 'challenges.' Our differences seem to be swallowed up in our larger context.

I recently had the opportunity to attend two very important and exciting conferences that reinforced these ideas repeatedly. The first was the Ninth Annual International Arms Control Conference in Albuquerque, N.M., April 16–18. The second was the 21st ESARDA Symposium on Safeguards and Nuclear Material Management in Sevilla, Spain, May 4–6. Both conferences had a broad range of international participants, both as presenters and attendees. Even though the topics were different, there were several common themes clearly visible in both events. At the core of both conferences was the pressing need to move beyond our individual differences, pooling our energies and resources to meet challenges such as safeguarding nuclear materials and preventing proliferation. A significant emphasis was made in both conferences in using lessons learned to focus our thoughts on the future. Key phrases I heard repeatedly were "global nuclear materials management," "cradle-to-grave transparency," "integrated approaches to problem solving," "international cooperation" and "strategic planning." I was greatly impressed by the high level of commitment apparent in all the participants. World differences? Certainly. Common problems? Undoubtedly. However, instead of being bogged down in how difficult these challenges are to face, I have a great deal of faith that there are dedicated nuclear materials management professionals who make world security and nonproliferation their highest priority. I am pleased that INMM can count itself among those ranks. Over the past few years we have worked hard to broaden our membership internationally. We have been infused with new energy from this growth and are better prepared for changes and challenges.

Our *Journal of Nuclear Materials Management* just keeps getting better and better. This issue reflects the international flavor of our organization — in articles, chapter news and the calendar of events. You will also find this perspective reflected at the upcoming 40th Annual Meeting of INMM, being held in Phoenix, Ariz. July 25–29. I know this meeting will be exciting, and I hope you will spread the word about it, especially to those who are new to our professional community.

I'm looking forward to the upcoming annual meeting and the opportunity to see so many of our "old" and "new" friends. I hope you'll be among them.

Debbie Dickman
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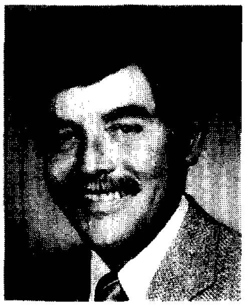
Growing Reputation Keeps *Journal,* Institute on Cutting Edge



I can remember when my predecessors Willie Higinbotham and Darryl Smith would occasionally include in their Technical Editor's Note the plea for papers for inclusion in the *Journal*. I'm sure many of you remember those pleas. Interestingly, I have not yet experienced the need to make such a plea, and I've asked myself why that is so. The reason seems to be the same as I attribute to the strong and increasing attendance at the annual meeting of the INMM. The institute offers a forum for a very important "name of the game in town," or maybe even a very important "name of the game in the state." Conversations in many settings these days fit nicely under the topics of INMM's technical divisions, be it international safeguards, materials control and accountability, nonproliferation and arms control, packaging and transportation, physical protection, or waste management.

This issue contains a variety of articles, all of which I found interesting. The paper "Korean Development of Safeguards Inspection Instruments for On-loading Reactors" provides a summary of the Korean approach to supporting IAEA inspections of CANDU reactors. The paper by E.C. Miller and J. Howell on "Tank Measurement Data Compression for Solution Monitoring" has an underlying theme of "data to information." Determining how to characterize waste heading to the Waste Isolation Pilot Plant is the topic of "Passive Active Neutron Radioassay Measurement Uncertainty for Aqueous Sludge Waste" by Larry Blackwood, Yale Harker and Teresa Meachum. Jim Brown, Steve Kadner, Ann Reisman and Elizabeth Turpen, in their paper "Technical Issues and Organizational Demands for Combating WMD Proliferation," take us into the world of weapons of mass destruction and suggest strongly that much needs to be done. Finally, Ed Kerr will create some nostalgic tears in the eyes of some old-timers with his historical account "IAEA Photo Surveillance: The First 30 Years."

More JNMM News

The peer-review process for technical articles for the *Journal of Nuclear Materials Management*, which will soon be implemented (hopefully by the fall 1999 issue of the *JNMM*), has been sent to the associate editors for their comments. In summary: I will distribute submitted papers to the appropriate associate editors, who in turn will engage peers for the review. We have developed review forms to provide guidance to the reviewers in order to achieve a more uniform process. The result of a review may be "accept as is," "accept with suggested changes" or "reject for the following reasons." For the first result, the author(s) will be notified of acceptance; for the latter two results, the author(s) will be provided the necessary information to respond. Assuming a one-time turnaround for corrections, we estimate that the peer-review process will take approximately 90 days, which means that papers will have to be received at INMM headquarters in a timely manner. The peer review process will be applied only to technical papers.

As always, I welcome any comments or suggestions you may have.

Dennis L. Mangan
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Preparing for the Future Today

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Introduction

At the July 1998 Annual Meeting of the Institute of Nuclear Materials Management, a closed session was held in the framework of a topical session on the role of analytical laboratories for safeguarding nuclear material. The closed session was intended for the discussion of subjects of common interest and common concern in an atmosphere that would encourage an opportunity to speak openly on sensitive matters. Experts from nuclear analytical laboratories from many countries participated in the discussion.

The focus of the discussion was directed towards strategic aspects rather than on specific technical problems.

Current Challenges

On both a national and an international basis, safeguarding nuclear material involves providing adequate assurance that these materials are present in the amounts stated in the nuclear material inventory. This is achieved by analytical measurements determining both elemental and isotopic content for accountancy or for verification purposes. Performing these measurements to the required degree of accuracy and at the necessary level of safety requires skilled and well-trained scientists. International safeguards verify that "nuclear plant and materials are being used for peaceful purposes only."[1] After the Gulf War, a highly visible application of this principle occurred within the International Atomic Energy Agency and is described in "Analytical Chemistry in the Aftermath of the Gulf War."[2] The combination of requirements for accurate and precise measurements in accountancy and verification, the need for development and implementation of environmental measurement techniques for safeguards application and the combat of illicit trafficking of nuclear materials require state-of-the-art analytical capabilities.

The participants noted that, in all countries, nuclear programs have changed, leading to cuts in funding and reductions of staff. Accompanying this, nondestructive online measurement techniques and remote sensors are increasingly being applied. However, the participants unanimously felt that analytical laboratory expertise is required to understand fully the chemical and physical phenomena linked to measurements relevant to the nuclear fuel cycle.

Discussion of Concerns

With the decreasing number and size of nuclear programs, the specific sector of nuclear material analysis also suffers from a reduced number of job opportunities and a lack of professional prospects. The special problems associated with working in "hot laboratories" and the current rather low standing of radiochemistry appear as constraints preventing recruitment in the field. In addition, public distrust in nuclear operations has become more vocal in recent years; as a consequence, working in nuclear analytical laboratories is becoming considerably less attractive. Young scientists and technicians are becoming more and more reluctant to undergo training and accept jobs in the highly specialized area of radiochemistry or nuclear physics. At the same time, the experienced scientists and technicians who have been working in these fields from the early days are now about to retire. A new generation of scientists is needed to take over.

These observations immediately lead to consequences which will have considerable long-term implications: The lack of well-qualified young people in nuclear analytical laboratories will render the transfer of experience extremely difficult. It will therefore be increasingly challenging to maintain the level of expertise that has been built up over many years. Not only will the proper operation of the laboratories suffer, but qualified advice will not be available to be given to safeguards or regulatory authorities. This prospect contrasts with the present and future challenges arising from the increasing amounts of excess weapons material, the growing capacities of reprocessing, waste conditioning and storage, illicit dumping of nuclear waste and illicit trafficking of nuclear materials.

Recommendations

Taking into account the significance of the material involved and the environmental and safeguards concerns, partici-

continued on page 18

40th Annual Meeting Promises to Be Timely and Challenging

The INMM Executive Committee invites you to attend the 40th Annual Meeting of the Institute of Nuclear Materials Management, to be held July 25–29 at The Pointe Hilton Resort at Squaw Peak in Phoenix, Ariz. The INMM annual meeting is the primary activity of the institute, where members and other professionals from around the world meet to exchange ideas regarding technological advances and policy in the area of nuclear materials management.

As the international political climate continues to change, this is a particularly important time for the exchange of technical information on numerous issues facing the nuclear materials management community. The INMM Technical Program Committee, chaired by Charles E. Pietri, has worked closely with the six technical divisions of the institute to arrange a program for this annual meeting that will appeal to nuclear materials professionals interested in materials control and accountability, physical protection, international safeguards, nonproliferation and arms control, packaging and transportation, and waste management.

The plenary session will focus on timely issues and the challenges we face. The technical program will consist of 325 papers presented during 42 sessions. Topics of immediate interest to the technical and policy communities will be discussed during these formal presentations, as well as during informal associations of the attendees. We are anticipating a meeting that will be timely and informative for all members of the nuclear materials management profession, including technology developers, operational personnel, national policy makers, regulators and members of international organizations. There will be an opening plenary session July 26 and a closing plenary session July 29. The topic of the closing plenary session is global nuclear material management. GNMM is a framework for implementing a new vision of ensuring the safe, secure and legitimate use of worldwide nuclear materials for the next nuclear era.

In addition to the formal technical program, the INMM annual meeting also provides attendees the opportunity to conduct business with one another productively and cost-effectively. One trip to Arizona will bring you in contact with your colleagues from the United States and around the world. Each of the INMM technical divisions — Materials Control and Accountability, Physical Protection, International Safeguards, Nonproliferation and Arms Control, Packaging and Transportation, and Waste Management — will conduct meetings July 25. There will also be a number of special-interest meetings being held before and after the technical program. These special meetings are open to all, and you are invited to attend any that are of interest.

The Pointe Hilton Resort at Squaw Peak is a great facility to host the annual meeting. Its conference facilities are organized to allow you to move quickly from exhibits to technical sessions and poster sessions. In addition, there is plenty of space to hold informal discussions and impromptu meetings. The resort also offers tennis, golf, a large spa and health center, plus a great recreation area for kids. The Phoenix area is great for shopping and sightseeing for you and your companions during your free time.

INMM will once again sponsor two popular events. INMM invites all interested attendees to participate in the seventh annual golf tournament, scheduled for July 25 at 7:30 a.m. at the Marriott Camelback Golf Club (7847 N. Mockingbird Lane, Scottsdale, Ariz.; telephone, 602/596-7050). The entry fee is $50, which includes a continental breakfast. Please contact Ron Hawkins, 423/481-8141, or Vince DeVito, 614/947-5213, for further information.

INMM will also sponsor a 3K fun run/walk at 6:00 a.m. July 27. This event will be scheduled to allow members to return in time for the Tuesday morning technical sessions. A T-shirt will be presented to each participant, and awards will be given to first-place winners for men and women in age groups 40 and under and over 40. The entry fee is $15. Contact Chris Hodge at 510/423-3590 or by e-mail at hodge2@llnl.gov if you have comments or questions.

Please mark your calendar and plan to attend the 40th Annual Meeting. The unique informational and networking opportunities provided by this year's meeting will be a valuable and rewarding experience for you.

James D. Williams
INMM Vice President
Sandia National Laboratories
Albuquerque, New Mexico, U.S.A.

Secretary's Corner

The INMM Executive Committee met March 3–4 in Palms Springs, Calif. The agenda included reports from technical divisions, ANSI committees, standing committees and ad hoc committees.

Finances
Current assets are $464,718, and the Merrill Lynch Trust Account contains $180,468. The 1999 fiscal year financial statement through December was approved by the Executive Committee.

Secretary Announcements
Stephen Ortiz from Sandia National Laboratories was appointed as the chair of the Physical Protection Division.

Technical Division Reports
Waste Management. The 16th Annual Spent Fuel Management Seminar was held Jan. 13–15 in Washington, D.C., with a total of 166 attendees.
Materials Control and Accountability. The committee is working on putting together a workshop in the late fall. The workshop will deal with regulatory issues.
Nonproliferation and Arms Control. The committee reported that there is a workshop tentatively planned for February or March 2000. Two previous workshops have spanned a spectrum of nonproliferation and arms control issues.
Physical Protection. The committee would like to conduct a two-day workshop on alarm communication and display sometime this fall. The exact time and location for this workshop is yet to be determined.
International Safeguards. The committee plans to have their next meeting May 7 in Sevilla, Spain. Proposed topics for discussion are the integration of INFCIRC/153 and INFCIRC/540 and issues surrounding a potential fissile material cutoff treaty.

Committee Reports
Annual Meeting. The Technical Program Committee met March 2 in Palm Springs, Calif. The committee organized more than 300 abstract submissions into sessions for the 1999 Annual Meeting.
Membership. The paid membership was reported as 624, including 23 sustaining members, as of Feb. 1.

Chapter Reports
Northeast Chapter. The chapter invited Michael Kea, a student at Lincoln University in Pennsylvania, to submit a technical paper for presentation at the INMM Annual Meeting. The paper will be nominated for the student paper award.
Southeast Chapter. The chapter has reorganized and elected a new Executive Committee.
Southwest Regional Chapter. The chapter held its second annual meeting at the Rocky Flats Technology Site March 16–17. A variety of technical papers was presented. The Executive Committee is in the process of establishing an outreach committee, a membership committee and state membership representatives.
Pacific Northwest Chapter. The chapter reported that a scholarship fund in the name of Robert J. Sorenson has been established.
Japan Chapter. The chapter's executive committee approved plans for the 20th Annual Meeting of the Japan Chapter in Tokyo Nov. 4–5.
Russian Federation Chapter. The Russian Chapter members have been very active within the framework of the Russian-American MPC&A Program, with involvement in a range of programs.
Vienna Chapter. The chapter co-sponsored the International Science Fair, which was held Dec. 5.

President Debbie Dickman gave a brief report on the Obninsk Chapter. There was no report from the Korea Chapter or the Central Chapter.

Old Business
The Executive Committee has set aside money to allow INMM to exhibit at industry trade shows. Thoughts on which trade shows to target are welcome.

A copy of the complete minutes of the Executive Committee meeting can be obtained from INMM headquarters, 60 Revere Drive, Suite 500, Northbrook, IL 60062; phone, 847/480-9573; fax, 847/480-9282; email, inmm@inmm.org.

Vincent DeVito
INMM Secretary
Waverly, Ohio, U.S.A.

Chapters

Japan

The chapter's executive committee approved plans to conduct the 20th Annual Meeting of INMM Japan Chapter in Tokyo Nov. 4–5, 1999. M. Akiba of JNC is designated as the program committee chairman. The committee is still being finalized. The program will include special events to commemorate the 20th anniversary meeting, including a panel discussion tentatively titled "The Nuclear Power Development Program and Nuclear Nonproliferation in the Asia Region."

Takeshi Osabe
Secretary, INMM Japan Chapter
Nuclear Material Control Center
Tokyo, Japan

Northeast

The last Northeast Chapter general membership meeting was an April luncheon in the Washington, D.C., area. A general membership dinner meeting is planned for the fall at Brookhaven National Laboratory.

Issues concerning candidates for chapter offices were resolved at the Feb. 1 Executive Committee meeting. The office of secretary/treasurer previously was split into the two offices of secretary and treasurer, the constitution and bylaws were changed accordingly and voted on, and INMM Executive Committee approval was obtained. The issue of having two chapter vice presidents was overcome by events with the withdrawal of one candidate at the Feb. 1 meeting. Ballots were distributed to chapter members Feb. 5 and balloting was completed in March.

The chapter treasury balance was $2,494.74 as of Feb. 1. The chapter had no expenditures since July 1998. The chapter Executive Committee is grateful for the INMM chapter stipend check for $500 that was received. The committee approved funding for the Chapter Awards and Incentives Account for $500 and funding for the Donations to Memorial Funds Account for $500, including contributions to the INMM in the memory of George Kucmycz, Bob Sorenson and Len Brenner, longtime personal friends and respected professional colleagues.

The chapter Executive Committee was notified that Michael Kea, a college senior at Lincoln University in Pennsylvania who completed an internship at Los Alamos National Laboratory under a Nuclear Regulatory Commission grant, was invited to submit a technical paper for presentation at the 1999 INMM Annual Meeting. The paper also is to be submitted for the student paper award. The committee understands that the INMM normally would cover travel and meeting expenses of the student. The chapter is prepared to pay the INMM membership fee for him.

The chapter Executive Committee agreed to sponsor and to begin planning for a workshop on implementation of the new Additional Protocol for a strengthened IAEA safeguards system. This protocol was signed by the U.S. in December 1998 and will affect many U.S. facilities. Brookhaven National Laboratory is the potential host for the workshop.

Ken Sanders
President, INMM Northeast Chapter
U.S. Department of Energy
Monrovia, Maryland, U.S.A.

Obninsk Regional

Obninsk Regional Chapter members are very involved in MPC&A collaboration with U.S. national laboratories, and many staff members from these laboratories are continuing to act as lecturers, instructors and course developers. A new field of activity under development at the Institute of Physics and Power Engineering is the creation of an Analytical Center for Non-Proliferation and Arms Control. This activity is supported by DOE and nongovernmental organizations such as Princeton University, the W. Alton Jones Foundation and others in the frame of the Russian Close Cities Initiative.

An Obninsk Chapter meeting was held Jan. 26. Gennady Pshakin, chapter president, introduced the two speakers of the evening: Debbie Dickman, INMM president, from Pacific Northwest National Laboratory, and Leslie Fishbone of Brookhaven National Laboratory. Dickman spoke about INMM history and present activity. She also explained INMM interaction policy with regional chapters, particularly with the two Russian chapters. Fishbone spoke about his experience in developing new containment/surveillance technologies for IAEA safeguards implementation. These new technologies were developed to support IAEA policy in saving resources (human and financial) and increasing the effectiveness of inspections. Future plans for Obninsk Chapter activities were announced and discussed.

Gennady M. Pshakin
President, INMM Obninsk Regional Chapter
Institute of Physics and Power Engineering
Obninsk, Russia

Pacific Northwest

The Pacific Northwest Chapter held a successful winter dinner meeting Feb. 3. The speaker was Robert Wilson, local coordinator of the Save the Reach organization. He spoke about current issues involving the Hanford Reach and the pros and cons of obtaining a "wild and scenic" designation for this part of the Columbia River.

A local INMM seminar was held

April 15 in Richland, Wash. Speakers are currently being lined up and topics identified; we are hoping to have two or three speakers from offsite. We are planning on approximately eight speakers in an afternoon program, to be followed by a reception.

The chapter has continued its long standing support of the Mid-Columbia Regional Science and Engineering Fair, with an increased donation of $100 this year. This funding assists in sending regional project winners to the national competition. In addition, we have made the same contribution to the DOE-sponsored Science Bowl.

A scholarship fund in the name of Robert J. Sorenson has been established by the PNW Chapter. We are currently developing the mechanism for selection of applicants and determining how to present applications through INMM Web pages and publications.

Brian Smith
Chair, INMM Pacific Northwest Chapter
Pacific Northwest National Laboratory
Richland, Washington, U.S.A.

Russian Federation

At present, the INMM Russian Federation Chapter includes 17 members from 11 governmental and nongovernmental organizations of three regions of Russia. We have corrected a list of the Russian Chapter membership with the INMM headquarters.

A meeting to hear reports and elect new officials of the Russian Chapter was held Oct. 20. Alexander V. Izmailov is again president, I. Bumblis and R. Timerbayev are vice presidents, and A. Zobov is secretary. The members have decided not to elect new leaders of the chapter within the period of its formation. The policy also stayed unchanged, meaning that we shall increase the number of members, involving the most active ones from peripheral regions of the Russian nuclear facilities who are participating in the MPC&A program.

Members of the Russian Chapter took an active part in different activities covering different INMM subjects during a period from October 1998 through February 1999, including:

- Leading activities under more than 20 contracts within the framework of the Russian-American MPC&A Program.
- Participating in the Workshop on Export Control Enhancement, held Feb. 17 at Moscow Carnegie Center. (The basic report was presented by E. Kirichenko, a member of the Russian Chapter.)
- Building up MPC&A activities at the Northern and Pacific navies (chapter members from Kurchatov Institute).
- Presenting lectures on physical protection systems at MIPhI (under contract with SNL) at the Kurchatov Institute for naval officers and for Gosatomnadzor inspectors at the Inter-Agency Special Training Center in Obninsk (chapter member A. Izmailov).

The Russian Chapter program includes the following:

- Active participation by chapter members in the 40th INNM Annual Meeting in Phoenix, Arizona, in July 1999.
- Involvement of new members from other regions (the Urals, Siberia, St. Petersburg).
- Arrangement of roundtable discussions on INMM problems.

The Russian Chapter maintains its relationship with the Obninsk Regional Chapter. A working meeting between INMM President D. Dickman and the presidents of the Russian and Obninsk chapters took place in November.

Alexander Izmailov
Chapter President, INMM Russian Federation
Eleron (Minatom of Russia)
Moscow, Russia

Vienna

The INMM Safeguards Symposium took place March 11 at the Vienna International Centre. An invitation to submit titles and abstracts for this event was mailed Jan. 22. Bruno Pellaud, the deputy director general of the Department of Safeguards, agreed to present the first talk at the symposium.

The election of Vienna Chapter officers was held last August 1998. Chapter Executive Committee members for the 1998–1999 period are as follows:
President — Jaime Vidaurre-Henry
Vice president — Anita Nilsson
Secretary — Lorilee Brownell
Treasurer — Richard Hartzig
Past President — Jill Cooley
Members at large — Ira Goldman
(first year of a two-year term)
Reinhard Antonczyk
(second year of a two-year term)
Special event chair — Martha Williams

The last chapter-sponsored luncheon meeting of the current period was held Nov. 19. Chung-Won Cho, councilor of scientific affairs with the Permanent Mission of Korea to the IAEA, spoke on the role of state systems of accountancy and control of nuclear materials in the Strengthened Safeguards System.

The International Science Fair, held Dec. 5, was a great success and had the participation of students from all international schools in Vienna. The Vienna Chapter co-sponsored the science fair, and several of its members participated as organizers or judges.

Jaime Vidaurre-Henry
President, INMM Vienna Chapter
International Atomic Energy Agency
Vienna, Austria

Technical Divisions

International Safeguards

A meeting of the INMM International Safeguards Division was held May 7 in Sevilla, Spain, on the occasion of the ESARDA 21st Annual Symposium. The topics for discussion were:

1. *Further discussions on the integration of INFCIRC/153 and INFCIRC/540.* An IAEA representative addressed the group with a brief presentation, "Integrated Safeguards System: Progress Report."
2. *Issues surrounding a potential nuclear material cutoff treaty.* There were short presentations about this subject by Gotthard Stein and Victor Bragin. The title of Stein's presentation was "Discussion of Technical and Institutional Aspects of a Future Cutoff Convention." Such aspects include scope, verification, the role of the IAEA, and relation to comprehensive safeguards. The scope of Bragin's presentation addressed similar aspects.

Cecil Sonnier
Chair, INMM International Safeguards Division
Jupiter Corp.
Albuquerque, New Mexico, U.S.A.

Nonproliferation and Arms Control

Animated discussions were held among a number of division members at the last annual meeting related to the possibility of educational outreach-type workshops in the Washington, D.C., area. The purpose would be to inform decision makers in both the executive and legislative branches of the federal government. Informal discussions along these lines have continued among division members. We have not yet narrowed the focus beyond three broad topics: international fissile materials issues (Russia, India, Pakistan, etc.), North Korea and Eastern nonproliferation issues, and nonproliferation education for neophytes and students. The next workshop held by this division should be in the February–March 2000 timeframe and be very topically focused; two previous workshops have spanned a spectrum of nonproliferation and arms control issues.

For the annual meeting this year, the division has worked with the U.S.-Russian MPC&A program managers at DOE headquarters to develop a more theme-based set of sessions, as opposed to seven to 10 sessions of status reports on progress at Russian sites since last year. The three or four sessions planned should be very interesting.

Along these lines, the division chair submitted a proposal for a U.S.-FSU MPC&A "lessons learned" breakout session for the 1999 INMM Annual Meeting. The session would have several parts:

1. An introductory panel discussion of key issues in the MPC&A area (allow about 1 hour). This panel would have a spectrum of members — U.S., Russian, other international (perhaps British or Euratom representation). Each member of the panel would give a brief (10 minutes each) summary of their perspective on given key issues. The panel chair would then facilitate the formation of breakout groups and give them their charge.
2. The breakout groups would be formed with one leader for each group. Perhaps this could be done in a room with round tables, like the rooms for the speakers' breakfasts at the annual meeting. These groups would focus for 1.5 hours on their assigned topics, and the leaders would take notes and prepare a summary.
3. The entire session would then (after a short break) re-form and the leaders would present their summaries to the entire session with a bit of Q&A allowed (about 30 minutes).
4. The panel chair would conclude with findings and recommendations (10–15 minutes).
5. The entire session could be written up as an article for *JNMM*.

C. Ruth Kempf
Chair, INMM Nonproliferation and Arms Control Division
Brookhaven National Lab
Upton, New York, U.S.A.

Physical Protection

Stephen Ortiz is the newly appointed chair for the Physical Protection Division. One goal for the division this year is to increase member participation. To support this goal, a strong physical protection session is being planned for the INMM Annual Meeting.

As a follow-up to the annual meeting, the Physical Protection Division would like to conduct a two-day workshop on alarm communication and display systems sometime in the fall. The first day of the workshop would include a tutorial on the design of an AC&D system, with breakout sessions to discuss issues around application of such systems. The second day would present information on commercial systems that are available and address their target applications. Exact time and location for this workshop is yet to be determined.

Stephen Ortiz
Chair, INMM Physical Protection Division
Sandia National Laboratories
Albuquerque, New Mexico, U.S.A.

Waste Management Division

The following summarizes the activities of the Waste Management Division for the period from November 1998 to February 1999.

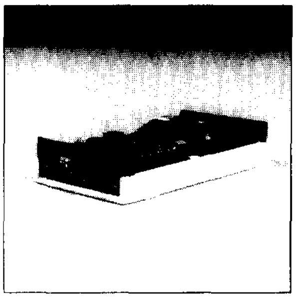
1. The 16th Annual Spent Fuel Management Seminar was held Jan. 13–15 at the Loews L'Enfant Plaza Hotel in Washington, D.C. Over the course of the 2 1/2-day meeting, six topical sessions were attended by approximately 166 persons. The six sessions covered spent fuel management programs and policies, spent fuel storage technology, spent fuel storage projects, spent fuel transport, and the status of repository and spent fuel disposal projects, and included a panel discussion titled "Management of the Pool: Much More Than Fuel." Seminar attendees included representatives from across the United States, as well as from Belgium, France, Czech Republic, Spain, Germany, Finland, Japan and the United Kingdom.
2. The WMD is putting together six sessions for the INMM Annual Meeting in Phoenix, Arizona, July 25–29. The sessions include the Waste Plenary Session (July 26 in the morning), "High-Level Waste" (July 26 in the afternoon), "Low-Level Waste I" (July 27 in the morning), "Low-Level Waste II" (July 27 in the afternoon), "Transportation" (July 28 in the morning) and "Decommission" (July 28 in the afternoon). Potential speakers are being contacted, with abstracts being submitted as quickly as possible.
3. The WMD made an unsuccessful attempt to procure the meeting management responsibilities for a proposed DOE High Level Waste Management Conference to be held in the Washington, D.C., area later this year. DOE has decided to have its management and operating contractor organize the meeting in-house.

E.R. Johnson
Chair, INMM Waste Management Division
JAI Corp.
Fairfax, Virginia, U.S.A.

New Product & Literature Showcase

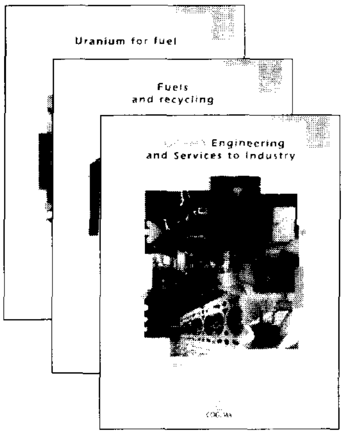
To find out more about the products shown here, or to receive a copy of the literature described, reach the companies directly using the contact information shown.

Aquila, A Canberra Company



Delta 2000
The Delta 2000 is an extremely flexible communications converter intended to provide access to legacy safeguards equipment via serial channels (RS232, RS485), Ethernet, and PIO ports. The Delta 2000 can be programmed to support installation specific needs such as authentication, encryption or conversion of data to specific network protocols. Current applications support remote monitoring of NDA equipment, extension of synchronous serial channels through a local area network, and data collection and conversion from environmental monitors.

Cogema



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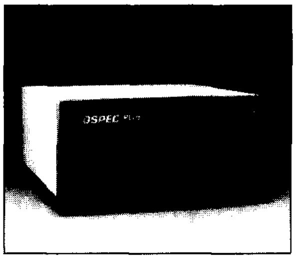

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N14 Technical Committee — Packaging and Transportation of Radioactive and Non-nuclear Hazardous Materials

N14.1 — 1995 Packaging of Uranium Hexafluoride for Transport
R.I. Reynolds, chair
This standard provides criteria for packaging of uranium hexafluoride for transport. Revision of this standard is currently underway. The chairman has issued 56 potential changes for writing group consideration. The writing group will hold a meeting in early 1999 to finalize a draft for N14 balloting.
Estimated completion date: 2000

N14.2 Tiedowns for Transport of Fissile and Radioactive Containers Greater Than One-Ton Truck Transport
R.E. Glass, chair
This standard prescribes general requirements for securing packages of radioactive materials so they are not likely to come off their vehicles in the worst nonaccident events of highway transportation. In accidents, packages secured as prescribed in this standard may come off their vehicle. The draft has been completed. Writing group consensus is being verified. Plans are to have the draft balloted by N14 in early 1999.
Estimated completion date: 1999

N14.5 — 1997 Leakage Tests on Packages for Shipment
L.E. Fischer, chair
This standard specifies methods for demonstrating that Type B packages comply with the package containment requirements of Title 10 of the Code of Regulations, Part 71, September 1983, as amended, or of the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6, 1985, or verification, and periodic verification. ANSI approved the standard Feb. 5, 1998.

N14.6 — 1993 Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More for Nuclear Materials
George Townes, chair
This standard sets forth requirements for the design, fabrication, testing, maintenance and quality-assurance programs for special lifting devices for containers weighing 10,000 pounds (4,500 kg) or more for radioactive materials. Review for an update will start in 2000.
Estimated completion date: 2001

N14.7 Guide to the Design and Use of Shipping Packages for Type A Quantities of Radioactive Materials
R.B. Pope, chair
This standard provides guidance for persons responsible for activities involving the packaging of radioactive materials in Type A quantities. Comments on the initial draft are being evaluated. The writing group will revise this in 1999, work with the N14.26 writing group and submit it for N14 ballot in early 2000.
Estimated completion date: 2001

N14.8 Fabricating, Testing, and Inspection of Shielded Shipping Casks for Irradiated Reactor Fuel Elements
D. Dawson, chair
This activity will utilize the peer panel review to determine standards that should be developed. It is currently not active, but will be when documents are received for standards consideration. Completion dates will be set for each document received.
Estimated completion date: N/A

N14.10 Guide for Liability and Property Insurance Aspects in Shipping Nuclear Materials
This guide discusses conventional liability (general liability and automobile liability), insurance policies and the attendant nuclear liability exclusion (Broad Form) as they apply to nuclear liability arising out of the transportation of nuclear material. It will be reactivated when a need arises.
Estimated completion date: N/A

Ancillary Features of Irradiated Shipping Casks (formerly N14.19)
This standard sets forth requirements for the performance, design, fabrication, testing, operation, maintenance and quality assurance of the ancillary features of irradiated fuel shipping casks. The standard has been withdrawn. The status of this standard is being evaluated based on ballot results. The need for this standard is questionable. Possible adoption of ISO standard on trunnions (TC85/SC5/WG9).
Estimated completion date: N/A

N14.23 Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater Than One Ton in Truck Transport
Ken Gwinn, chair
This standard specifies minimum design values for shock and vibration in highway transport, by truck or tractor-trailer combination, for radioactive materials when package weight exceeds one ton. A final draft has been approved by the N14.23 Committee. Balloting started Sept. 15, 1998, and ended Dec. 1, 1998.
Estimated completion date: 1998

N14.24 — 1985 (R1993) Domestic Barge Transport for Highway Route Controlled Quantities of Radioactive Materials
David L. Cummings, chair
This standard identifies the organizations, equipment, operations and documentation that are involved in domestic (i.e., between U.S. ports) barge shipments of highway-route controlled quantities of radioactive material on inland waterways and in coastwise and ocean service. A writing group has been formed and the revision process has started.
Estimated completion date: 2001

N14.25 Tiedowns for Rail Transport of Fissile and Radioactive Material Containers
Bob Glass, chair
This standard applies to attachment or tiedown of containers of radioactive materials to railroad cars where the gross

N-14 Technical Committee

continued from previous page

weight of the containers exceeds one ton. A preliminary draft was sent to the N14 Management Committee for their review and comment. A Project Initiation Notification System will be prepared for submittal to ANSI. The scope will be sent to the N14 Committee for approval prior to submitting to ANSI.
Estimated completion date: TBD

N14.26 Fabrication, Inspection and Preventative Maintenance of Packaging for Radioactive Materials
Kevin Nelson, chair
This standard provides requirements for the fabrication, maintenance and inspection to ensure the packaging is (1) properly fabricated in accordance with appropriate specifications, (2) properly maintained, (3) properly inspected and (4) properly assembled for shipment. A new chair has been appointed and a writing group is being formed.
Estimated completion date: TBD

N14.27 — 1986 (R1993) Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents
Bill Pitchford, co-chair
Ella McNeil, co-chair
The scope of this standard encompasses the preparation and execution by carriers and shippers of their emergency response program. It does not include the responsibilities of the first-on-the-scene response personnel, actions of governmental authorities or specific responsibilities of the carrier or shipper during recovery operations. Reaffirmation was approved June 28, 1993. Writing group co-chairs have been appointed. Planning for a new scope and extensive revision began in 1997. A writing group is being formed.
Estimated completion date: 2001

N14.29 — 1988 Guide for Writing Operating Manuals for Packaging
Dennis McCall, co-chair
Mike Burnside, co-chair
This guide describes the preparation and distribution of operating manuals for the use, maintenance and inspection of packages for shipping radioactive material. It prescribes the contents of such a manual and their arrangement, and contains a sample manual that can be used as a model. A draft is being reviewed internally prior to sending it to the writing group for review and approval.
Estimated completion date: TBD

N14.30 — 1992 Design, Fabrication, and Maintenance of Semi-Trailers Employed in the Transport of Weight-Concentrated Radioactive Loads
Ralph Best, chair
This standard established the design, fabrication and maintenance requirements for the highway transport of weight-concentrated radioactive loads. A weight-concentrated load is any payload that exceeds 1,000 pounds per linear foot over any portion on the semi-trailer. In addition, the standard provides detailed procedures for in-service inspections, testing and quality assurance. Revision of this standard will start in 1998. The chair is currently collecting information for a proposed revision. A meeting of the writing group was held Oct. 22–23, 1998.
Estimated completion date: 2001

N14.31 Standard Tiedowns on Legal Weight Transport System (80,000 lbs) for Packages Containing Hazardous Materials and Weighing Greater Than 500 Pounds
Larry Shappert, chair
This standard provides a method for defining an appropriate tiedown system through the use of the Tiedown Stress Calculation Program. The standard describes general requirements for tiedown securing hazardous materials packages to conventional trailers. The packages have a suitable base plate (pallet or skid) or flat base, and appropriate size arrangement of tiedown assemblies for packages that are within the weight and dimensional limits of the equipment. The writing group commented that the text and computer model need work. The IAEA recently modified package securement requirements (ST-2, 1998), and results need to be considered in modifying the draft standard. Work has been on hold since FY 1998, when EM-76 funding was terminated. When funding is provided, the work could be completed and a standard put forward for balloting by the N14 Committee in a time period of 14–18 months.
Estimated completion date: TBD

N14.32 Gas Generation in Packages Used for the Storage or Transport of Radioactive Materials
L.E. Fischer, chair
The scope of this standard is gas generation in packages used for the transport or storage of radioactive materials. This standard includes, but is not limited to, the following gas-generation mechanisms: radiolysis, chemical reactions, thermal expansion and biological degradation. This standard will provide a consistent approach to testing, analysis and mitigation of gases that could cause a pressure buildup or a potentially flammable mixture in a package containing radioactive materials. A PINS form has been prepared. N14 balloting of title and scope was completed and approved with a few comments. A writing group has been formed and work has started on preparing the first draft.
Estimated completion date: 2000

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continued on page 18

In Memoriam
Glenn Theodore Seaborg (1912–1999)

The modern technological world appears overwhelming to many people. It drives some to pessimism and despair. It makes others doubt the future of mankind unless we retreat to simpler lives and even to the ways of our ancestors.

What these people fail to realize is that we cannot go back to those ways and those days. Furthermore, for all our difficulties, life today is far better for more people and the possibilities for the future can be brighter than ever if we develop not only new knowledge, but a greater faith and confidence in the human mind and spirit.

— Glenn T. Seaborg

Glenn T. Seaborg — Nobel laureate chemist and discoverer of 10 atomic elements including plutonium — died Feb. 25 at the age of 86. Mr. Seaborg died at his home in Lafayette, Calif., near his office at Lawrence Berkeley National Laboratory, from complications following a stroke he suffered in August 1998.

Mr. Seaborg won a Nobel Prize before he was 40, making him one of the youngest Nobel laureates in the history of the prize. He shared the 1951 Nobel Prize in chemistry with Edwin McMillan for research into the transuranium elements. Forty years later, in 1991, Mr. Seaborg also received the National Medal of Science, the highest award for scientific achievement in the United States.

His accomplishments include:

- Research scientist, discoverer of numerous atomic isotopes and 10 elements, including plutonium and the element that now bears his name, seaborgium;
- Section head in the top-secret Manhattan Project;
- Chancellor of the University of California at Berkeley;
- Chairman of the U.S. Atomic Energy Commission under Presidents Kennedy, Johnson and Nixon;
- Co-founder and chairman of the Lawrence Hall of Science;
- Associate director at large of Lawrence Berkeley National Laboratory, the nation's first national research facility;
- Member of President Reagan's National Commission on Excellence in Education.

These are just the highlights: Mr. Seaborg is listed in the Guinness Book of World Records as having the longest entry in "Who's Who in America."

Mr. Seaborg began his scientific pursuits when he worked his way through the University of California at Los Angeles and earned a degree in chemistry in 1934. He continued on to Berkeley, forming friendships and partnerships with scientists like Ernest O. Lawrence and J. Robert Oppenheimer along the way. After completing advanced research in nuclear chemistry, he was awarded a doctorate in 1937.

It was in the lab, mostly at the University of California at Berkeley, that Mr. Seaborg gained renown as one of the century's greatest scientists. The discovery of element 94 — plutonium — happened in February 1941, when Mr. Seaborg, McMillan, Joseph Kennedy and Arthur Wahl bombarded a sample of uranium with deuterons and transmuted it into the new element. A month later, joined by Emilio Segrè, the team identified the isotope plutonium-239 and showed that it was fissionable, making it the candidate for the explosive ingredient in an atomic bomb as well as the fuel for nuclear power plants. Mr. Seaborg was often asked if he had any idea what he had unleashed when his team discovered plutonium. "I was a 28-year-old kid and I didn't stop to ruminate about it," he stated in a 1997 interview. "I didn't think, 'My God, we've changed the history of the world.'"

In 1944, Mr. Seaborg formulated a concept of the structure of heavy elements that was called one of the most significant changes in the periodic table since Russian chemist Dmitri Mendeleev's 19th century design. This actinide concept of heavy element electronic structure led Mr. Seaborg and his colleagues to the

Glenn Seaborg in 1941, adjusting a Geiger-Mueller counter during the search for transuranium elements. Mr. Seaborg discovered or co-discovered 10 elements and numerous isotopes.

creation of other transuranium elements, including americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium and seaborgium. Mr. Seaborg's co-discoveries during his years of research also included many isotopes that have practical applications in research, medicine and industry, such as iodine-131, technetium-99m, cobalt-57, cobalt-60, iron-55, iron-59, zinc-65, cesium-137, manganese-54, antimony-124, californium-252, americium-241 and plutonium-238.

Mr. Seaborg served on the faculty of the Berkeley campus from 1939, including a term as chancellor of that campus from 1958 to 1961. During World War II, Mr. Seaborg was called away from his work at Berkeley to head the group at the University of Chicago's Metallurgical Laboratory that devised the chemical extraction processes used in the produc-

In Memoriam
Vladimir F. Kossitsyn (1937–1999)

The field of science in Russia and the world has suffered a great loss. Vladimir Kossitsyn, a charter member of INMM Russian Chapter and a lifelong contributor to the advancement of nuclear materials management, died March 7 after an extended illness.

Mr. Kossitsyn was born in Moscow in 1937. He graduated in 1964 from the Moscow Physics Engineering Institute, where he specialized in experimental nuclear physics.

After earning his degree, Mr. Kossitsyn pursued a fruitful and creative career, almost up to the time of his death, connected with the Russian Research Institute of Inorganic Materials. He contributed greatly in the development and implementation of nuclear materials control methods at Minatom of Russia sites. His most significant results were in the sphere of neutron control methods.

Mr. Kossitsyn authored of more than 150 scientific works, including articles and reports for Russian and international conferences, and was responsible for a number of inventions. In 1991, he was awarded a doctor of science (technology) degree. He was a member of many scientific societies, commissions and committees, including the Russian Nuclear Society and INMM.

Mr. Kossitsyn began to participate in international cooperation efforts more than 20 years ago. During his last years, he contributed actively to the U.S.-Russian MPC&A Program and worked to improve the methods for control and accounting of nuclear materials at Russian nuclear facilities.

"A well-educated expert, an interesting speaker, a person of ready sympathy — that is how Vladimir Kossitsyn will be remembered," wrote Alexander Izmailov, INMM Russian Chapter president. "We'll keep him in our hearts forever."

INMM will miss Mr. Kossitsyn and the contributions — both personal and professional — he would have made in the future.

tion of plutonium for the top-secret Manhattan Project.

In 1961, he was appointed chairman of the Atomic Energy Commission by President John F. Kennedy, championing the peaceful use of atomic energy. He agreed to a two-year term. He was subsequently reappointed by Presidents Johnson and Nixon, serving in that position until 1971. Even after leaving the AEC, Mr. Seaborg continued to advise Washington decision makers, serving nine presidents in all.

In addition to the Nobel Prize and a great many other awards for his work in chemistry, science education and community service, Mr. Seaborg was award 50 honorary doctoral degrees. The academies of sciences of eight foreign countries have elected him an honorary member.

Mr. Seaborg authored a number of books. During the spring of 1994, he published three: *Chancellor at Berkeley*, *Modern Alchemy: The Selected Papers of Glenn T. Seaborg* and *The Plutonium Story: The Journals of Professor Glenn T. Seaborg, 1939–1946,* which describes his discovery of plutonium and work on the Manhattan Project. *Elements Beyond Uranium* (1990) is a comprehensive summary of all aspects of transuranium elements. He has written a trilogy about his service as chairman of the Atomic Energy Commission: *Kennedy, Khruschev, and the Test Ban* (1981), *Stemming the Tide: Arms Control in the Johnson Years* (1987) and *The Atomic Energy Commission Under Nixon: Adjusting to Troubled Times* (1993). In addition, he wrote an autobiography, *A Chemist in the White House: From the Manhattan Project to the End of the Cold War,* soon to be published by Farrar, Strauss & Giroux. He also authored more than 500 scientific articles and guided the graduate studies of more than 65 successful Ph.D. candidates.

Among his many interests were international cooperation in science, the history of science (documenting the early history of nuclear science), nuclear arms control (advocating a comprehensive test ban treaty) and hiking. Mr. Seaborg was a member of the National Commission on Excellence in Education, which published the much-publicized *A Nation at Risk* in 1983, and chairman of the Lawrence Hall of Science. He was recognized as a national spokesman on education, addressing in particular the crisis in mathematics and science education.

Mr. Seaborg continued to work as an active research scientist until his last illness with a research group in the search for new isotopes and new elements at the upper end of the periodic table, including a search for the "superheavy" elements. In all, Mr. Seaborg held more than 40 patents, including those on the elements americium and curium (making him the only person ever to hold a patent on a chemical element).

"His work reveals the excitement of scientific discovery — and a look into the mysterious world of nuclear science," one eulogist wrote. "It opens a window onto the corridors of power. Glenn Seaborg's work has forever changed our fundamental understanding of nuclear chemistry, shaped the nation's best efforts in education and forged the global imperative to harness the awesome power of the atom. This gentle giant of science will be sorely missed and never forgotten."

Glenn Seaborg and Helen Griggs were married in 1942 and had six children. Mr. Seaborg is survived by his wife and five of their children.

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continued from page 15

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Future

continued from page 4

pants noted the situation with alarm. It was perceived that immediate, active steps must be taken to conserve the knowledge and skills resident in specialized facilities. In particular, the training and development of younger staff members should be fostered.

To ensure that the presently shrinking technical culture of nuclear material handling and analysis remains viable in the future throughout the world, these experts from the nuclear analytical laboratories recommend the following measures to be implemented in the very near future:

- Improved communication among workers in the field. This can be achieved, for instance, by provision of funds to allow training at accepted center of excellence and staff interchanges. In many cases, only minimal additional funding is needed to cover small expenses such as travel.
- Provision of scholarships designed to attract new workers into the nuclear field.
- Public recognition of the needs and joint statements of concern from governments and extragovernmental organizations.

The participants recognized that supranational organizations (e.g., the IAEA) have a key role to play in the realization of these proposals, but call at the same time on national authorities to recognize the gravity of the problem and to undertake steps along the lines outlined here to ameliorate the situation before it is too late.

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Korean Development of Safeguards Inspection Instruments for On-loading Reactors

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Abstract

Korea is operating four CANDU reactors, which are on-loading reactors, and is planning to have two more in the future. Safeguards implementation on CANDU reactors is quite complex and requires more safeguards efforts. Korea has developed three inspection instruments to optimize its efforts for Korean national inspection with potential use by the IAEA. They are the Spent CANDU Fuel Verifier (SCAV), for verifying spent fuel inventory in the storage pool; the Spent CANDU Fuel Bundle Serial Number Identifier (SCAI), for reading the serial numbers of spent fuel bundles inside of the storage pool; and the Spent CANDU Fuel Fingerprinter at Dry Storage (SCAD), for dry storage inventory verification. These instruments were field tested, performed well and are being used in inspections.

Introduction

Korea has been carrying out national safeguards inspections since 1997. Since then, CANDU reactors have been considered more important for safeguards efforts due to their complexities. About half of safeguards inspection efforts in Korea are directed to CANDU reactors, even though the number of CANDU reactors is much smaller than that of PWR.

Korea is operating four CANDU reactors (the first began operations in 1980) and is planning to build two more in the future. A unique character of the CANDU reactor is its on-loading fuel. This means that every day some fresh fuels are loaded to the reactor core and some fuels are discharged from the core to a spent fuel storage pond. This on-loading of fuels and the potential for diversion has made IAEA pay more attention to CANDU reactors for verification than to light water reactors. According to facility attachments, every CANDU reactor is subject to 45 person-days of inspection, whereas LWRs require only 15 PDIs. Besides verification on nuclear materials at the reactor, in some countries — like Korea and Argentina — safeguards inspection is also carried out on the spent fuel transfer campaign that takes place once or twice every year and usually lasts several months. In Korea, a spent fuel transfer campaign moves old spent fuels, which are cooled over seven years in the spent fuel storage pond, to dry storage silos due to lack of storage space in the pond. Spent fuel bundles have to be thoroughly managed under the IAEA and national safeguards criteria because they are classified as direct-use nuclear materials. It requires substantial safeguards inspection efforts for international and national safeguards.

The overseer of national safeguards inspection in Korea is the Ministry of Science and Technology. The Technology Center for Nuclear Control of the Korea Atomic Energy Research Institute supports MOST by implementing safeguards and conducting related technical developments. TCNC has a technical edge in developing nondestructive instruments. Three instruments for safeguards inspection at the Wolsong nuclear power plants, which are CANDU-type reactors, were developed and field tested and are being used in safeguards inspection. These instruments were mainly developed for use in Korean national safeguards inspection, with consideration of potential common use with IAEA. Joint use of this safeguards inspection equipment is being discussed between IAEA and MOST. All of these instruments performed well in real safeguards inspections. They were named with SC** (Spent CANDU **) for easy pronunciation and to denote that it is used for CANDU reactors.

The first is the Spent CANDU Fuel Verifier (SCAV), which is used to measure gamma rays emitted from spent fuel bundles stored in a spent fuel storage pond. The second instrument is the Spent CANDU Fuel Bundle Serial Number Identifier (SCAI); its purpose is to identify spent fuel bundles, the serial numbers of which are often inscribed with small-sized letters and corrupted with dirties. The last one is the Spent CANDU Fuel Fingerprinter at Dry Storage (SCAD), to verify the gamma profile signature of spent fuel canisters stored at dry storage silos. More details are provided in each dedicated section.

Spent CANDU Fuel Verifier

SCAV was made to verify — by means of an underwater gamma-scanning device equipped with a supporting and index-

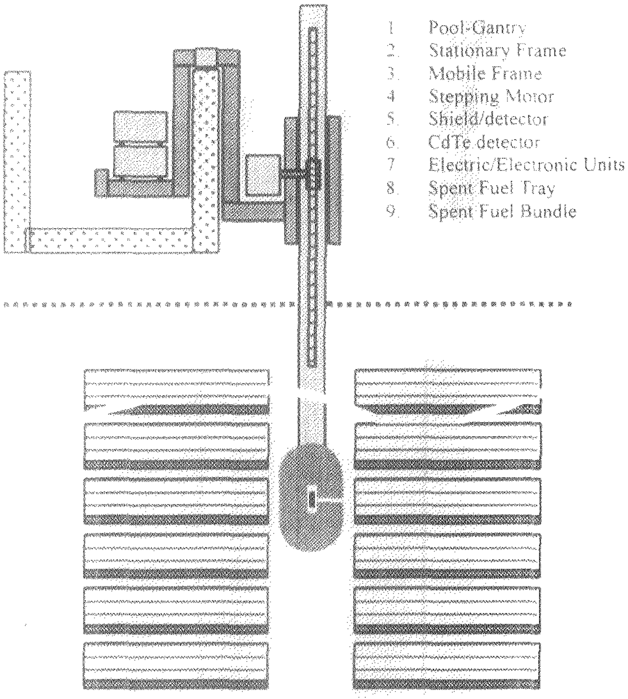

Figure 1. Schematic layout of SCAV installed at spent fuel storage pool

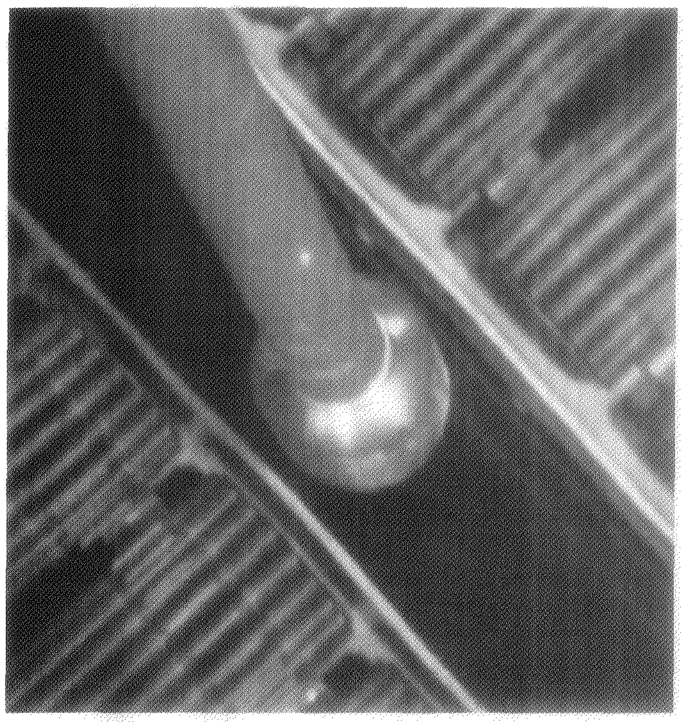

Figure 2. Photo of SCAV detection head and spent CANDU fuel bundles in storage rack of pool

ing frame, a stepping motor and a semiconductor radiation detector — the spent fuel inventory stored in the storage pond. Spent CANDU fuel bundles are stacked in multiple layers horizontally on the rack, whereas spent LWR fuel assemblies are stored vertically. The space between racks is fairly narrow, creating restrictions on the manipulation of any verifying system. A mechanical system and sensors were designed and fabricated to get exact indexing of each bundle. The current SCAV is the second generation, upgraded from the first SCAV.

Figure 1 shows a general layout of SCAV installed in the spent fuel storage pond at Wolsong nuclear power plant; the pond has a storage capacity of about 40,000 bundles, a nominal water depth of 7.7 m and a height of 19 layers (2.8 m) in the water. The stationary frame of SCAV is held on the operator guard bar of the facility gantry, which moves above the pool area. The mobile frame can be moved vertically with a variable speed ranging from a few millimeters per second to several centimeters per second by a stepping motor that is driven by a control unit equipped with a palm-top computer. Detector supporting tubes of the mobile frame are assembled with several pipe nodes to match the water depth of the storage pool. All mechanical parts except the stepping motor, rack gear and detection head were made of aluminum material, and the surfaces were coated for easy decontamination. All parts can be packed in a rigid case (1.7 m × 0.4 m × 0.3 m), and the entire system weighs some 80 kg. For gamma-ray measurement, a small pin-type CdTe or CdZnTe semiconductor detector with a radiation-tolerant preamplifier in its housing is positioned at the central hollow of a detector head that consists of a cylindrical tungsten shield/collimator and stainless housing. Shield diameter is 90 mm or 110 mm (two types) and the collimating horizontal air-hole diameter is 7 mm. Gamma-ray signals from the preamplifier are sent to a portable multichannel analyzer mounted on the rack of stationary frame. Figure 2 shows the detection head part of SCAV and spent CANDU fuel bundles stacked in a storage rack of the pond. The gap between tray layers shown in this figure, through which the detector head moves downwards or upwards, is about 15 cm in width. This gap width restricted the increasing of shield thickness for the verification of short-cooled fuel bundles.

Figure 3 shows one of the inspection results performed at Wolsong Unit 1 by using SCAV operated at a scanning speed of 1.5 cm per second. In this figure, solid circles denote the measured, background-subtracted gamma-ray intensities at different vertical positions, and discrete peak-type lines are taken by smoothed second derivative[1-3] of the measured raw data for counting the number of inspected fuel bundles by a software program. Nineteen peaks corresponding to the number of spent CANDU fuel bundles are found by an autosearch program in this figure. There is some difficulty in verifying clearly when the bundles with very short cooling time (less than 0.5 year) are stacked together or when the fuel with extremely low burn-up (less than 1 GWD/MTU) is surrounded with fuel bundles with normal burn-up because high-level background counting strongly disturbed the gamma-ray intensities collected through the collimator. It seems that this problem could be solved by using a smaller detector and/or by upgrading the analyzing program. The TCNC staff is also improving the mechanical and electric/electronic parts for easy treatment at the spent fuel storage pond area.

Spent CANDU Fuel Bundle Serial Number Identifier

SCAI was developed to read the serial numbers of spent fuel bundles loaded in the basket placed in the spent fuel storage pond and spent fuel bundles moving to a tray in the reception bay after discharge from initial core. A spent CANDU fuel transfer campaign[4] has taken place for several months every year at Wolsong Unit 1 under IAEA safeguards inspection since 1992. During the spent fuel transfer campaign to dry storage silos, facility operators load 60 bundles from the tilt table to the basket placed on the underwater working table. Before operators place a cover onto the basket, i.e., before the nuclear materials in the basket become difficult to access, inspectors confirm the number of spent fuel bundles loaded in the basket and randomly select and identify two bundles from each fully loaded basket. They also verify the selected fuel bundles for gross defects. Operators move the covered basket to the welding station, weld the covered basket inside the transfer flask and ship the transfer flask with the basket to the dry storage silos.

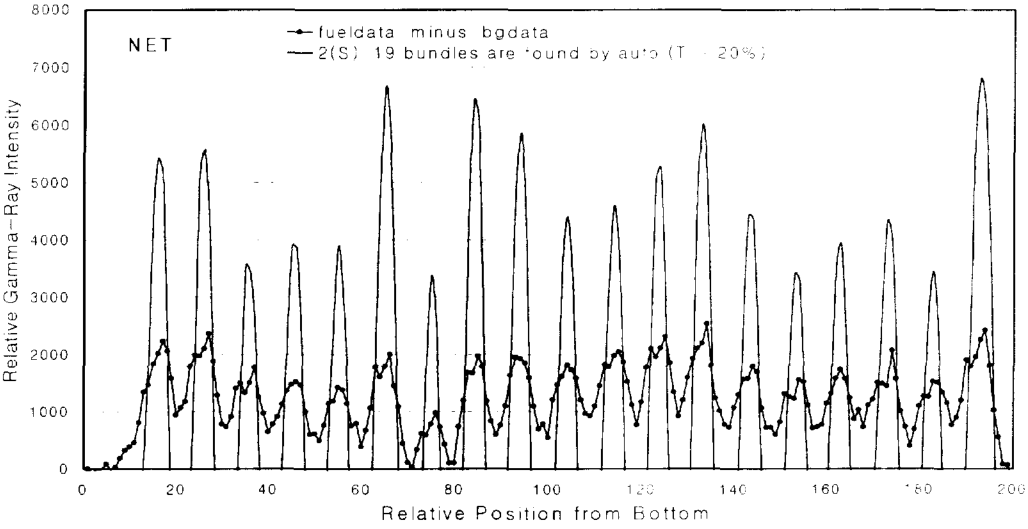

Figure 3. An example of gamma-scanning results on spent CANDU fuels of Wolsong NPP by SCAV

One of the bottlenecks among safeguards inspection activities during the fuel transfer campaign is identifying spent fuel bundles, because inspectors must read serial numbers inscribed with small-sized letters (about 20 mm wide × 2 mm high) and corrupted with dirties due to lengthy storage in the deep pond and the reactor core. Figure 4 shows a schematic drawing of SCAI installed on the facility structure, which can effectively read serial numbers of spent fuel bundles loaded in the basket placed in the storage pond during the fuel transfer campaign. The serial numbers of spent fuel bundles discharged from the initial core of Wolsong power plant can also be identified using SCAI installed on the facility structure as shown in Figure 5.

SCAI consists of three components as shown in Figure 6. The underwater camera and light — watertight and with a permissible dose rate of 3×10^6 rads hr^{-1} — can approach closely to the end-plate of a spent fuel bundle and take a distinct picture of the serial number. As the underwater camera has a non-browning 8- to 24-mm zoom lens, SCAI can take pictures of serial numbers with high resolution in the deep storage pond. The guiding and supporting tool guides the underwater camera and light part close to the end-plate of the selected spent fuel bundle without interfering with the fuel-loading process. It also supports the underwater camera and light part safely for the duration of the inspection. The control and monitor part controls the camera and light part to get a distinct picture of the serial number, adequate for safeguards information. It displays the image on the monitor and records it on videotape for review and storage.

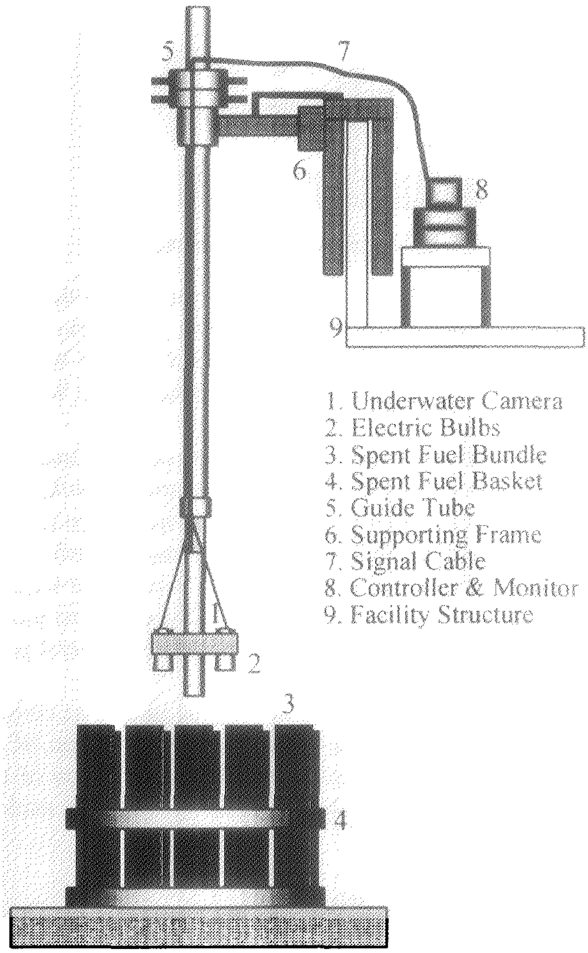

Figure 4. SCAI installed in storage pond

During the recent spent fuel transfer campaign at Wolsong Unit 1, inspectors randomly selected two bundles from each fully loaded basket and effectively did the serial number identi-

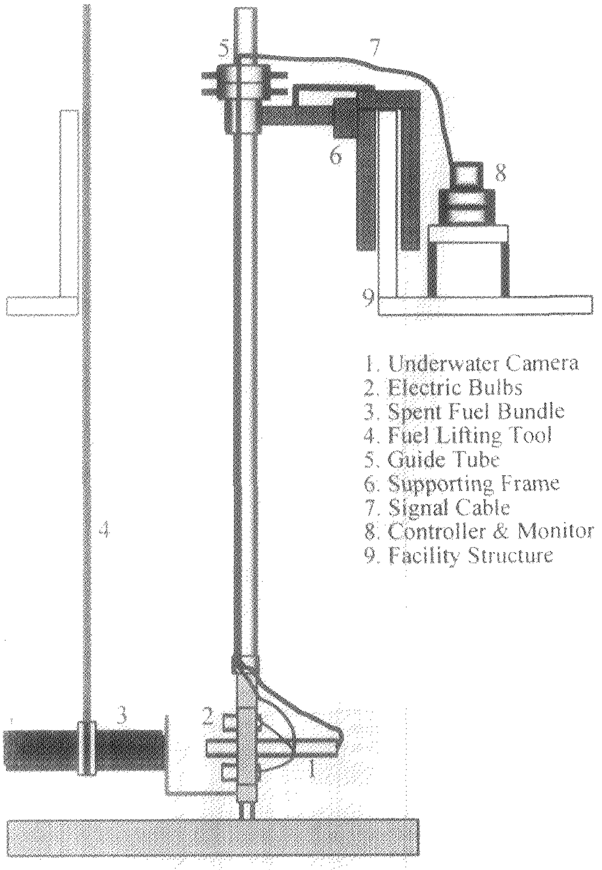

Figure 5. SCAI installed in reception bay

fication by using SCAI. SCAI was also used to read the serial numbers of the spent fuel bundles moving to the tray in the reception bay after discharge from the initial core of Wolsong Unit 3. Figure 7 shows one of the results taken at the Wolsong power plant.

SCAI showed several advantages compared to the underwater periscope used for international safeguards inspections. It can save substantial inspection time and efforts due to its easy indexing and handling and fine picture. A major benefit is the savings in workforce and related cost. It is inspector-friendly because inspectors can easily assemble SCAI due to its modular design, and they can easily operate SCAI after several practices in the storage pond.

Because international as well as national inspectors considered its result to be acceptable as safeguards information, SCAI is jointly used with IAEA inspectors for identification of the spent fuel bundles in the storage pond at Wolsong nuclear power plant.

Spent CANDU Fuel Fingerprinter at Dry Storage

SCAD was developed to verify the spent fuel inventory stored in dry canister (diameter, 3.1 m; height, 6.5 m) at the Wolsong power plant. Spent CANDU fuel bundles cooled over seven years in the spent fuel storage pool are transferred to a dry storage silo that has a storage capacity of nine baskets with 60 bundles in each basket.

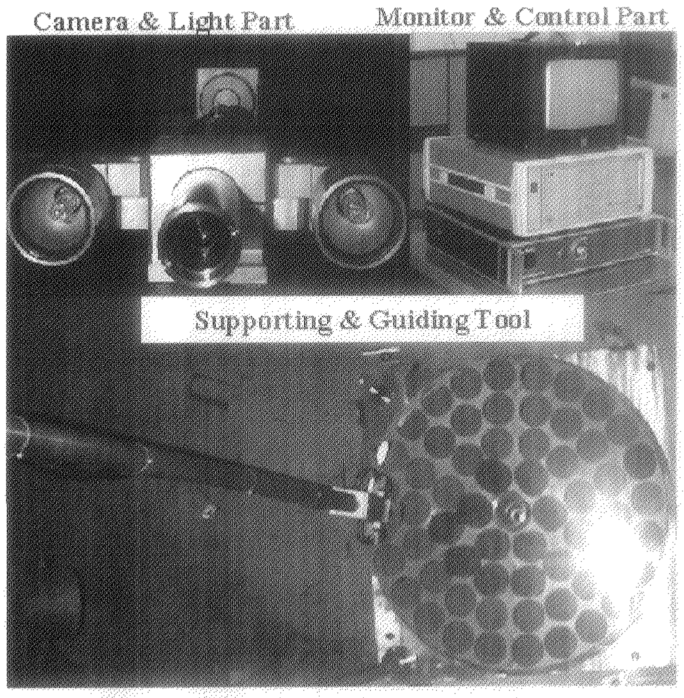

Figure 6. Picture of SCAI components

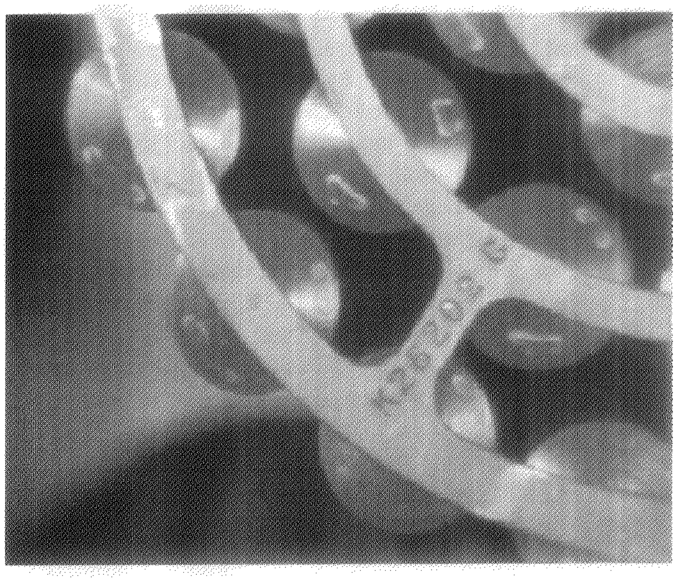

Figure 7. Picture of a serial number taken by SCAI

A schematic layout of SCAD installed at the dry storage silo is shown in Figure 8. A small pin-type CdTe or CdZnTe detector (diameter, 9 mm; length, 80 mm) encapsulated in a cylindrical tungsten shield (diameter, 30 mm) is used as a radiation detector. A stepping motor and its controller is used for positioning and moving the detector inside the reverification tube. A portable multichannel analyzer and a computer with software are used for data collection and verification evaluation.

The details of the operating procedures of SCAD are as follows. A detector cable holder guides the detector to move inside the reverification tube of a dry storage silo by a stepping motor driven by a motor controller equipped with a notebook computer. Control and analysis software programmed by Lab windows/CVI controls the PMCA and motor controller simultaneously and/or independently through the RS-232 communication port. It is possible to adjust the detector position in the reverification tube and to control the motor speed, direction and moving distance. Gamma-ray signals measured through the detector are sent to the PMCA and displayed on its LCD panel during measurement time. Measured raw data are transferred to the Note PC and saved automatically, and a spectrum displayed on the monitor is automatically analyzed. The mechanical hardware part is set up on the dry storage silo, and other parts such as the PMCA, motor controller and notebook computer are located on the ground. Figure 9 shows a photo of the mechanical hardware and shielded CdTe detector.

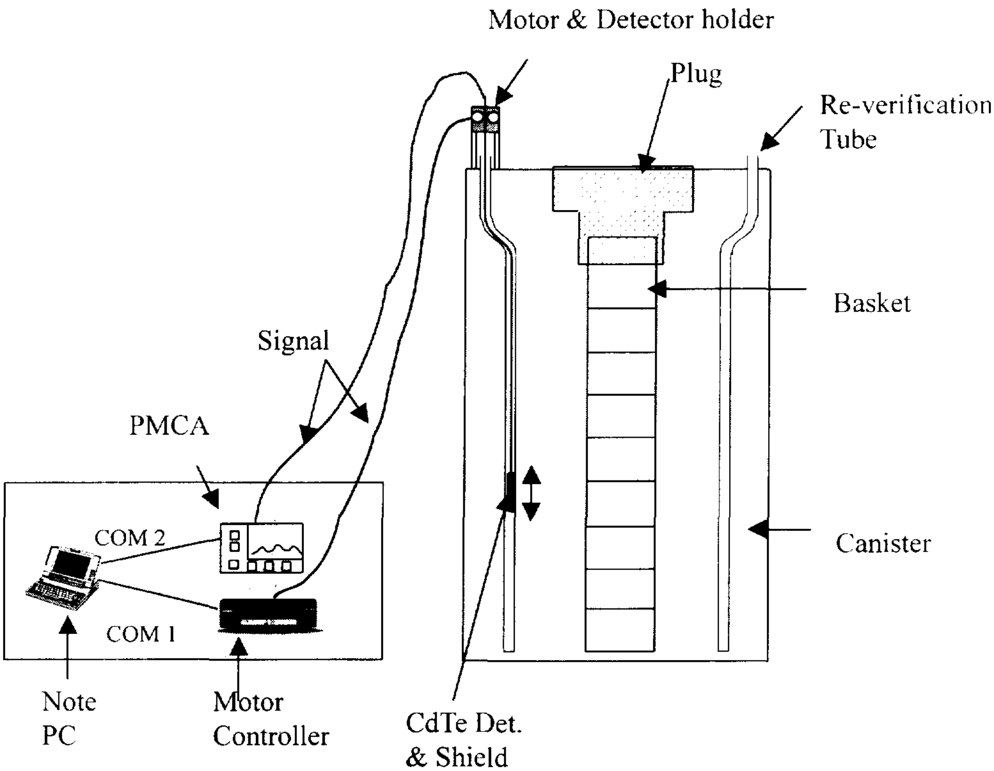

Figure 8. Schematic layout of SCAD installed at dry storage silo

Figure 10 shows the inspection result called a fingerprint, obtained through the reverification tube at dry storage in the Wolsong power plant by using the scanning method of SCAD. The scanning speed was about 5 cm per second, and the dwell time of the multichannel scaling mode of the PMCA was set at 1 second. The scanning direction was from bottom to top of the dry storage silo. In this figure, nine peaks corresponding to the number of baskets stocked in the silo are detected by treating the measured raw data by using a smoothed second derivative method.[1-3]

Currently, SCAD is used as an effective instrument to verify the fingerprint of spent fuel in the dry storage silo for safeguards inspection. As the next step, TCNC is trying to use Cs-137 (662 keV) intensity distribution instead of gross gamma-ray intensity distribution as the fingerprint indicator because it can provide more evident signal of a specific position of spent fuels in the silo.[5]

Conclusion

Since initiation of national inspection, TCNC has tried to reduce inspection efforts through careful analysis of process and procedures. Inspection on CANDU reactors was relatively complicated and required new inspection instruments to streamline the process. Three inspection instruments have been developed, field tested and are under operation for national safeguards inspection. TCNC will continue to put efforts into the development of new instruments that can erase the bottlenecks of safeguards inspection, with the goal of optimizing the use of workforce, time and money, especially in CANDU reactors that

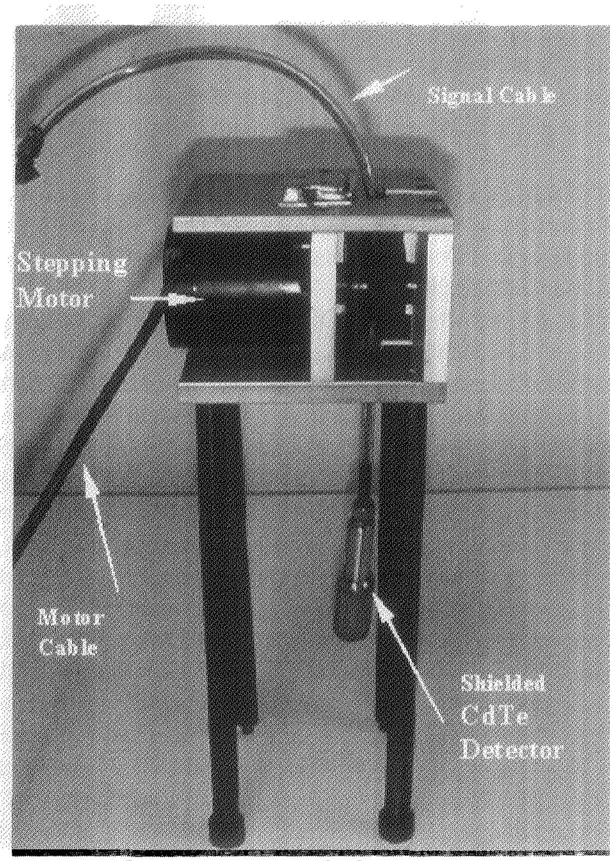

Figure 9. Mechanical system and shielded CdTe detector

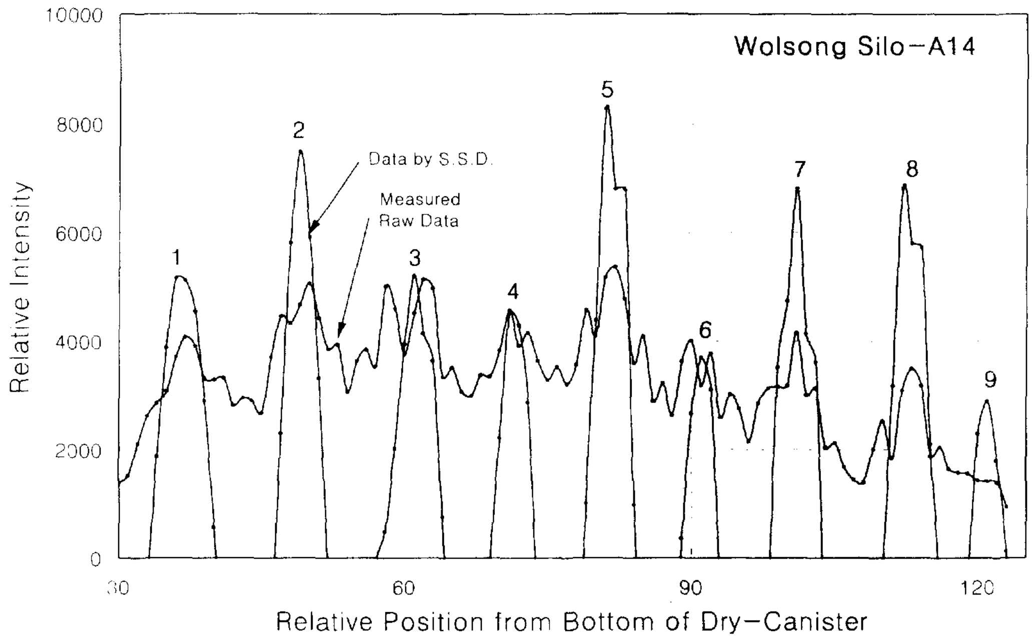

Figure 10. Example of a fingerprint by SCAD on spent CANDU fuels at dry storage of Wolsong Unit 1 (scanning from bottom to top)

occupy a major portion of inspection efforts.

IAEA is planning to apply remote monitoring to nuclear facilities in the near future. Its initial targets will be expected to be LWRs because of their simplicities. With introduction of remote monitoring, on-site safeguards inspection efforts for LWRs will be drastically reduced and thus more focus will be applied to CANDU reactors in Korea.

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Wan Ki Yoon has worked in safeguards for more than 10 years. His experience includes policy development, research and development, inspection, international coordination on safeguards and physical protection. His current interest is unattended NDA, remote monitoring and containment/surveillance.

Young Gil Lee has a background in experimental nuclear physics. He has been working for KAERI as a research scientist since 1979. His major field is instrument development for evaluation and safeguards on spent nuclear fuel by means of nondestructive gamma-ray and neutron measurement.

Hong Ryul Cha joined KAERI after completing an advanced degree in physics in 1988. He is working on instrument development and management for safeguards on fresh and spent nuclear fuel by means of nondestructive gamma-ray and neutron measurement.

Won Woo Na has worked in safeguards for the last seven years. His experience includes research and development for NDA safeguards instruments and national safeguards inspection. His current work covers unattended integrated monitoring systems and low-background gamma-ray counting technology.

Seung Sik Park has been working on an NDT (nondestructive test) that includes Eddy Current Testing and Visual Testing for the nuclear power plant since 1985. Currently, remote monitoring on C/S in safeguards is his concern.

Tank Measurement Data Compression for Solution Monitoring

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Abstract

A tank measurement data compression scheme is described that has been developed to meet the peculiar needs of nuclear materials safeguards in general, and solution monitoring in particular. The scheme has two stages, a filtering stage followed by a correlate and test stage. The filter might be viewed as an extension of the box car algorithm that enables feature extraction; the correlate substage uses a recursive least squares estimator, and the test stage is based on the Cusum test. The scheme has been developed by testing with data obtained from a commercially operated facility.

Introduction

Solution monitoring has been defined as the "essentially continuous monitoring of solution level, density and temperature in all tanks in the process that contain, or could contain, safeguards-significant quantities of nuclear material."[1,2] As such it is a candidate "defense in-depth" approach, the need for which has been discussed by Andrew.[3] To perform solution monitoring with the data-collection rates thought to be necessary to monitor normal plant activities,[4] it is likely that at least 15,000 points/sensor/month will need to be collected for subsequent analysis. Although not excessively large, it is clear that a large portion of these data would be redundant because a high data-collection rate is only needed when a change in plant activity actually occurs, and this is relatively infrequent. Some form of data compression is therefore desirable from a data-storage viewpoint. In addition, any sensible data compression would also be of benefit to the solution-monitoring system installed if it enables its complexity to be reduced in some way. Solution-monitoring-system development work described to date has not examined this primarily because the data have not been made available to motivate such work. Both Burr and Wangen[1,2] and Scothern and Howell[5] have used similar data to test their respective systems. Either real data, recorded at very infrequent intervals of time, have been used directly, or data have been synthesized; for instance, infrequently recorded real data have been linearly interpolated, sampled at five-minute intervals and corrupted with Gaussian noise. Perhaps it is worth pointing out that these particular infrequently recorded data had already been compressed using a variation of the well-known combined box car and backward slope algorithm,[6] but the justification for using this algorithm is unclear.

The need for data compression is not peculiar to solution monitoring. Data compression is used in many areas and in particular in the process industries.[6–10] However, what might be peculiar about data compression for solution monitoring is that the objective is somewhat different: Process industry data compression is about recording the underlying trends in the data whereas, with its close relationship with nuclear materials accountancy, data compressed for input to a solution-monitoring system should reflect more the quantitative state of the contents of the tank. A good example of the difference arises when a tank is sparged. It might then be necessary to ignore level measurements because level fluctuations would be misleading; level is used to infer volume via a calibration obtained with sparging switched off. Thus any data compression algorithm that is suitable for solution monitoring is likely to have an element of feature extraction in it and is hence unlikely to be generally applicable to the process industries.

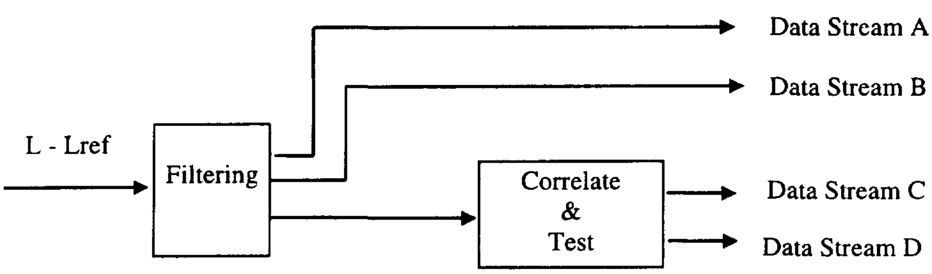

Figure 1. Data reduction scheme

This paper describes a data compression scheme (Figure 1) that extracts all the important features of data pertaining to tanks in which liquor is not imported and exported at the same time. The results are output as four separate streams: Stream A contains times at which sparging occurs, stream B contains spikes that might be viewed as "odd" events, while streams C and D contain only those data records that need to be input into a solution-monitoring system like that developed at the University of Glasgow.[1-5] The only difference between streams C and D is in their data format. The scheme would need to be modified to process measurement data obtained from tanks that can have simultaneous inputs and outputs to and from them (e.g. a solvent-extraction-cycle receiving tank), and this is discussed in the conclusions.

The scheme has been developed and tested by analyzing data collected from a number of tanks located in a product storage area of a reprocessing plant. The data were collected using the Ispra VLTM system,[11-13] which is capable of collecting data through six multiplexed channels. Each channel is interrogated over a three-second period, approximately once every 18 seconds; about eight measurements are input and averaged over the three-second period, and the standard deviation can also be calculated. Note that the maximum collection rate of once every 18 seconds is about six times faster than that which is nominally required. Instead of just slowing down the sampling rate, the developers have chosen to provide the facility to compress the data instead using a variation of the box car algorithm.[5,11] Typical data compressions of between 75 percent and 85 percent have been obtained where

$$\text{Data compression} = \frac{\text{Total number of averaged measurements input} - \text{Total number of averaged measurements recorded}}{\text{Total number of averaged measurements input}}$$

Note that an average data compression of about 88 percent would give the nominal goal of 15,000 points/sensor/month, whereas the scheme described in this paper has achieved better than 99.9 percent. To avoid confusion, it is worth pointing out that the work described here has largely been carried out using data collected with the developer's facility switched off; that is, the scheme has been developed using data recorded approximately every 20 seconds. Each data record is assumed to contain, where available, level, density and reference dip-tube averaged pressure measurements, plus the standard deviations of each of the level dip-tube averaged pressures. On input, the equivalent level and density are then calculated and added to each record. The data-compression algorithms are then applied to level and density as opposed to dip-tube pressures, because not only are level and density of primary interest, but also data compression based on the level recording eliminates the common influence on all the dip-tube pressures caused by changes in atmospheric pressure.

Typical Measurement Records

A typical tank level history is shown in Figure 2 for a period of time where there are no transfers of material into or out of the tank. Note that the level does not remain constant because the tank is sparged about every seven minutes and there is evaporation. Two sparge cycles that are clearly identifiable in Figure 2 are characterized by a series of about six points: a downward reflection, followed by a sharp upward increase to some point above the true level, followed by a plateau for two to three points that remains above the true level, followed by a short upward trend and then a sharp downward decrease to another reflection before returning around the true mean. Figure 2 also has some temporal deviations or spikes, where the level deviates from and then immediately returns to the true level. Figure 3 shows the data collected while the tank was recirculated and sampled.

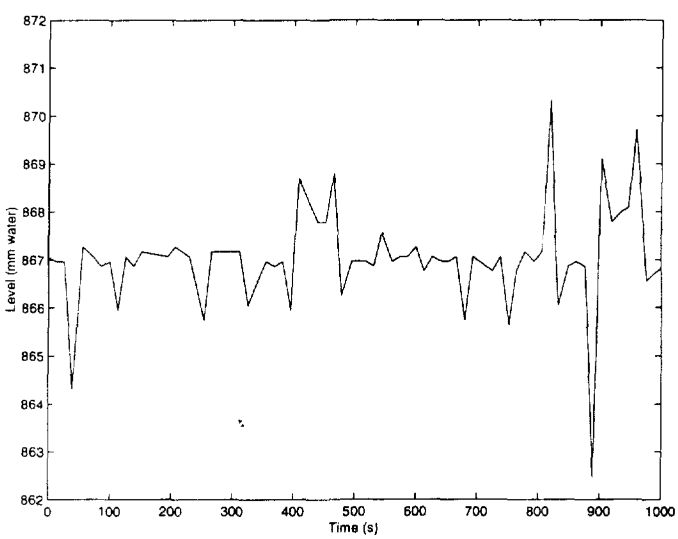

Figure 2. Typical tank level data

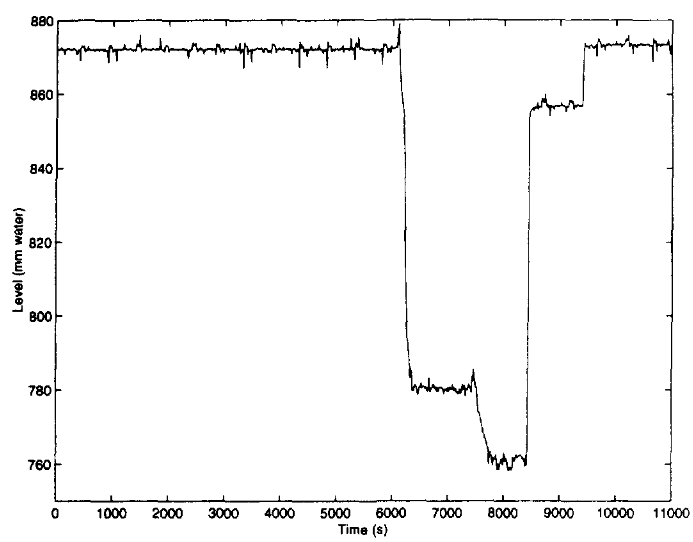

Figure 3. Typical tank level data during recirculation

Several actions can be identified:

1. Recirculate through pump for about 1,800 seconds;
2. Fill and recirculate through the measuring pot;
3. Stop pump and sample measuring pot;
4. Drain measuring pot back to tank.

Application of a Simple Data Compression Algorithm

The application of something like the box car algorithm can add a bias to the data if process noise is one-sided over timescales of interest. As far as solution monitoring is concerned, process noise includes sparging and small temporal deviations, as these are of no interest in the longer term. An example of this one-sided effect is shown in Figures 4 and 5, where the exponentially weighted moving average has been calculated for both tank level data and for tank level data compressed using the box car algorithm with a 3 mm H_2O tolerance, respectively. The faint, highly noisy data are the original level data that fluctuates around 867 mm (approx.); a time constant of $\lambda = 0.1$ was used in the EWMA.[8]

The Scheme

The data compression scheme is composed of two parts (Figure 1), filtering followed by correlation and testing. The aim of filtering is to:

1. Remove unnecessary data points from the main output stream;
2. Output those times at which sparging occurs through stream A;
3. Output those points that pertain to odd events through stream B;
4. Remove those points pertaining to streams A and B from the main output stream.

The main output stream should then contain only data points corrupted with measurement errors as opposed to process noise. Typically, a data compression of 99.3 percent is obtained at this point. A correlate and test stage is then applied so that only the following are output:

1. Those points pertaining to physical activities like recirculation and transfers;
2. Sufficient points to enable an overall, gradual trend to be observed, for instance, a gradual reduction in level as a result of evaporation.

Depending on the activities ongoing on the plant, the final output stream might contain as little as a few tens of points per month.

The Filtering Procedure

The data-filtering algorithm iterates through the time series by making use of two limits: a *proximity* limit, τ_p, and a *change* limit, τ_{ch}. The proximity limit specifies the bounds within which a data point must lie for it to be ignored and the focus of the algorithm moved on to the following point. The change limit seeks to isolate those events that might be of interest to the solution-monitoring system. Thus it specifies the magnitude that the difference between two adjacent points must exceed before it is passed to the output stream. Let the data series to be filtered be defined by $X_1, X_2, X_3, \ldots, X_n$, let the main output stream be $Y_1, Y_2, Y_3, \ldots$, and note that the input series need not be collected at a constant rate. Then the following tests (Figure 6) are applied:

a) No real change: Ignore X_k if $|X_{k+1} - X_k| \leq \tau_p$;

b) Important event: X_k and $X_{k+1} \rightarrow$ Stream Y if $|X_{k+1} - X_k| > \tau_{ch}$ and $|X_k - X_{k-1}| \leq \tau_p$;

c) Sparging: $X_{k+3} \rightarrow$ Stream A if $\tau_p < |X_{k+n} - X_k| \leq \tau_{ch}$ and $|X_{k+n+1} - X_k| \leq \tau_p$, $\forall_n n : 1 \leq n \leq m : 3 \leq m \leq 10$;

d) Important event: X_k and $X_{k+n+1} \rightarrow$ Stream Y if $\tau_p < |X_{k+n} - X_k| \leq \tau_{ch}$ and $|X_{k+n+1} - X_k| > \tau_{ch}$, $\forall_n n : 1 \leq n \leq m : 3 \leq m \leq 10$;

e) Sudden change in bias: X_k and $X_{k+n} \rightarrow$ Stream Y if $\tau_p < |X_{k+n} - X_k| \leq \tau_{ch}$, $\forall_n n : 1 \leq n \leq 11$.

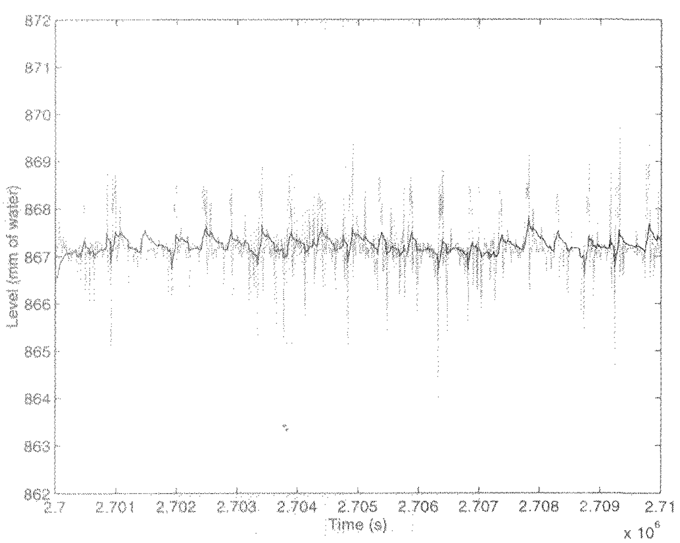

Figure 4. EWMA of original data

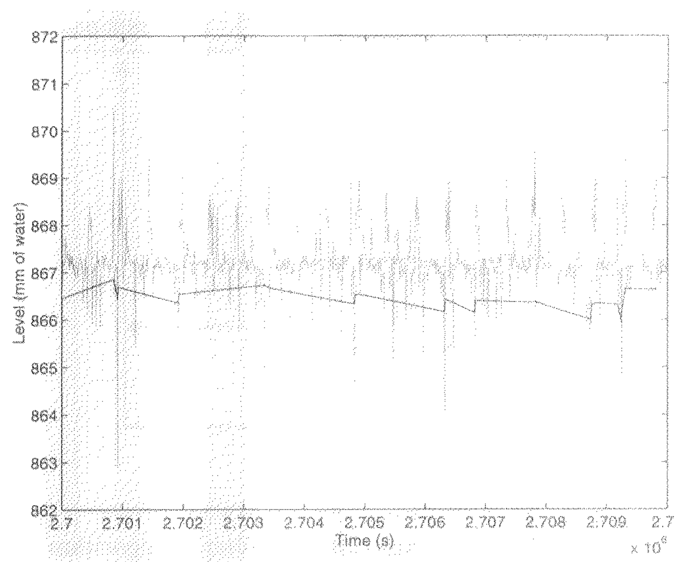

Figure 5. EWMA of compressed data

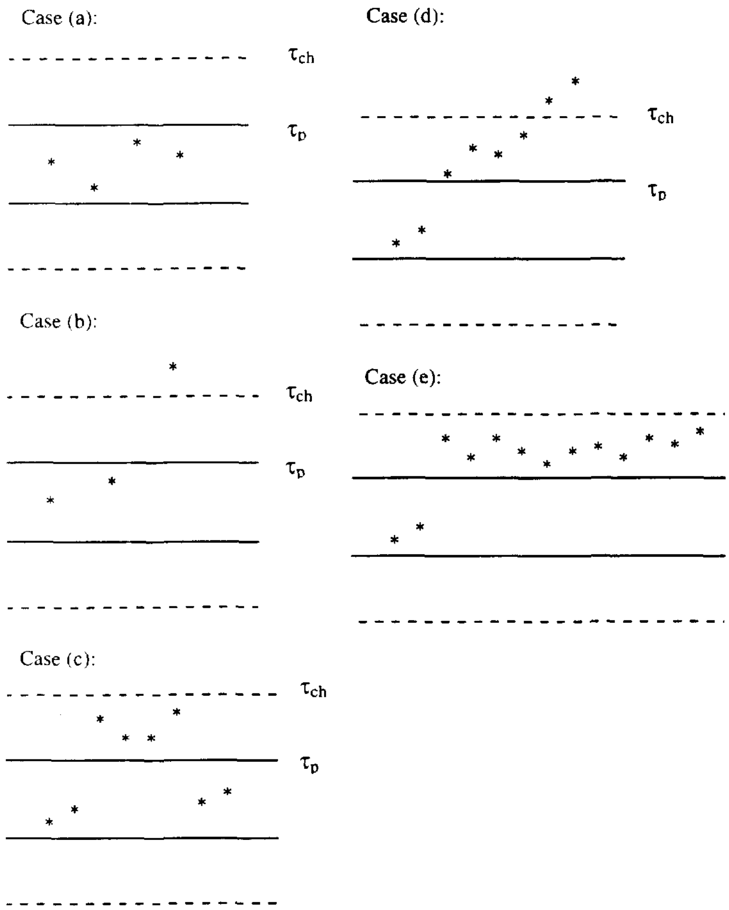

Figure 6. Features identified

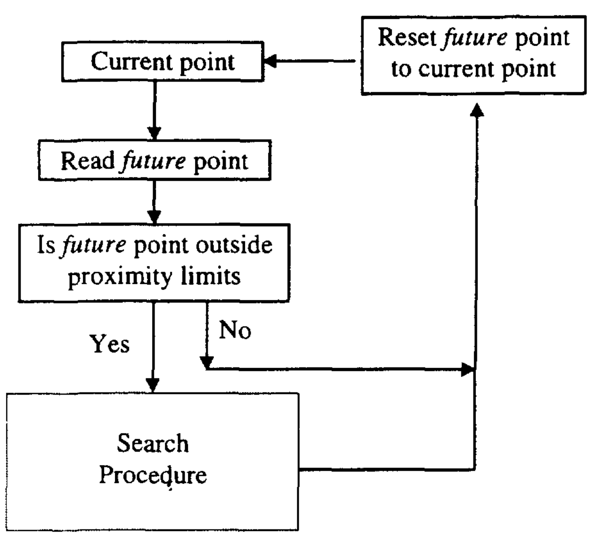

Figure 7. Logical description of filtering algorithm

Odd events are eliminated by looking at the associated level dip-tube standard deviations σ_1, σ_2, σ_3, ... *after* the other tests have been completed:

a) Odd event: X_k and $X_{k-1} \rightarrow$ Stream B if

$\sigma_k > \tau_\sigma$, where τ_σ is another tolerance.

Note that these tests are not guaranteed to filter out all features that are unimportant. Duplicate records are sometimes output, but these are easily detected and removed.

The main steps of the iterative procedure are shown as flow diagrams in Figures 7 and 8. Starting from the top of the diagram, the algorithm compares the proceeding point with the current point; if the proceeding point is within the proximity limits, it becomes the current point and the next point assumes the mantle of the proceeding point, and so on. If the proceeding point lies outside the proximity limits, the search algorithm is invoked and the current point remains the same until a search is completed. On completion, passing both points to the output stream is important, as it means that both the start point and end point are collected. The proceeding point is checked to ensure that it does not lie within the proximity limits. It is then checked to see if it lies outside the change limit. If it fails to meet either of these criteria, the focus of the algorithm shifts to the next point, i.e., it becomes the proceeding point. This loop continues until either the proceeding point returns to lie within the proximity limits or exceed the change limit. Note that the procedure is more complicated than this to accommodate the maximum loop count of 10 and hence the possibility of a sudden change in bias. Under a certain set of conditions, the level could remain between the proximity and change limits indefinitely, thus causing corruption of the filtered data. If the points lie between the proximity and change limits for 10 points (i.e., for 10 loops of the search loop), it is assumed that the level will never return to within the proximity limit of the current point; the current point and the proceeding point are then passed to the output stream and the proceeding point is then reset as current. The entire process is then started again.

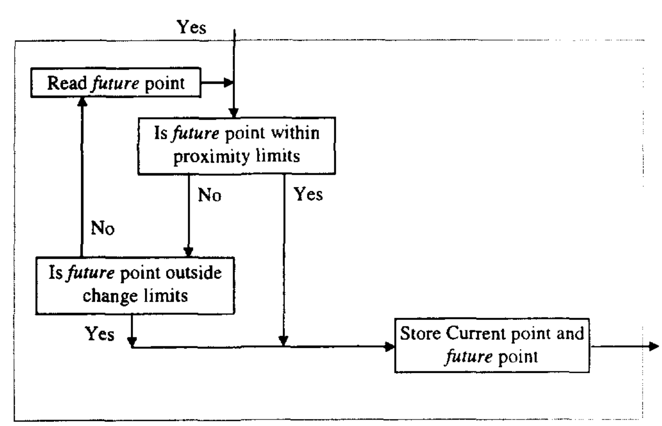

Figure 8. Logical description of search algorithm

Figure 9 shows the resultant filtered output obtained from a small sample of input data. The input data are superimposed as a faint line and each * denotes an output point. Note that a significant number of points are output because of the significant number of temporal deviations that have occurred. To smooth the output further, the filtered data were passed through the filtering algorithm a second time with the proximity limit set to twice that of the first pass and with the same change limit. No additional output streams are required, as all the features of interest should have been passed on the initial filter pass. Figure 10 shows the sample data after being filtered twice: Each point output to the sparging record file is marked as 'o'.

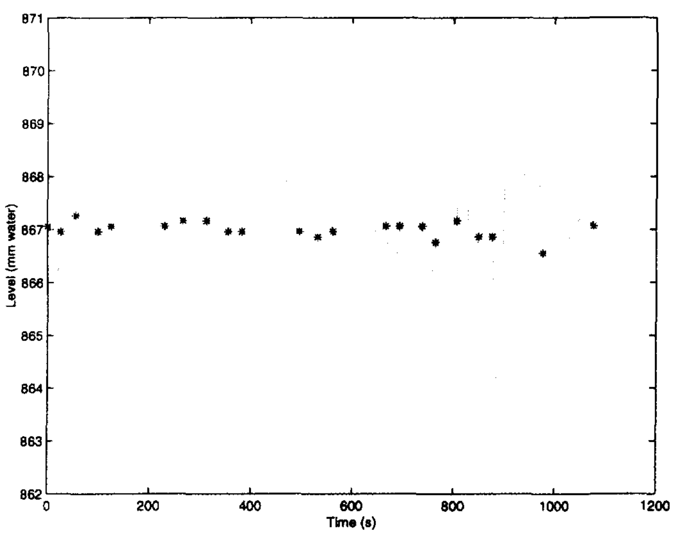

Figure 9. Sample data + output (*) from first filter pass

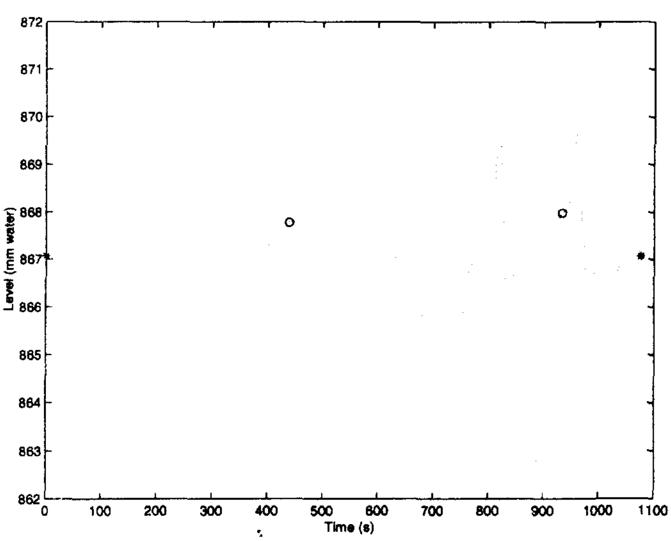

Figure 10. Sample data, output (*) from second filter pass, and sparging (o)

The Correlate and Test Procedure

Although the above achieves a significantly high level of data compression, the level is still likely to be too low for a solution-monitoring system where only relatively infrequent events are of interest. Typically, only 100 points might be of interest in 100,000 points, suggesting a data compression down to, say, one per 1,000, or 99.5 percent. Thus a further procedure is required to extract the desired points.

The correlate and test procedure is based on the observation that, if process noise is ignored, then a level history plot can be represented by a series of straight-line segments, the change points of which correlate with those physical events that might be of interest to a solution-monitoring system. This then leads to the application of an estimator to generate equations for the straight-line segments and the application of a test procedure to detect the change points. The basic scheme is shown in Figure 11. There are several points that need to be taken into consideration in order for this procedure to function in the desired manner:

1. The estimator must be reset upon detection of a change in order for it to construct a new estimate for the process mean;
2. The test procedure has to be switched off whenever the program is restarting (including the initial start) to allow an accurate estimate for the equation of the line. Failure to do so will result in false alarms.

This approach does not output appropriate start and end points for an entire measurement history so, to reduce the effect of process noise, these points are obtained from the EWMA (with $\lambda = 0.1$)[14] that is calculated in parallel with the filter, correlate and test procedures. The start point is then taken to be the 15th point of the EWMA value, and the end point is the last point calculated. This is the only time that calculated data, as opposed to recorded data, are output.

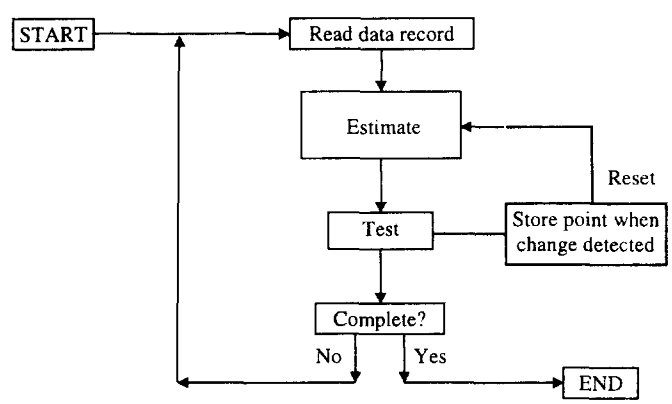

Figure 11. Logical description of the correlate and test procedure

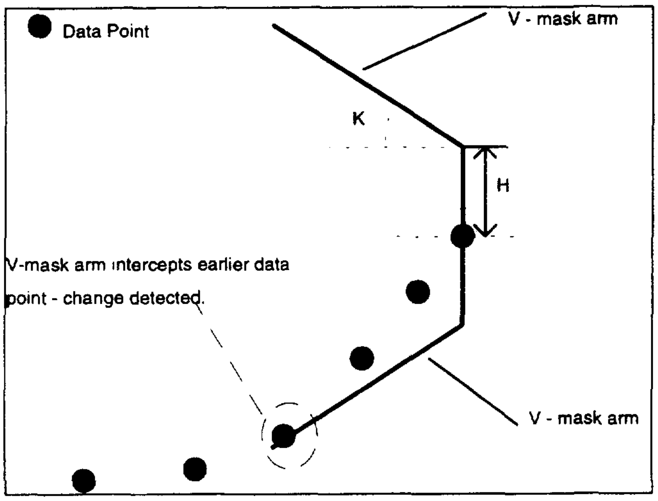

Figure 12. V-mask template

The Correlate Procedure

A recursive least squares algorithm[15] is used to estimate the gradient m and constant c $[m, c : y_i = mz_i + c ; z_i = t_i - t_1 ; t \text{ is time}]$ as follows:

$$x_{n+1} = x_n + P_{n+1}\, h_{n+1}\, (y_{n+1} - h^T_{n+1}\, x_n),$$

where:

$y = h^T x + n$
$h = [z\ 1]^T$
$x = [m\ c]^T$
n – noise
$P_{n+1} = P_n - P_n\, h_{n+1}\, (1 + h^T_{n+1}\, P_n\, h_{n+1})^{-1}\, P_n\, h^T_{n+1}$

To apply this, $P_0 = \infty * 2 \times 2$ identity matrix and x_0 has $m = 0$ and c = the first data point. It is necessary to reset the RLS calculation every time a point of change is detected. This is easily achieved by simply resetting P_{n-1} to its initial value and setting X to have $m = 0$ and c = value of process mean at this point.

Due to problems encountered later on when finding m and c at points of change, the values calculated by the above code are stored in a simple ring buffer with a delay between the write and read counters.

The Test Procedure

A modified version of the standard Cusum test[14,16] is used to test for changes. From reference 14, expressions for the upper Cusum (C^+) and the lower Cusum (C^-), when applied to a normalized data point x_i, are as follows:

$$C_i^+ = \max\,[0, x_i - (\mu_0 + K) + C^+_{i-1}]$$

$$C_i^- = \max\,[0, (\mu_0 - K) - x_i + C^-_{i-1}]$$

where μ_0 is the target process mean and K is a constant.

If either C_i^+ or C_i^- exceeds appropriate tolerances, then the process mean is deemed to be changing. This procedure is often represented by a V-mask (Figure 12) that is applied at every point of the data; if one of the arms of the V-mask intercepts a data point then a change in the mean is deemed to have taken place. The values of H and K relate to the vertical height and the angle of the arms of the V-mask respectively. If $K = 0$, the arms are at right angles. Here, the Cusum test is applied to the data without normalization, and hence the value of H is related to the standard deviation, σ, of the input data:

$$H = h * \sigma$$

where h = a constant ($1 < h < 5$). Note that standard deviation estimates are output by the VLTM system directly.

This procedure has to be modified to account for the fact that the test is not on a process mean that is assumed to be constant, but on whether or not the data have deviated from a straight-line trajectory. Thus μ_0 is replaced by $mz_i + c$.

Due to the nature of the V-mask test, the time at which the change is detected is at least one time step after the start of the actual physical change. There are two ways of procuring a more accurate estimate, the choice of which is dependent on the output that is desired by the user.

1. Store both the gradient and the constant of the line prior to the point of change and, once the estimate of the subsequent line has been completed, calculate the intersection of both lines to obtain a new point of change that might not exist within the original data;
2. Temporarily store the data points so that an appropriate point can be recalled and used as the change point. Thus the point of change will exist within the input data set.

In this instance the latter option was chosen because the output of genuine data points was preferred.

The V-mask requires careful calibration for it to process data successfully. Many factors affect its operation. For example, how soon after least squares should it be restarted? Answers to these and other questions are dependent on the density of the data points to be processed. The VLTM data sets are of relatively low density, with substantial changes in the process mean occurring within five or more points *before* filtering.

Figure 13 shows the points output over a one-month period (approx.) superimposed over the filtered data because the input data set is so large. Figure 14 is a close-up of the recirculation period. Note that the end points can be used to estimate the effect of evaporation and that there are sufficient points to extract all the important features of the recirculation/sampling.

Conclusions

A tank measurement data compression scheme has been described that has been developed to meet the special needs of nuclear materials safeguards in general and solution monitoring in particular. Depending on the amount of activity that is associated with the tank, a high degree of data compression can be obtained. The outputs from a number of recorded data sets have been input into the solution-monitoring system developed by Scothern and Howell[4] and, in every instance, the recirculation/sampling activities were detected and diagnosed.

The scheme has been developed to compress data pertaining to tanks whose imports/exports are in the form of batches. It is a moot point whether it would work without modification on, for instance, the receiving tank of a solvent-extraction cycle, because here the level history is likely to have some form of sawtooth profile. In such cases, the V-mask test might produce erroneous outputs if the vertices of the profile are too sharp. There are a number of ways of accommodating this, but modification is not thought to be worthwhile until appropriate real test data are available to work with.

Acknowledgments

This work was funded by the U.K. Department of Trade and Industry through the Safeguards R&D Programme in support of International Atomic Energy Agency Safeguards. The results of this work may be used in the formulation of government policy, but views expressed in this report do not necessarily represent government policy.

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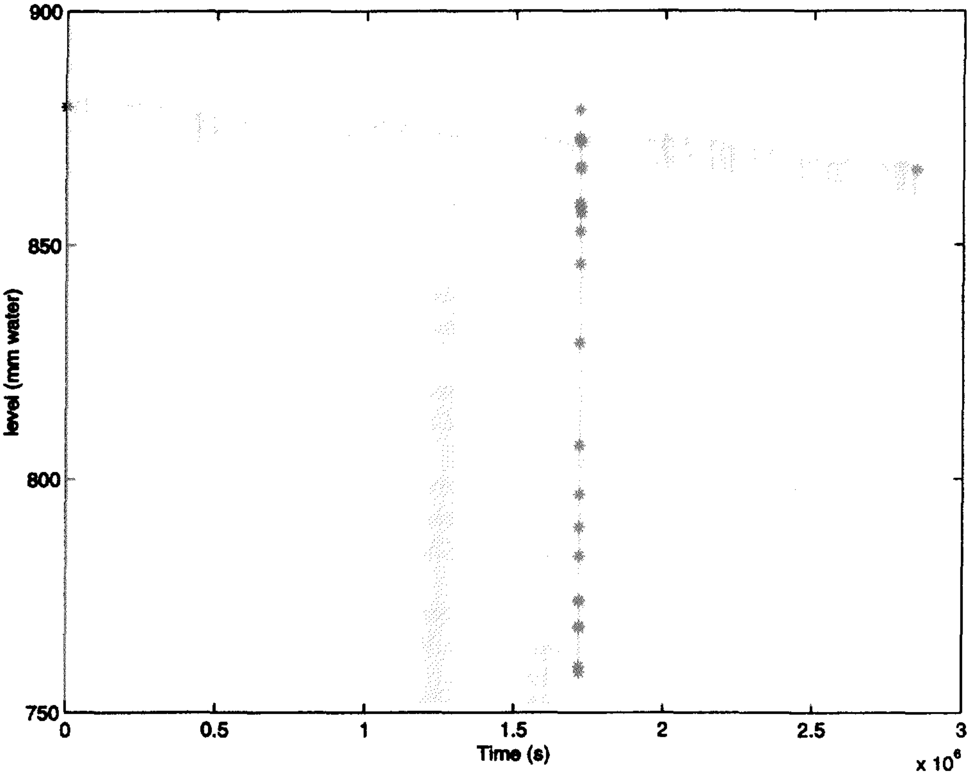

Figure 13. V-mask output superimposed on filtered data

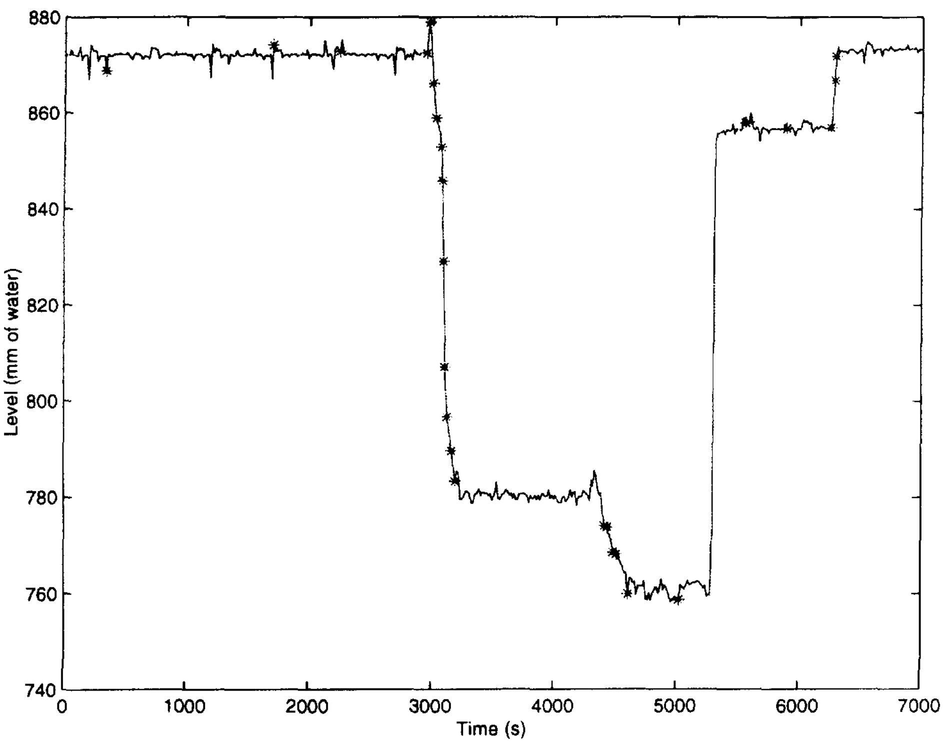

Figure 14. V-mask output superimposed on recirculation

Physical-model-based Diagnostic Aid for Safeguarding Nuclear Material in a Liquor Storage Facility," *Journal of Nuclear Materials Management* 25(4), 1997, pp. 20–29.
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Passive Active Neutron Radioassay Measurement Uncertainty for Aqueous Sludge Waste

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Abstract

To meet Waste Isolation Pilot Plant waste characterization requirements, a total uncertainty analysis of active-mode measurements of aqueous sludge waste using the Idaho National Engineering and Environmental Laboratory's passive active neutron radioassay system was performed. The uncertainty analysis was based on statistical sampling and verification. PAN system active-mode measurement results were compared to radiochemistry results for 125 waste drums containing aqueous sludge. The radiochemistry data were obtained from core samples of the waste drums. Bias in the PAN system was estimated by regression of the radiochemistry results (assumed to be unbiased) on the PAN measurements. Precision of the PAN measurements was assessed by examination of the variance components associated with the regression.

Analysis of the results indicates that a bias correction multiplier of 1.55 should be applied to the PAN aqueous sludge measurements. Without this correction, the PAN measurements are biased low by 35 percent relative to the radiochemistry measurements. With the bias correction, the uncertainty bounds on the expected bias are 0 ± 27%. These bounds meet the Waste Isolation Pilot Plant Quality Assurance Program Plan requirements for radioassay systems.

1. Introduction

The Idaho National Engineering and Environmental Laboratory is being used as a temporary storage facility for transuranic waste generated by the U.S. nuclear weapons program at the Rocky Flats Plant in Golden, Colo. Currently, there is a large effort in progress to prepare to ship this waste to the Waste Isolation Pilot Plant in Carlsbad, N.M. In order to meet the TRU Waste Characterization Quality Assurance Program Plan nondestructive assay compliance requirements and quality assurance objectives, it is necessary to determine the total uncertainty of the radioassay results produced by the Stored Waste Examination Pilot Plant passive active neutron radioassay system. This paper is one of a series of reports quantifying the results of the uncertainty analysis of the PAN system measurements for specific waste types and measurement modes. In particular, this report covers PAN active-mode measurements of weapons-grade plutonium-contaminated aqueous sludge waste contained in 208 liter drums (item description codes 1, 2, 7, 800, 803 and 807).

The PAN assay system itself calculates uncertainty based on the counting statistics of the assay technique. However, depending on the waste form involved, there can be significant additional systematic and random errors that need to be quantified before the total assay uncertainty can be quoted. To estimate the magnitude of the additional effects, a sampling and verification approach was used, i.e., a sample of PAN measurements was compared to confirmatory measurements on an alternative measurement system. For the aqueous sludge wastes, the confirmatory measurements consisted of radiochemistry data. The radiochemistry data were obtained from core samples of the waste drums. Bias in the PAN system was estimated by regression of the radiochemistry results (assumed to be unbiased) on the PAN measurements. Precision of the PAN measurements was assessed by examination of the variance components associated with the regression. Because the active-mode result is always selected as the reported mass for sludge wastes, this report only addresses uncertainty in the active-mode measurements.

Sections 2, 3 and 4 of this report give a general description of the PAN assay system and operation (in particular the active mode) and potential sources of uncertainty in the measurement. The uncertainty analysis approach is described in detail in Section 5. Section 6 discusses the data used in support of the uncertainty analysis. Results of the analysis are presented in Sections 7 and 8.

2. Passive Active Neutron Assay System

The SWEPP PAN system is a second-generation passive active neutron system developed in the early 1980s by Los Alamos National Laboratory for the U.S. Department of Energy and delivered to the Idaho National Engineering and Environmental Laboratory in 1983. This system was designed to assay drums containing transuranic contaminated waste. The SWEPP PAN assay system is described in an INEEL internal document; for more details, the reader is referred to that document.[1] A summary description is given below.

The PAN assay system consists of a shielding housing that surrounds the drum on all four sides, top and bottom. Each side of the housing contains moderator (i.e., graphite, polyethylene), thermal and low-energy neutron shielding (i.e., cadmium, boron) and He-3 neutron detectors. There are two types of detector assemblies contained in each side of the assay system, i.e., bare detectors and shielded detectors.

The shielded detectors are grouped into detector packages, where each package is surrounded by a thermal and low-energy neutron shield consisting of cadmium and borated rubber. Inside the cadmium and borated rubber are three or four He-3 neutron detectors surrounded by polyethylene. This type of detector assembly is sensitive to fast neutrons and insensitive to thermal and low-energy neutrons. The bare detectors are also He-3 detectors surrounded by polyethylene but are not shielded by cadmium or borated rubber. In this configuration they are sensitive to all neutrons.

The assay system operates in two modes, passive and active. In the passive mode, the detector assemblies (bare and shielded) are detecting neutrons produced by spontaneous fission and (α,n) interactions in the waste matrix. Differentiation between the fission neutrons and the (α,n) neutrons is accomplished by coincidence-event counting. In this type of counting, a coincidence event is recorded when two neutrons are detected by the system within a specified time window. There are two coincidence windows used: One is 35 µs long and looks for coincidence events from the shielded detectors in the enclosure. This is referred to as the short-gate or shielded coincidence mode. The other gate is 250 µs long and looks for coincidence events from all system detectors (shielded and bare) in the enclosure. There are two coincidence circuits that use all system detectors and a 250 µs gate window. The first circuit is referred to as the long-gate or system coincidence mode. The second circuit is the shift register coincidence unit.

In addition to the coincidence counting, single-event counting is also accumulated during the passive mode. The single-event counting data are used to derive chance coincidence corrections to the coincidence data and also to arrive at a moderator index.

In the active mode, the shielded detectors are used to detect neutrons produced by stimulated fission resulting from thermal neutron interrogation. The interrogation neutron source for the active mode is a Zetatron 14 MeV neutron generator located at one corner inside the system shield enclosure. The high-energy neutrons are moderated to thermal via the graphite moderator in the enclosure walls and varying amounts of moderator in the waste matrix. For the active mode, the signal of interest is taken from a gated count of the shielded detectors for the time window from 700 µs to 2,700 µs following each neutron burst from the neutron generator. This time window was selected to allow the fast neutrons from the generator to thermalize in the enclosure and thereby have a higher probability to stimulate fission in Pu-239, while at the same time the thermalized interrogation neutrons are not detectable by the shielded detectors. To account for background, another count window is opened from 5,700 µs to 15,700 µs after each neutron burst. It is expected that during this time window only background neutrons will be present.

Also during the active mode, two monitors are used to monitor the interrogation neutron flux and the effective transmission of interrogation neutrons through the contents of the drum. The first monitor, called the cavity monitor, consists of one bare He-3 detector mounted inside the assay system enclosure on the back wall of the chamber along an upper corner. The second monitor, called the barrel flux monitor, is a single He-3 detector inside a cadmium collimator mounted at mid-height in the adjacent back corner of the assay system enclosure so that the detector's field of view is the center of the drum. These two monitors are operated with the same time windows as the shielded detectors during the active mode. The ratio of the cavity monitor count during active mode to the barrel monitor count during active mode is referred to as the absorber index.

The moderator index (from passive-mode counts) and the absorber index (from the active-mode count) are used in the analysis algorithm to arrive at correction factors which are intended to correct for moderator and absorber effects on the measured responses (both active and passive responses). The corrected responses are used to determine the measured plutonium mass. Therefore, both the active and passive counts must be completed to obtain the needed correction factors. Four measured mass values are obtained by the system for each measurement sequence (passive count + active count). That is, there is a mass value determined from the active-mode count, a mass value determined from the passive short-gate coincidence count, a mass value determined from the passive long-gate coincidence count and a mass value determined from the shift register coincidence count. However, not all four values are valid over the mass range and waste forms covered in SWEPP waste. A set of selection algorithms is included in the system software to determine which of the four assay values should be used in the waste certification documentation.

2.1 *Assay of Sludge Waste Forms Using the PAN System*

Sludge is a general term referring to solidified process waste. Under this general category there are several Item Description Codes, e.g., 1, 2, 3, 7, 92, 800, 801, 802, 803, 806, 807, etc. The subdivision into IDC designations is based on the process from which the waste was generated and the treatment and packaging of the waste after generation. Generally speaking, there is no evidence of any clumping of plutonium into chunks large enough to create significant self-shielding. The major difficulty concerning assay using passive coincidence methods on sludge waste drums is high (α,n) neutron backgrounds present in most sludge drums. Because of high (α,n) background and relatively low plutonium content, the passive mode was considered to lack the sensitivity or accuracy to assay sludge waste forms. However, this assessment was done prior to the installation of the shift register coincidence unit. This new unit has virtually removed (α,n) backgrounds as a reason to exclude passive techniques; however, passive techniques still lack the sensitivity to assay plutonium in those cases where it is less than 5 g.

By default, the active mode became the mode of choice for reporting plutonium mass in sludge waste. The relatively high density and hydrogen content do pose problems concerning interrogation neutron penetration into the center of a drum and do affect the overall accuracy of the active mode when assaying sludge waste. Early studies have indicated that the bias and precision of the active-mode results were suspect. For example, a previous assessment was conducted where radiochemistry data on samples taken from 24 sludge drums were analyzed by Oak Ridge National Laboratory and compared with early PAN assay data for the same set of drums. Because of incomplete data and low sample population, the results from this assessment were not formally reported. However, they did indicate that the active assay results from early PAN assays were low by a factor of 2.2 and that the relative precision error was about 40 percent.

2.2 *Active-mode Response*

The interrogation/counting sequence used in the PAN active-mode assay is commonly referred to as the differential die-away technique. In the active-mode assay, the PAN neutron generator is operated at a rate of 50 pulses per second. At this repetition rate and with $\approx 2 \times 10^6$ interrogation neutrons per pulse, the output from the neutron generator is $\approx 10^8$ neutrons per second. Currently, an active-mode data assay will use 4,000 neutron generator pulses, which takes about 80 real-time seconds to complete.

There are three detector systems used during active-mode interrogation:

1. Shielded detector banks in walls, door, top and floor of enclosure;
2. Cavity flux monitor mounted in an upper corner of the assay chamber;
3. Barrel flux monitor with collimator shield mounted in the cavity at drum mid-height.

Each shielded detector bank, cavity flux monitor and barrel flux monitor has two count registers; one accumulates detector counts arriving during the early gate time window and the other accumulates detector counts arriving during the late gate time window. For total plutonium analysis, the individual detector bank count data are summed to produce a shielded total count for the whole system. In the active-mode assay, there is one shielded total count for the early gate time window and one shielded total count for the late gate time window.

The basic active-mode signal is derived from shielded detector counts produced by fission neutrons arising from thermal neutron stimulated fission in Pu-239 or other fissile nuclides. The purpose of the neutron generator is to produce a source of neutrons that will produce fission. However, the neutron generator produces high-energy neutrons (14 MeV) whose fission cross section for Pu-239 is relatively low ($\approx$ 1 barn), whereas the fission cross section for thermal neutrons is $\approx$ 700 barns. In order to achieve the required sensitivity to plutonium, the 14 MeV source neutrons must be moderated to thermal or near-thermal energies.

The energy of the neutrons produced by fission is $\approx$ 2 MeV. Each shielded detector bank is surrounded by low-energy neutron absorber material (i.e., cadmium and boron). As a result, the shielded detectors are not sensitive to the interrogation thermal neutrons but are sensitive to the higher-energy fission neutrons. The moderation process, which takes neutron generator neutrons from 14 MeV to thermal, involves several scattering events in the graphite liner of the PAN shield enclosure cavity and/or in the hydrogenous material of the waste matrix and shield walls. These scattering events occur over a period of time following the neutron generator pulse. At about 700 μs, the thermal neutron population is approaching a maximum and the epithermal neutron population is approaching a minimum. To take advantage of the optimal thermal-to-epithermal flux ratio, a detector time gate window is opened from 700 μs to 2,700 μs. This time interval is referred to as the early gate.

An active background count is taken by opening a second detector time gate window from 5,700 μs to 15,700 μs following each neutron generator pulse. During this time window the interrogation thermal neutrons will have died away and what remains are neutrons from spontaneous sources, e.g. cosmic neutrons, spontaneous fission neutrons and (α,n) neutrons. This time interval is referred to as the late gate.

Each shielded detector bank, cavity flux monitor and barrel flux monitor has two scalars, one to accumulate counts from the early gate window and one to accumulate counts from the late gate window.

After completing an active-mode acquisition, the following information is used to arrive at plutonium mass.

1. Shielded total early gate (700 μs–2,700 μs) count;
2. Shielded total late gate (5,700 μs–15,700 μs) count;
3. Cavity flux monitor early gate (700 μs–2,700 μs) count;
4. Cavity flux monitor late gate (5,700 μs–15,700 μs) count;
5. Barrel flux monitor early gate (700 μs–2,700 μs) count;
6. Barrel flux monitor late gate (5,700 μs–15,700 μs) count;
7. Number of neutron generator pulses.

2.3 *Data Analysis and Reported Pu Mass Selection*

SWEPP Assay System Version 2.1 analysis code was used to produce the PAN plutonium mass values given in this report. A description of the analysis algorithms is given in the SAS code software requirements document and will not be repeated in this report.[2] As stated previously, the PAN system does both an active-mode assay and a passive-mode assay. Therefore, there are two Pu mass values generally available to report, i.e., active Pu mass or passive Pu mass. The passive Pu mass, however, is chosen from among the short-gate coincidence Pu mass, the long-gate coincidence Pu mass and the shift register coincidence Pu mass. So in fact, there are four Pu mass values generated in a PAN system assay, one from active mode and three from passive mode.

Ideally, all four mass values should agree. In most cases they do not, and so a decision has to be made as to which value is best in terms of accuracy and should be reported as the Pu mass. For each content code, an assessment is performed to determine generally whether the active-mode or passive-mode assay results should be used for that content code. The choices are (1) active mode for all drums of that content code, (2) passive mode for all drums of that content code or (3) default to SAS code selection algorithm. In the default option, the decision between active and passive Pu mass is based on a threshold value of 5 g measured passive Pu mass. If the passive Pu mass is at or above 5 g, the passive Pu mass will be reported. If, on the other hand, the passive Pu mass is less than 5 g, the active mode Pu mass will be reported. If the passive Pu mass is chosen (either by option 2 or option 3 above), the shift register coincidence Pu mass will be used in almost all cases. If the shift register Pu mass is not available or is suspect, then either the short-gate coincidence mode Pu mass or the long-gate coincidence mode Pu mass will be reported as the passive Pu mass. The decision between these two is based on which has the smaller relative error.

For most sludge waste codes and certainly for the IDCs analyzed in this report, high (α,n) background and low plutonium concentration has led to the active mode Pu mass (option 1), being specified as the reported Pu mass.

2.3.1 U-235 Correction to the Active Pu Mass Determination
In the original PAN calibration and analysis routines, the assumption was made that there is only weapons-grade plutonium in the transuranic waste drums from Rocky Flats Plant.[3,4] However, the addition of the SWEPP Gamma Ray Spectroscopy system quickly identified that uranium was also present, and for some content codes U-235 is the dominant fissile nuclide. The SAS code version 2.1 contains routines that account for fission from U-235 as well as fission from Pu-239 in the active mode assay.[2] Therefore, uranium compensation can only be accomplished if the U-235–to–Pu-239 mass ratio is passed over from the SGRS to the PAN prior to the commencement of the SAS analysis.

3. Calibration of the PAN Assay System

The basic calibration of the PAN system is performed using standard sealed neutron sources in an empty waste drum. The original calibration was performed by Los Alamos National Laboratory prior to delivery of the PAN system to the Idaho National Engineering and Environmental Laboratory. Because of changes made to the detector electronics and the addition of the shift register coincidence system, a baseline calibration was repeated in June 1997.[5]

Listed below are the basic equations used by the PAN assay system to determine the mass assay values.

$$\text{Mass}_A = C_A * [\,(\text{Net Total Shld Adj Rate} / \text{Net Flux Mon Rate}) - \text{Int. Bkgd}]_A * CF_A * CF_I \quad (3.1)$$

$$\text{Mass}_{lg} = C_{lg} * (\text{Net LG Coincidence Rate})_P * CF_{lg} * CF_I \quad (3.2)$$

$$\text{Mass}_{sg} = C_{sg} * (\text{Net SG Coincidence Rate})_P * CF_{sg} * CF_I \quad (3.3)$$

$$\text{Mass}_{src} = C_{lg} * (\text{Net SRC Coincidence Rate})_P * CF_{sg} * CF_I * (\text{SRC calibration adjustment}) \quad (3.4)$$

where:

Net Total Shld Adj Rate = Net total shielded adjusted rate;
Net Flux Mon Rate = Net flux monitor rate;
Int. Bkgd = Interrogation background;
Mass_A = Pu mass as determined from the active mode;
Mass_{lg} = Pu mass as determined by the long-gate coincidence mode;
Mass_{sg} = Pu mass as determined by the short-gate coincidence mode;
Mass_{src} = Pu mass as determined by the shift register coincidence mode;
C_A, C_{lg}, C_{sg} are the base calibration coefficients for the active, long-gate coincidence and short-gate coincidence modes, respectively;
CF_A, CF_{lg}, CF_{sg} are the matrix correction factors for the active, long-gate coincidence and short-gate coincidence modes, respectively;
SRC calibration adjustment is the factor applied to the long-gate base calibration coefficient to arrive at the SRC base calibration coefficient;
CF_I is the isotopic correction factor which takes into account that the Pu-240 (passive mode) and Pu-239 (active mode) mass fractions may be different from those used during the base calibration.

The effects of waste matrix, etc., on the system response were estimated during the original calibration series and an algorithm for determining the correction factors was developed by LANL. The correction factors were determined empirically using surrogate waste drums in which generic materials, e.g., vermiculite, boric acid, sand and metal scraps, were used to simulate the waste matrix. The basic assumption in the development of the simulated waste was that the matrix was uniform, the source distribution was uniform and that each waste drum was filled to near the volume capacity of the drum. Over the years, there have been small changes made to the correction-factor algorithm, but the basic premises of uniform matrix and uniform source distributions have not changed. Additional matrix effects resulting from violations of the uniformity assumptions are discussed in the next section. The presence of these effects is the reason a more thorough uncertainty analysis is required.

4. Contributors to the Assay Uncertainties

This section describes sources of uncertainty in PAN measurements. It is the combined effects of these various contributors to errors in measurements that must be estimated in the uncertainty analysis.

4.1 *Base Calibration*

In the base calibration, the system response is measured for a well-characterized neutron source (i.e., known neutron strength and elemental and chemical composition) at specified positions in an empty waste drum. There are three primary uncertainties associated with the base calibration. The first is the uncertainty for the source strength, which includes any decay corrections that are applied and the number of neutrons produced per decay. The second is the uncertainty about the elemental and chemical composition of the neutron source material. The elemental and chemical composition can significantly affect the reported neutron source strength by producing an unknown number of neutrons produced by (α,n) interactions in the source. The third uncertainty is the counting statistics associated with the base calibration data acquisition.

4.2 *Matrix and Source Effects*

In quantifying the estimates for systematic and random uncertainties, the major issue involves the validity of the uniform matrix and uniform source premise used in the PAN algorithm to the application of assaying a particular class of waste and what kind of errors are introduced as a result of making this assumption. Listed below are the specific ways that real waste may differ from the uniform matrix and uniform source premise.

1. Source isotopic/chemical composition effects;
2. Nonuniform matrix absorption;
3. Nonuniform matrix moderation;
4. Nonuniform source distribution;
5. Variations in source particle size;
6. Significant voids in the matrix;
7. Shadow shielding of one region by high neutron absorption in another region;
8. Waste elemental composition not addressed by the calibration routine.

4.3 *(α,n) Source Interference*

In addition to the matrix- and source-introduced errors, there are also uncompensated effects resulting from (α,n) reactions occurring in the waste. Since the (α,n) reactions only produce one neutron per reaction, the coincidence-counting method in the passive mode should differentiate between neutrons produced by fission (more than one neutron per fission) and neutrons produced by (α,n) reactions. However, the coincidence-counting method will have a contribution due to accidental or chance coincidences. There are standard techniques to correct the coincidence-counting data for these spurious events, and these techniques work well when the chance coincidence rate is small compared to the real coincidence rate. In those cases where the (α,n) source strength is clearly dominant over the fissile neutron source strength (i.e., the chance coincidence rate is dominant over the true coincidence rate) there is a very large uncertainty associated with the correction for chance coincidence events.

In addition, high count rates will also lead to counting losses that are not compensated for in the simple correction applied in the assay system analysis routine. For example, the standard corrections applied for counting losses are based on the assumption of random events and are not applicable to correlated events, as is the case in coincidence counting. The random event-based corrections are valid when the correction is small but not when the counting loss is the same order of magnitude as the basic count rate. There are drums at RWMC where the neutron count rate is high enough that this circumstance applies. Under these situations, the corrections are considered suspect and contribute significantly to the overall uncertainty of the measurement.

Thus (α,n) interference and counting losses can be sources of significant uncertainties in the assay results. In fact, recent experience has indicated that these effects can be the dominant contribution to the uncertainty of the passive-assay results.

5. Uncertainty Analysis Approach

Evaluating the uncertainty of a complex nondestructive assay system presents a number of challenges. While the intricate makeup of the system itself can make it difficult to adequately characterize performance, further complications occur when external factors must be considered. Such is the case with radioassay systems used to certify waste for shipment to the Waste Isolation Pilot Plant. The DOE requires that uncertainty evaluations for these systems include the effects of waste matrix parameters and other external factors having potential effects on system performance. Section 9 of the DOE's Transuranic Waste Characterization Quality Assurance Program Plan requires performance goals be "achievable in the presence of backgrounds generated by alpha- and gamma-emitting sources and in the presence of interfering quantities of neutron- and gamma-absorbing and moderating material."[6] In other words, the uncertainty characteristics of the system in its intended real-world application must be established.

Standard methods of uncertainty analysis, primarily based on propagation of errors, will almost always underestimate measurement uncertainty in real-world applications. This is because the uncertainties for the component parts are generally based on laboratory experiments on standard test materials. Such assessments are useful in that they provide a best-case scenario of a system's performance capability. However, to the extent that they fail to include effects of external factors, they are insufficient to establish the quality of measurements achievable in a true operational setting. Factors not commonly considered in laboratory assessments of uncertainty include highly variable background levels or interference, operator effects (e.g., fatigue, level of training) and heterogeneity of materials being tested (matrix effects). The amount of variability inherent in some of these factors, especially matrix effects, makes them difficult or inappropriate to incorporate into analyses using standard methods.

When external factors such as matrix effects are expected to have significant influence on measurements, a key requirement for a study designed to assess the uncertainty of an NDA system is that the test items must be representative of those on which the system is intended to be used. Another way to think about uncertainty that focuses on the issue of representativeness is to consider the following question. If one selects an item at random from a population of items of interest and measures it, what is the expected bias and precision error for that measurement? Stated in this manner, the importance of the representativeness of sampled items in the presence of matrix effects is clear. In a waste drum radioassay system, for example, results from an uncertainty evaluation using drums filled with a benign matrix cannot be legitimately used to infer the uncertainty for drums containing large quantities of shielding material such as lead.

Once uncertainty is considered from the viewpoint of the bias and precision of a randomly selected item from a population of interest, a general alternative method of uncertainty analysis emerges. This approach is a sampling and verification approach. For the PAN system, the sampling and verification approach is based on measuring a sample of real waste drums using both the PAN system and a confirmatory system and comparing the results. Under the assumption that the confirmatory data are unbiased, a regression analysis of the pairs of measurements yields estimates of both bias and precision of the PAN system for solidified aqueous sludge waste measurements.

The confirmatory measurement results for the solidified aqueous sludge waste drums were obtained from destructive radioassay of core samples from selected drums. A facility has been built at the INEEL for coring and sampling sludge waste drums. Originally developed for sampling for Resource Conservation Recovery Act listed hazardous constituents, core-sampling plans were modified to include sampling for radioassay analysis as well. While the comparative drum core radioassay data contain a certain amount of uncertainty themselves, they are expected to be unbiased. So by comparing the mean core sample results to the mean PAN results, the bias of the PAN system can be easily established. Furthermore, applying the proper variance component analysis will allow the standard deviation of errors to be estimated as well.

Uncertainty analyses for debris waste forms previously reported also used sampling and verification methods.[7] However, the debris waste evaluations were based on computer-simulated measurements. The computer simulations for debris waste forms were necessitated by the lack of any practical method of verifying drum Pu content. For the sludge wastes, the existence of the coring facility made it quite practical to obtain actual confirmatory measurements.

As mentioned in the introduction, while the PAN system produces Pu mass estimates based on active-mode and three types of passive-mode counts, this report only addresses the uncertainty in the reported active mass value. The active mass value is always selected as the reported mass for sludge drums processed through the PAN system.

5.1 *Basic Steps in Performing the Uncertainty Analysis*

The basic steps used in performing the sampling and verification uncertainty analysis for the solidified aqueous sludge waste were as follows:

1. From IDCs 1, 2, 7, 800, 803 and 807, select at least 100 drums for which PAN measurements are available from those being sent to the coring facility for RCRA evaluation;
2. Send samples from the cores for each of the selected drums to the INEEL Analytical Chemistry Laboratory for radiochemical assessment of TRU contents (Pu, Am and U isotopes);
3. Convert the chemical radioassay results (pCi/g) to the equivalent total drum contents (i.e., total grams of Pu);
4. Compare the radiochemical analysis results with the PAN Pu measurement results for the same drums. From these data, estimates of both total bias and total precision for the PAN system sludge drum measurements can be obtained.

Details of the data collection and analysis activities are given in the following sections.

6. Data

The aqueous waste sludge drums selected to support the uncertainty analysis represent a subset of drums sampled to meet RCRA waste stream toxicity characterization requirements. The sampling plan for the RCRA analysis is described in detail in an internal engineering design file.[8] The RCRA sample procedure basically comprised a pseudo-random sample, i.e., random within the operational constraints of the facility (safety, accessibility, etc.). RCRA sampling was already in process when the decision was made to obtain radiochemistry samples as well. Once the procedures for the radiochemistry samples were determined, radiochemistry data on the remainder of the drums in the process were requested. Since the drums were sent to the coring facility in no particular order, the drums sent for radiochemistry analysis should be a representative sample of the aqueous waste sludge drums.

Of the total set of sludge drums selected for coring, 135 were initially identified to support the solidified aqueous waste uncertainty analysis using IDCs 1, 2, 7, 800, 803 and 807. However, radiochemistry analysis was not performed on seven of the 135 drums. For most of these drums, the cores had already been obtained for the RCRA analysis when the request for the radiochemistry analysis was received at the laboratory. For one drum, sufficient core material on which to perform the radiochemistry analyses was not obtained during coring. Three additional drums were later eliminated from the uncertainty analysis due to lack of data associated with the PAN measurements, leaving 125 drums for the uncertainty analysis.

(Note: The IDC 807 waste included in this analysis is the solidified bypass sludge waste from Building 374 at Rocky Flats. Generation of this waste began in March 1987. This 807 sludge is the same as the IDC 7 sludge generated using the bypass system. This analysis does not include the IDC 807 cemented incinerator sludge from Building 771, generated from November 1985 to March 1987.)

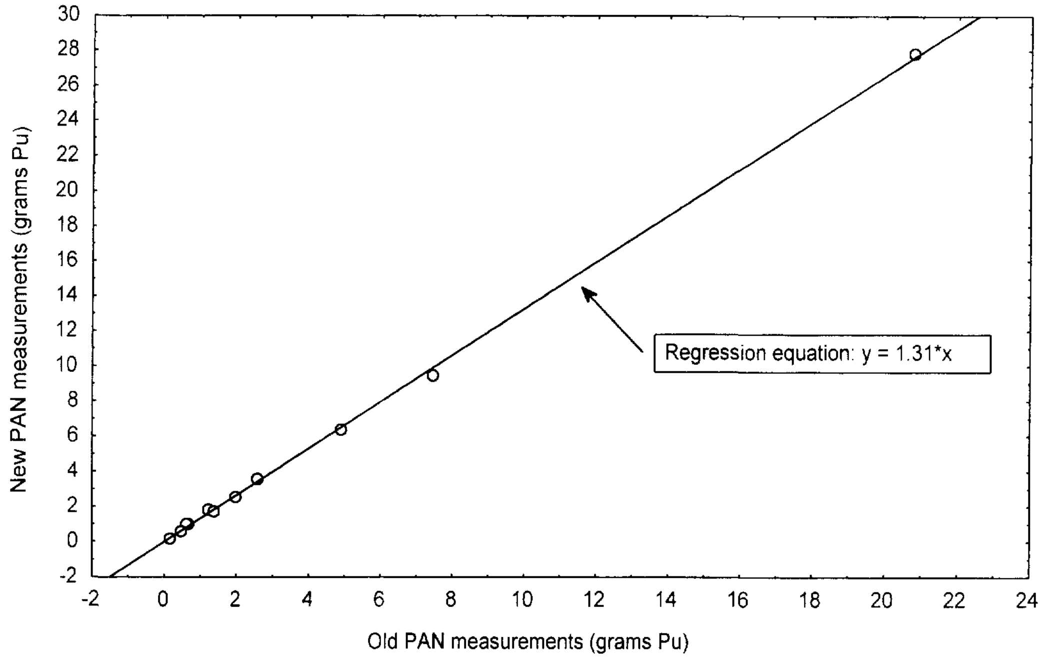

Figure 1. Comparison of PAN system measurements before and after software and hardware system changes

6.1 *PAN Measurements*

Data on the PAN measurements for each of the 125 drums in the uncertainty analysis were obtained from the PAN historical database. Since the time the PAN measurements on these drums were obtained, changes in the PAN system have been made that affect the reported Pu mass values. These changes include installation of new electronic components, incorporation of the shift register passive-counting mode and revision of the zero-matrix calibration factors. Since it is not possible to remeasure the drums once the destructive core sampling has taken place, the original PAN measurement results for the 125 drums were adjusted to reflect the effects of the hardware and software changes. The proper adjustment was determined by comparing PAN measurements taken on a set of uncored sludge drums from the same content codes before and after the changes were implemented. Eleven such drums were selected. Their measured mass values before (old) and after (new) the PAN system changes were implemented are plotted in Figure 1. The reported numbers for the new PAN data are averages of results from two PAN measurement runs on each drum. For the old PAN data, only two drums had replicate measurements that were averaged. The remaining nine drums had only one measurement.

The new PAN data were regressed on the old PAN data using weighted least squares, where the weights were based on the measured counting statistics error as described below. (In the cases where the avérages of replicate measurements were used, the counting statistics errors were propagated to get the error for the average value.)

Let y_i and x_i be the observed new and old measurements (perhaps the average of two replicate measurements) for drum i. Assume that y_i is distributed with mean μ_{yi} and standard deviation σ_{yi}. Similarly assume that x_i is distributed with mean μ_{xi} and standard deviation σ_{xi}. A linear measurement model for the relationship between the old and new PAN results is then

$$\mu_{yi} = \beta_0 + \beta_1\mu_{xi}. \tag{6.1}$$

Letting $\varepsilon_{yi} = y_i - \mu_{yi}$ and $\varepsilon_{xi} = x_i - \mu_{xi}$, the model can be restated in terms of the observed measurements as

$$\begin{aligned} y_i &= \beta_0 + \beta_1(x_i - \varepsilon_{xi}) + \varepsilon_{yi} \\ &= \beta_0 + \beta_1 x_i + \varepsilon_{yi}^* \end{aligned} \tag{6.2}$$

where

$$\varepsilon_{yi}^* = \varepsilon_{yi} - \beta_1\varepsilon_{xi}\,. \tag{6.3}$$

Now the variance of y_i is

$$\begin{aligned} \mathrm{var}(y_i) &= \mathrm{var}(\varepsilon_{yi}^*) \\ &= \beta_1^2\sigma_{xi}^2 + \sigma_{yi}^2\,. \end{aligned} \tag{6.4}$$

Since $\mathrm{var}(y_i)$ changes from one drum to another, a weighted least squares analysis is appropriate. The weights are estimates of $1/\mathrm{var}(y_i)$. The squares of the measured counting statistics errors (or propagation of those errors for cases where replicate measurements are involved) are used to estimate σ_{xi}^2 and σ_{yi}^2. Since β_1 must be estimated from the regression analysis itself, an iterative process is used. An initial value of 1.0 is used for β_1 to calculate the weights. This produces a corresponding least squares estimate of β_1 in the regression. This new regression coefficient is used to recalculate the weights, and the least squares analysis is repeated. These iterations continue until the estimates of β_1 converge.

The weighted least squares regression of the new PAN values on the old PAN values showed the intercept to be not statistically significant ($p = 0.31$) so that term was eliminated from the model. The final regression equation was

$$\text{new PAN Value} = 1.31 * \text{old PAN value}. \quad \textbf{(6.5)}$$

The bulk of the difference in the two sets of values is attributable to the change made in the zero-matrix calibration coefficients for the PAN active-mode measurements. (The ratio of the new-to-old coefficients is 1.26.) Equation 6.5 fits the data very well, explaining 99.9 percent of the variability in the new PAN values. The standard error of the 1.31 adjustment factor is 0.037.

Using Equation 6.5, the old PAN measurements for the 125 drums used in the uncertainty analysis were adjusted to reflect the measurements that would have been obtained after the changes in the PAN system had been implemented. These adjusted data values are used in all subsequent uncertainty calculations. The standard error of the adjustment factor is propagated along with other parameter estimate errors in calculating the final uncertainty value below.

6.2 *Radiochemical Analysis Results*

A minimum of two cores was planned from each of the 125 waste drums used in the uncertainty analysis. For one drum, multiple drilling attempts produced only one usable core. For one other drum, three cores were taken. Coring locations for each drum were selected at random from seven possible ports using a template placed over the drum prior to coring. Once the cores were removed from the drum, a slice of the recovered material, running the full length of the core, was obtained and homogenized. One aliquot was randomly sampled from each homogenized core slice and sent to the lab for analysis. An additional aliquot was obtained from some of the cores for quality assurance purposes.

The analytical laboratory reported data for each drum sample in terms of activity (pCi per gram) for Am-241, Pu-238 and Pu-239. However, the isotope labeled as Pu-239 by the laboratory actually represented the sum of Pu-239 and Pu-240. To get a single activity value for each drum, the Pu-239 + Pu-240 data for samples from a particular drum were averaged first across replicates for each core and then across cores. Standard errors for the drum activity values were also calculated (based on the between core standard deviations in the drum).

The drum activity values were converted to Pu mass quantities using the formula

$$M_{Pu} = (W \times A \times 10^{-12}) / [(SA_{Pu\text{-}239})(MF_{Pu\text{-}239}) + (SA_{Pu\text{-}240})(MF_{Pu\text{-}240})] \quad \textbf{(6.6)}$$

where:

M_{Pu} = drum plutonium mass (g);
W = drum weight (g);
A = average activity from the drum core samples (pCi/g);
$SA_{Pu\text{-}239}$ = Pu-239 specific activity;
$MF_{Pu\text{-}239}$ = Pu-239 mass fraction in weapons-grade plutonium;
$SA_{Pu\text{-}240}$ = Pu-240 specific activity;
$MF_{Pu\text{-}240}$ = Pu-240 mass fraction in weapons-grade plutonium.

Errors in the mass fraction and drum concentration values were propagated to give the error in the total Pu mass value. (The drum mass was assumed to be known without error since its uncertainty is negligible compared to the other components.) These data were then compared to the PAN measurement values for total plutonium.

7. Uncertainty Analysis

The total Pu mass, as determined by radiochemistry analysis, and the corresponding PAN measurements for each of the 125 drums in the uncertainty analysis are plotted in Figure 2. The line of perfect agreement specified in the plot (the solid line) indicates where the data would fall if there were no measurement bias or precision error. The second line in the plot (the dashed line) is a regression line fit to the data using the method described below. The regression line indicates the degree of bias in the PAN system. That the regression line (and most of the data) fall above the line of perfect agreement indicates that the PAN Pu measurements are biased low compared to the confirmatory radiochemistry results. The degree of scatter in the points about the regression line is an indicator of the degree of precision in the measurements. Since both the PAN system and radiochemistry data are subject to precision error, the precision of the PAN system must be estimated by the decomposition of variance components in the regression model. The appropriate treatment of the variance components is determined by consideration of measurement models in the next section.

7.1 *Measurement Models*

Let ξ_η be the theoretical mean of the PAN measurements of all drums in the waste population of interest that contain η g Pu. If the PAN system is unbiased, $\xi_\eta = \eta$. If there is constant and/or relative bias in the PAN system then the relevant model is

$$\eta = \alpha + \beta\xi_\eta \quad \textbf{(7.1)}$$

where α is the constant bias effect and β is the relative bias effect. If $\alpha \neq 0$ and $\beta = 1$, then there is a constant bias in the measurement system. If $\alpha = 0$ and $\beta \neq 1$, then there is constant relative bias in the system. It is also possible to have both constant and relative bias terms at the same time. To estimate the

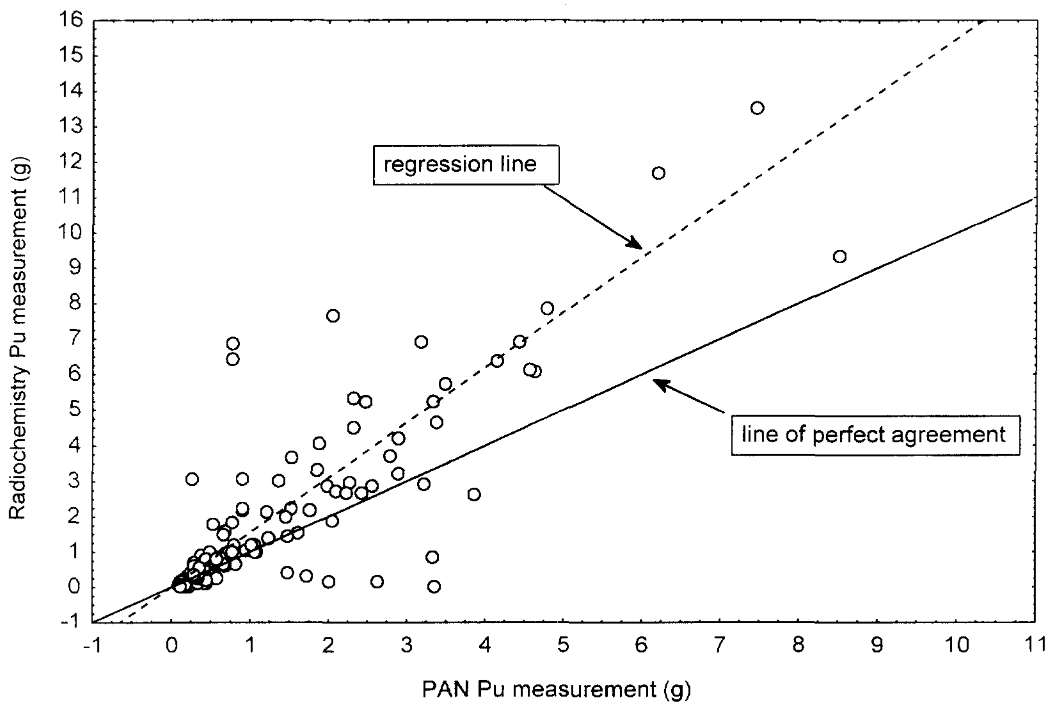

Figure 2. Comparison of PAN and radiochemistry Pu measurement results

bias terms as well as address the precision error in the PAN system, we need to compare the measured Pu values from the PAN system and the radiochemistry data.

The observed PAN measurement for a randomly selected drum from those containing η g Pu is equal to the theoretical mean ξ_η plus random errors due to matrix effects and counting statistics. That is, if x_i is the PAN measurement for drum i and η_i the true Pu value for drum i then

$$x_i = \xi_{\eta i} + \delta_{mi} + \delta_{ci} \quad \textbf{(7.2)}$$

where δ_{mi} is the matrix effect of drum i, δ_{ci} is the counting statistics error from the PAN system, and

$$E(\delta_{mi}) = E(\delta_{ci}) = 0 \quad \textbf{(7.3)}$$

$$Var(\delta_{mi}) = \sigma^2_{mi} \quad \textbf{(7.4)}$$

$$Var(\delta_{ci}) = \sigma^2_{ci}. \quad \textbf{(7.5)}$$

E(.) and Var(.) are the expected value and variance of the indicated terms. The *i* in the subscript of the σ^2 terms indicates that the variance values can change from drum to drum. (Below we show that the error variances can be modeled as functions of the measured Pu quantity in the drum.)

Since the radiochemistry data are unbiased but measured with error, the measured radiochemistry value for drum i is the true value plus a random measurement error term, i.e.,

$$y_i = \eta_i + \delta_{ri} \quad \textbf{(7.6)}$$

$$E(\delta_{ri}) = 0 \quad \textbf{(7.7)}$$

$$Var(\delta_{ri}) = \sigma^2_{ri}. \quad \textbf{(7.8)}$$

The measurement error in the radiochemistry value for drum i, δ_{ri}, comprises all the error in the radiochemistry data (e.g., analytic error and core-to-core variability in the radiochemistry measurements).

A measurement model relating the radiochemistry data to the PAN data from which bias and precision estimates can be obtained via regression is created by first replacing the η_i term in Equation 7.6 with Equation 7.1:

$$y_i = \alpha + \beta\xi_{\eta i} + \delta_{ri}. \quad \textbf{(7.9)}$$

Next, solve for $\xi_{\eta i}$ in Equation 7.2 and substitute into Equation 7.9 to get

$$\begin{aligned} y_i &= \alpha + \beta(x_i - \delta_{mi} - \delta_{ci}) + \delta_{ri} \\ &= \alpha + \beta(x_i) + \delta_{ri} - \beta(\delta_{mi} + \delta_{ci}) \\ &= \alpha + \beta(x_i) + \varepsilon_i \end{aligned} \quad \textbf{(7.10)}$$

where

$$\varepsilon_i = \delta_{ri} - \beta(\delta_{mi} + \delta_{ci}). \quad \textbf{(7.11)}$$

The model in Equation 7.10 is in terms of the observed PAN and radiochemistry measurements so estimates of α and β can be obtained using statistical regression analysis techniques. Since the residual values (the differences between actual and predicted y_i values) from this regression are estimates of the ε values, the residuals, along with additional information, can be used to obtain precision component estimates.

7.2 *Bias*

A regression analysis was performed to estimate the parameters α and β in Equation 7.10. Since the variability of the data increases with increasing Pu quantity (see Figure 2), a weighted least squares analysis was performed.[9] Ideally, the weights used in the analysis should be $1/\sigma_x^2$ where σ_x is the standard deviation of ε for a given value of x. True values of σ_x are unknown but can be estimated by estimating ε, since $s_x = |\varepsilon|$ is an estimate of σ_x.

Equation 7.11 cannot be used to estimate ε. While we have estimates of two of the needed components for each drum, the radioassay measurement error δ_{ri} and the PAN counting statistics error δ_{ci}, independent estimates of the remaining two components β and δ_{mi} are not available. Hence, both the weights and the regression coefficients were estimated by the following iterative method.

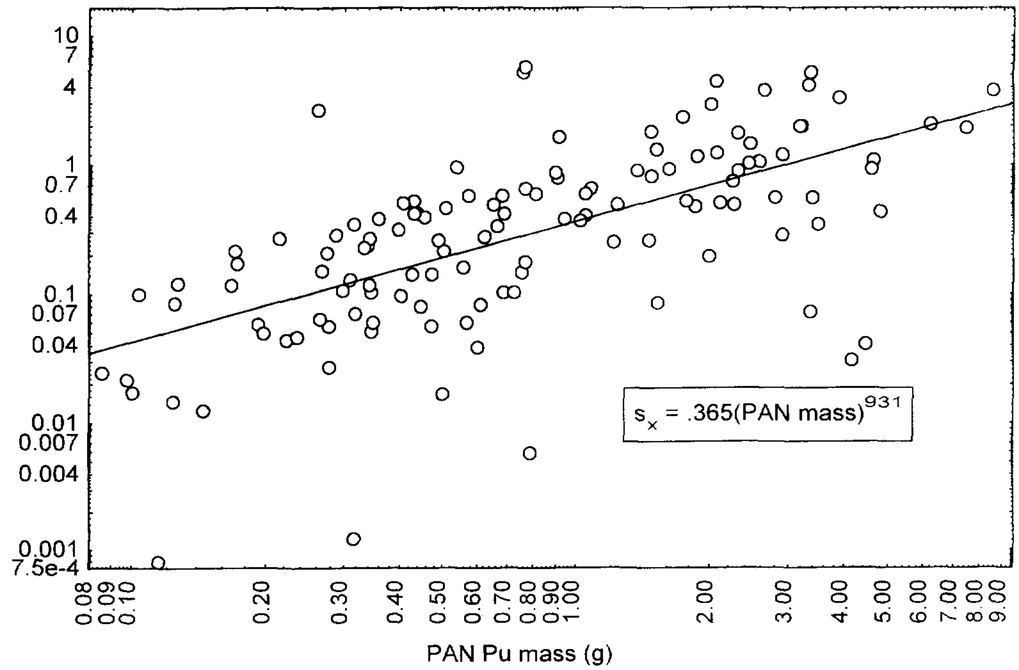

Figure 3. Final weight function used in the weighted least squares regression of the radiochemistry results on the PAN results

7.2.1 Weighted Least Squares Estimation

In the first iteration of the weighted least squares analysis, the weights were all set to 1.0 (i.e., an ordinary least squares analysis was performed). To obtain new weight estimates, the estimated values of α and β from this regression were first substituted into Equation 7.10. Solving for ε_i and taking absolute values gives the new s_x value for each of the x_i data points. While each of the s_x values is an estimate of the corresponding σ_x value, taken individually they are highly inaccurate estimates. Better estimates of the weights can be obtained by considering the whole set of s_x estimates in terms of their relationship to the PAN measured mass values. A scatterplot of the s_x values and the measured PAN mass values showed the relationship to be linearly increasing on a log-log scale. A numerical estimate of this increasing relationship was obtained by regressing the logarithms of the s_x values on the logarithms of the PAN mass values. New estimated values for s_x obtained from this regression equation were then squared and, after taking reciprocals, used as weights in the second iteration of the weighted least squares analysis. This yielded new estimates of α and β, from which new estimates of the ε_i could be obtained. This iterative process was repeated until the estimates of α and β and ε_i did not change in the first three significant digits.

The final equation used for calculating s_x and hence the weights in the final iteration of the weighted least squares analysis was

$$s_x = 0.365\ (\text{PAN Pu mass})^{0.931}. \qquad (7.12)$$

The data from which this equation was obtained via regression analysis are plotted in Figure 3.

7.2.2 Weighted Least Squares Analysis Results

The weighted least squares analysis for the measurement model in Equation 7.10 produced an estimate for α that was not significantly different from zero, so that term was dropped from the model. The estimated value for β is $\hat{\beta} = 1.55$ with a standard error of 0.128. To check the adequacy of a linear model for the data, a quadratic term was also tested. The quadratic term was not statistically significant ($p = 0.48$), indicating the linear model is sufficient to represent the data. Therefore, the only applicable bias term is the relative bias term β. That is, the model relating the PAN system measurements to the radiochemistry results is simply

$$y = \beta x \qquad (7.13)$$

which is estimated as

$$y = 1.55x. \qquad (7.14)$$

Under the assumption that the radiochemistry data are unbiased, Equation 7.14 becomes an expression for quantifying the bias in the PAN system.

While the standard error of $\hat{\beta}$ from the weighted least squares regression is 0.128, the total uncertainty in estimating y also includes the uncertainty in the correction factor applied to the PAN data prior to the analysis as described in Section 6.1. The uncertainty in the correction factor is, however, not included in the regression standard error of 0.128 for $\hat{\beta}$.

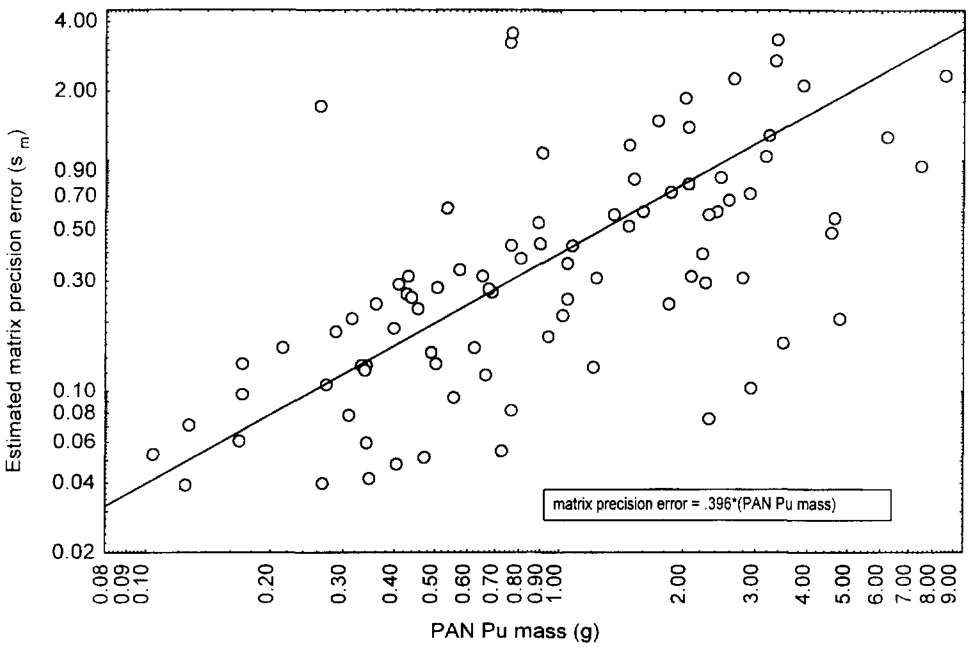

Figure 4. Estimated matrix precision error as a function of PAN Pu mass

How that error should be propagated into the error for $\hat{\beta}$ is described below.

First, note that x in Equation 7.13 is the estimated "new PAN value" obtained from the "old PAN value" via the correction factor derived in Section 6.1. Thus Equation 7.13 can be restated as

$$y = \beta * \text{new PAN value} \tag{7.15}$$

$$= \beta * \delta * \text{old PAN value} \tag{7.16}$$

$$= \gamma * \text{old PAN value} \tag{7.17}$$

where δ is the correction factor from Section 6.1 and $\gamma = \beta * \delta$. Performing a regression to estimate γ in Equation 7.17 is the same as the regression for estimating β in Equation 7.13, except for the constant correction factor δ applied to the data. The estimated correction factor was $\hat{\delta} = 1.31$, so the regression estimate of γ in Equation 7.17 is

$$\hat{\gamma} = \hat{\beta} * \hat{\delta} \tag{7.18}$$

$$= 1.55 * 1.31 \tag{7.19}$$

$$= 2.03. \tag{7.20}$$

The standard error of $\hat{\gamma}$ is 1.31 * 0.128 = 0.168. (The error in the estimate of 1.31 is not applied here because we are just backing out the constant to get the results in terms of the old rather than new PAN data.)

From Equations 7.18 we can get a new expression for $\hat{\beta}$ from which its total uncertainty, including that due to the correction factor $\hat{\delta}$, can be calculated. We have

$$\hat{\beta} = \hat{\gamma} / \hat{\delta} \tag{7.21}$$

Applying standard propagation of errors to Equation 7.21, the standard error of $\hat{\beta}$ is calculated as

$$s_{\hat{\beta}} = \sqrt{\{(\hat{\gamma} / \hat{\delta})^2[(s_{\hat{\gamma}} / \hat{\gamma})^2 + (s_{\hat{\delta}} / \hat{\delta})^2]\}} \tag{7.22}$$

where $s_{\hat{\gamma}}$ and $s_{\hat{\delta}}$ are the estimated standard errors for $\hat{\gamma}$ and $\hat{\delta}$ obtained from the previous regression results. Substituting in the values for the variables in Equation 7.22 gives $s_{\hat{\beta}} = 0.136$.

Thus, under the assumption that the radiochemistry data are unbiased, applying a correction factor of 1.55 to PAN system measurements of aqueous sludge waste will yield an expected bias of zero with standard error 0.136. An approximate 95 percent confidence interval for the true relative bias of PAN measurements after the adjustment is (-27%, 27%).

7.3 *Matrix Precision Error*

An expression for calculating matrix precision error can be found by calculating the variance of both sides of Equation 7.10 and solving for the matrix precision error. This gives the precision error as

$$\sigma_{mi} = \sqrt{[(\sigma_{\varepsilon i}^2 - \sigma_{ri}^2 - \beta^2\sigma_{ci}^2) / \beta^2]} \tag{7.23}$$

where $\sigma_{\varepsilon i}$ is the residual standard deviation (i.e., the standard deviation of the ε values) and all the other terms are defined as before.

From Equation 7.23, estimates of the matrix precision error can be calculated using reported radiochemistry measurement error values to estimate σ_{ri}, PAN reported counting statistics error values to estimate σ_{ci}, and estimates of β and $\sigma_{\varepsilon i}$ produced in the weighted least squares regression above.

Matrix precision error is related to the mass of Pu in the drum, as can be seen in Figure 4, which plots the calculated matrix precision error terms as a function of the PAN Pu mass. A weighted least squares regression was applied to the matrix precision error data, resulting in the following formula for estimating the matrix precision error:

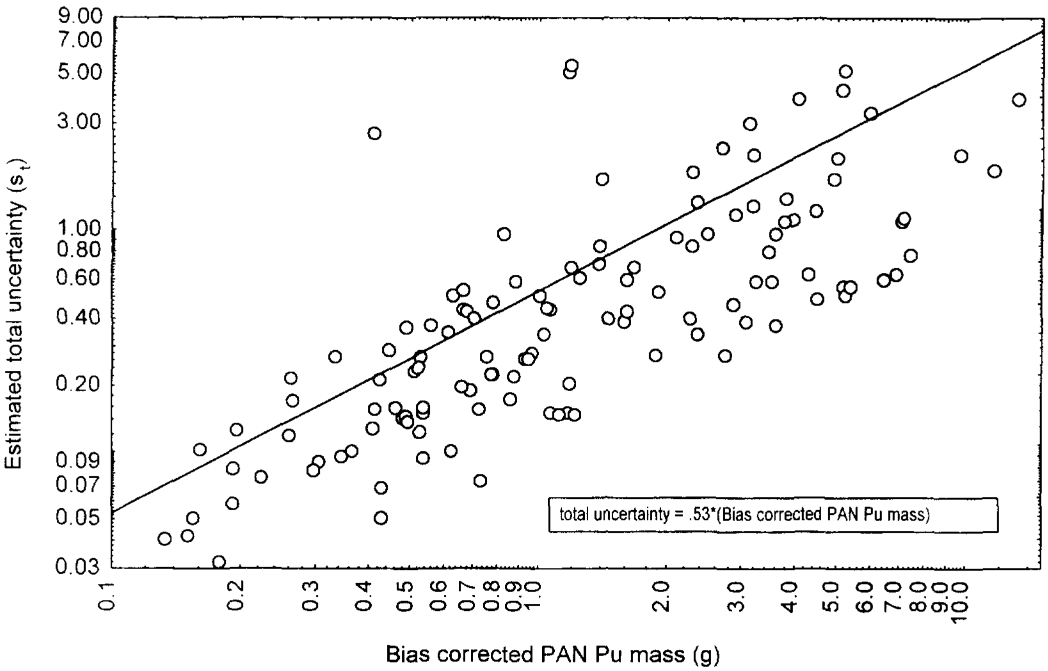

Figure 5. Estimated total uncertainty as a function of bias-corrected PAN Pu mass

$$s_m = 0.40 * (\text{PAN Pu mass}). \quad \textbf{(7.24)}$$

(The data in Figure 4 are plotted using logarithmic scales for clarity. However, the weighted least squares regression was performed on data expressed in the original scales. Negative error estimates were set to zero for the analysis.)

Equation 7.24 indicates a relative matrix precision error of approximately 40 percent. It should be noted that the regression fit is affected somewhat by several high uncertainty values. If the relative matrix precision error is calculated for each of the 125 individual drums, the mean value is 0.43, which agrees closely with the regression parameter estimate of 0.40. However, the median relative uncertainty value is 0.16, a considerably lower value.

7.4 *Total Precision Error*

Total precision error, σ_p, is comprised of the matrix precision error and the counting statistics error. For a given PAN measured mass, the total precision error (expressed as a standard deviation is) is

$$\sigma_p = \sqrt{(\sigma_c^2 + \sigma_m^2)}. \quad \textbf{(7.25)}$$

Substituting the values for the matrix error estimated in previous section gives the estimated total precision error as

$$s_p = \sqrt{(s_c^2 + s_m^2)} \quad \textbf{(7.26)}$$

where s_c is the PAN reported counting statistics error and s_m is the matrix precision error. (For the analysis in this report, matrix precision error as calculated by Equation 7.23 is used. In general, Equation 7.24 must be used for PAN system reporting because the radiochemistry information needed for applying Equation 7.23 is not available.)

7.5 *Total Uncertainty*

To estimate the total uncertainty in a bias-corrected PAN measurement for aqueous waste, consider propagation of error in the bias-corrected Pu mass formula given in Equation 7.14. That equation was

$$y = \hat{\beta}x \;= 1.55x \quad \textbf{(7.27)}$$

where x is the PAN mass value before bias correction and $\hat{\beta}$ = 1.55 is the bias correction parameter determined by the weighted least squares analysis.

Acknowledging that both the measured Pu mass x and $\hat{\beta}$ have associated precision error, applying standard propagation of errors to Equation 7.13 gives the estimated total uncertainty in a bias-corrected measurement as

$$s_t = \sqrt{(1.55^2 s_p^2 + 0.136^2 x^2)}, \quad \textbf{(7.28)}$$

where s_p is the total precision error for the PAN measurement and 0.136 is the standard error of $\hat{\beta}$ as derived in Section 7.2.

The calculated total uncertainty in the bias-corrected PAN Pu mass for each of the 125 aqueous waste drums is plotted in Figure 5. The uncertainty is plotted as a function of bias-adjusted mass. A weighted least squares analysis was performed on the data to obtain a regression line for the data. (The data are plotted on a log-log scale for clarity. However, the regression was performed on the data in their original scales.) The fitted regression line is

$$\text{total uncertainty} = 0.53\ (\text{bias-corrected PAN Pu mass}) \quad \textbf{(7.29)}$$

indicating a total error approximately half the measured value. It should be noted that the regression fit is affected somewhat by several high uncertainty values. If the relative error is calculated for each of the 125 cases, the mean value is 0.50, which agrees closely with the regression parameter estimate of 0.53.

However, the median relative uncertainty value is 0.30, a considerably lower value.

It should be noted that Equation 7.29 was included in this section as a means of summarizing the overall trend in total uncertainty. It should not be used to calculate and report total uncertainties for individual drum measurements. For individual drums, the total uncertainty should be based on the specific drum measurements (i.e., the value from Equation 7.28).

Table I. Comparison of QAPP QAO limits for bias to calculated 95-percent bounds for bias in PAN measurements of aqueous sludge.

Nominal Compliance Point (g Pu)	Allowable lower bound for total bias (%)	Allowable upper bound for total bias (%)	PAN lower bound for total bias (%)	PAN upper bound for total bias (%)
.1	25	400	73	127
1.0	35	300	73	127
10	67	150	73	127
160	67	150	73	127

8. Summary and Discussion of Results

This report describes the results of a total uncertainty analysis of the PAN system's active-mode measurements of aqueous sludge waste (item description codes 1, 2, 7, 800, 803 and 807). The uncertainty analysis was performed by comparing PAN system active-mode results to radiochemistry results for 125 aqueous sludge drums. The radiochemistry data were obtained from core samples of the waste drums. Bias in the PAN system was estimated by regression of the radiochemistry results (assumed to be unbiased) on the PAN measurements. Precision of the PAN measurements was assessed by examination of the variance components associated with the regression.

Analysis of the results for the 125 aqueous waste drums indicates that a bias-correction multiplier of 1.55 should be applied to the PAN aqueous sludge measurements. Without this correction, the PAN measurements are biased low by 35 percent relative to the radiochemistry measurements.

The total uncertainty (expressed as a relative standard deviation) for the PAN measurement of a typical drum was found to be approximately 53 percent, based on a regression analysis. However, the median value for the relative total uncertainty in the 125 cases was only 30 percent. (For reporting purposes, the total uncertainty for each drum will be determined individually and may be higher or lower than these typical values.)

Using the results of this evaluation, we can make comparisons with quality assurance objectives as established in Table 9-1 of the TRU Waste Characterization Quality Assurance Program Plan (U.S. DOE, 1996). The parameter of interest in this table is "Total Bias," which is what has been evaluated in this report. QAOs are given for four different levels of total alpha activity or the equivalent quantity of weapons-grade Pu.

If the 1.55 estimated bias correction is applied to PAN measurements of aqueous sludge, the mean bias will be 0. Equation 7.22 establishes the uncertainty in the total bias in the PAN Pu measurements. Based on the calculated standard error of 0.136, approximate 95 percent confidence interval bounds for the true Pu mass after the bias correction is applied are $0 \pm 27\%$ of the actual Pu mass being measured. That is, the confidence bounds on the true value are 73 percent and 127 percent.

Table I gives the bias limits for the four different Pu mass levels specified in the QAPP and compares them to the QAPP QAO limits. Since the bias correction is proportional to the measured Pu mass, the relative bounds on the PAN measurements are the same for all four compliance point levels. The relative bias error bounds for the PAN system compare favorably to the QAPP requirements.

In order to be critically safe, there is a safety limit requiring that the measured Pu mass plus two times its standard error must not exceed 200 g. Based on the average total uncertainty calculations derived in this report, the measured mass must be below approximately 97 g in order to meet this criterion for drums containing aqueous sludge waste. However, if the median total uncertainty value is used, the limit is increased to 125 g. These summary mass values are only rough indicators of limits on shippable quantities, as the actual upper limits will be calculated individually for each drum. In any case, the 200 g shipping limit is not likely to be an issue for sludge wastes as these drums typically contain only small quantities of Pu (i.e., < 10 g).

Acknowledgments

The authors would like to acknowledge the support of others who have made significant contributions to the production of this report. L.V. East and C.R. Hoffman developed the data files and data listings containing the results of the PAN measurements pertaining to the aqueous sludge measurements. L.A. Van Ausdeln and C.V. McIsaac served as technical reviewers. G. Twedell is the physics support technical leader at SWEPP. and the authors would like to thank him for his assistance in obtaining the PAN assay data used in this project. D.E. Menkhaus is the project sponsor, and the authors would like to thank him for his support and encouragement during the course of this evaluation.

This document was prepared for the U. S. Department of Energy Office of Environmental Restoration and Waste Management under DOE Idaho Operations Office Contract DE-AC07-94ID13223.

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Technical Issues and Organizational Demands for Combating WMD Proliferation

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Abstract
The proliferation of weapons of mass destruction currently represents one of the greatest threats to international security. Just as the threat of "loose nukes" exemplifies a risk that cannot be countered via sole reliance on traditional safeguards, the threats exemplified by chemical and biological weapons proliferation require the formulation of strategies focused on prevention and preparedness. The emerging international security environment is characterized by overlapping objectives of persons involved in the formulation, implementation and verification of international regimes to counter these threats. Such overlapping objectives create redundancy in effort unless persons involved in nonproliferation initiatives are afforded sufficient opportunities to discuss their concerns and exchange information. This paper discusses four interrelated strategies aimed at countering the WMD proliferation threat and addresses the need for coordination among persons involved in developing and implementing these strategies. These include: (1) denying or controlling access, (2) detection and interdiction, (3) crisis management and (4) consequence management. These four strategies will be discussed in detail for nuclear, chemical and biological threats in order to assess the technical issues involved in effectively implementing such measures. The paper outlines the strengths and weaknesses of current technical capacity in countering the threat and offers guidelines for the further technical developments essential to the effective implementation of prevention and preparedness strategies. The paper further argues that in the formulation of coherent approaches for mitigating proliferation threats there is a need for a forum that brings scientists and policy makers in the nonproliferation arena together to exchange ideas, discuss technical issues and foster greater awareness of their common objectives and concerns.

Introduction
In response to the emerging threat of the proliferation of weapons of mass destruction, policy decisions in recent years center on achieving capabilities to counter those threats, both on the battlefield and in civilian settings. International regimes represent the first best solutions at the international level in attempting to control access to or production of the materials requisite to attainment of WMD capability. Whereas materials control and accounting largely succeeded in assuring restricted acquisition of nuclear materials for nonpeaceful objectives, and similar approaches are contained in the nonproliferation regimes for chemical and biological weapons, increasing awareness of the difficulty in controlling access in the latter two types of weaponry leads to heightened focus on counterproliferation efforts.

* Elizabeth Turpen's contribution to this article was not performed in her official capacity as a legislative assistant in the U.S. Senate. This article is not to be construed as a statement of policy or a political position of Senator Domenici.

Countering WMD proliferation threats encompasses four interrelated strategies. These are: (1) denying or controlling access, (2) detection and interdiction, (3) crisis management and (4) consequence management. Perhaps more than any other security concern, this threat necessitates coordination among persons involved in developing and implementing these strategies. While international organizations such as the International Atomic Energy Agency and the Organization for the Prohibition of Chemical Weapons fulfill the operational tasks of verifying treaty compliance, domestic agencies are responsible for ensuring civil protection against the rogue state or terrorist organization with the capacity to use WMDs to inflict, if not "mass destruction," at least sufficient panic or injury to achieve short-term success. This discussion will focus more on the technical issues of domestic measures of prevention and preparedness in response to the perceived emerging threats. These strategies will be evaluated in order to assess the technical issues of implementation. An evaluation of the current technical capabilities to counter such threats will delineate the needs for further technical developments in achieving effective response. Regardless of the technical prowess attained, the formulation of coherent approaches for mitigating proliferation threats inherently involves in-depth coordination between first responders, scientists and policy makers to overcome technical barriers and organizational impediments as well as to foster greater awareness of their common objectives and concerns.

Domestic Prevention and Preparedness

In 1996, the Defense Against Weapons of Mass Destruction Act of 1996 gave the Federal Bureau of Investigation, in conjunction with other agencies, the lead for those measures focused on detection and/or interdiction. The FBI is also responsible for crisis managment, including resolving a hostile situation, investigating the incident and preparing the case for prosecution. The Federal Emergency Management Agency is the lead federal agency charged with responsibilities of consequence management. FEMA coordinates federal activities in support of state and local governments to protect public health and safety, restore essential federal services and offer emergency relief.

With enactment of Nunn-Lugar-Domenici legislation, the Department of Defense was charged with the responsibility of establishing the Domestic Preparedness Program. This program's objective is to enhance the capability of the federal government to prevent or respond to terrorist incidents involving WMDs as well as to improve state and local emergency response capabilities for nuclear, biological and chemical (NBC) threats and potential consequences. The bulk of the course materials and equipment made available to domestic responders clearly targets crisis and consequence management capabilities. The DOD's role in prevention assumes that awareness training is a necessary and not inconsequential aspect in attaining prevention objectives.[1] Under this training program, selected cities receive an equipment set that includes four categories of devices: protective, detection and decontamination equipment, and training kits.[2] This program has focused on training the trainers in order to maximize its impact. Thus far, 9,000 individuals in 27 cities have received training. The program plans to have conducted training in 120 cities by the year 2001.

In even a cursory overview of current activities, the degree of focus on consequence and cleanup evidences the technical and organizational issues involved in countering a WMD attack. In short, the lack of remote detection and identification capabilities puts the emphasis on postdiffusion or postdetonation mitigation of damage. This is particularly true with respect to biological threats. These issues will become clearer in the discussion of the nature of NBC agents and the current status of technology.

Technologies for Detection and Response

Prevention of an attack will most probably hinge on intelligence capabilities, whether its origins are domestic or international. The fact that the Aum Shinrikyo had yet to attract the attention of U.S. intelligence agencies prior to its chemical assault on the Tokyo subway indicates a substantial deficit in our earlier awareness and understanding of the potential threat of NBC terrorism. An intelligence failure necessitates effective crisis and consequence management. This, in turn, is heavily contingent on detecting an attack early on and achieving sufficient agility in the response so as to mitigate damage or injury. The technical issues of counterproliferation involve comprehending the nature of different agents and how delivery or dissemination is impacted by other circumstances for different NBC agents. The following overview attempts to briefly summarize these complexities and extrapolate from these to the technical issues involved in providing adequate capabilities to counter these threats. Biological and chemical threats will be examined more closely based on probability factors and emphasis on these threats in the Domestic Preparedness Program itself.

Nuclear

As human senses do not respond to ionizing radiation, special instrumentation must be used for radiation detection and measurement. The hazard from radiation depends on the type of radiation, its energy spectrum and the quantity to which one is exposed. Thus, qualitative and quantitative measurement capabilities are required of radiation detectors used in the field. No single instrument at present incorporates all the necessary characteristics for comprehensive evaluation of different types of radiation hazards. The Pocket Radiac and Radiac sets represent state-of-the-art, portable radiation detection equipment.[3] Although not ideal, achieving these detection capabilities would have required a suite of devices just a few years ago. Improvements are still necessary in measuring dose rate in units directly applicable to the tissue of concern; responding to only one kind of radiation at a time; having sufficient sensitivity and accuracy, independent of the energy of the radiation; being free of extraneous effects from immediate environmental or weather conditions; and having a means of field checking operability.

It is important to note that meteorological conditions greatly

Table I. Characteristics of biological agents.

Agent/Disease	Dissemination	Transmissibility (b/t persons)	Infectivity	Incubation period	Duration of illness
Anthrax Plague (pneumonic)	Spores in Aero 1. Aerosols 2. Infected Vector	No No	Moderate High	1-6 days Days to months	3-5 days 1 or more weeks
Smallpox	Aerosol	High	High	1-5 days	Days to weeks
Ricin	Aerosol	No		Hours	Days

affect fallout, particularly local fallout. Snow and rain can accelerate local fallout, and rain showers above a radioactive cloud can create areas of heavy contamination.

Biological

The intrinsic features of biological agents related to their utility as weapons include infectivity, virulence, toxicity, pathogenicity, incubation period, transmissibility, lethality and stability. Unlike their chemical counterpart, biological agents have the ability to multiply in the host and increase their impact over time. Biological weapons are most likely to be delivered by aerosol, though other routes are possible. Inhalation through respiratory exposure, ingestion through contamination of water supply, foodstuffs or medicines, and dermal exposure are the most probable routes of entry. Another possibility is live vector (mosquitoes, ticks or fleas) dissemination. Table I offers cursory information on typical biological agents. This table serves to underscore the complexity of detection and difficulties countering this threat.

For better or worse, humans are the most sensitive biodetectors. Detection of a BW attack is difficult due to the prolonged incubation time for most agents and complexity of diagnosis in many cases. At present, a BW attack will most likely be completed before anyone is aware of its occurrence. First responders in this instance are likely to be medical personnel, and any single physician is unlikely to be able to distinguish between the symptoms arising from a biological event and a naturally occurring phenomena. However, if sufficient coordination among medical professionals exists, a BW attack distinguishes itself from an epidemic in several ways. Among other indicators, an artificially induced outbreak will usually be more compressed than a naturally occurring epidemic, and rather than peaks and troughs most common in natural disease outbreaks, a steady and increasing stream of patients is likely.[4]

In countering this threat, medical professionals must maintain routine disease surveillance, and an atypical pattern should trigger immediate notification of authorities and other agencies. Although emerging technology may soon provide provisional diagnostic capabilities locally, specialized laboratory facilities will be required for a definitive diagnosis in most cases. While medical personnel are responsible for the collection and submission of diagnostic materials from patients (blood culture, acute serum, organ tissues), environmental sampling by other agencies is required for corroborating the occurrence of a BW attack. Success in offering a timely and effective response will depend on the rapidity and accuracy of diagnostics in conjunction with timely information from organizations responsible for environmental sampling.

Detection and identification devices for BW defense are evolving and represent a high priority within the research and development community. Three primary detection systems have already been fielded, but these systems are largely applicable to battlefield operations rather than civilian defense operations.[5] As in the case of a physician's diagnosis, the principal technical difficulty in biological agent detection is differentiating between an artificially generated biological cloud and the background of organic matter normally present in the atmosphere.

Small, portable and sensitive detection and identification technologies with adequate range capabilities would enhance first responders' capability to minimize the impact of a biological assault. Effective long-range detection, in conjunction with virtual-reality analysis capability, would buttress our defenses. At present, however, the best available technology for detection by first responders consists of "smart tickets," as identification technologies are neither inexpensive nor particularly portable. Critical to biological defense is adequate training and coordination among health-care professionals themselves as well as real-time communication with intelligence agencies and entities responsible for environmental sampling. As detection equipment evolves, integration into systems providing meteorological and terrain information can further enhance response capabilities.

Chemical

Chemical agents in munitions are liquid, but with the detonation of the munition container, the chemical is dispersed as an aerosol. As chemical agents are volatile by nature, under certain conditions they evaporate, forming an often-invisible vapor. An agent's tendency to evaporate is a factor of its chemical composition, temperature and air pressure, as well as variables such as wind velocity and the underlying surface with which it is in contact. Volatility is related to persistence, and a more persistent agent is a more significant liquid hazard, while less persistent agents create a serious vapor hazard. Persistent agents, such as mustard and VX, are suitable for contaminating an area for an extended duration. Nonpersistent agents, such as sarin and cyanide, are largely more suitable for tactical direct assault due to their quick evaporation.[6] Wind, temperature, rain and atmospheric stability play a significant role in augmenting or diminishing the impact of any given agent.

The concentration of the agent at the time of exposure governs the dose received. Chemical agents are similar to biological in that the routes of entry also include inhalation, ingestion or dermal exposure. They differ from their biological counterparts in that most chemical agents will induce an immediate effect. Subsequently, there is substantially less difficulty in delineating between a chemical attack and a natural occurrence. Nerve agents, vesicants (blister agents), choking agents and vomiting agents all constitute different threats, depending on the conditions under which they are dispersed and the dosage.

While chemical "smart tickets" are widely available for detection or identification of chemical agents after dissemination, the M22 Automatic Chemical Agent Alarm provides a remote continuous air-sampling device with a range limited to 400 m between the alarm units and the detector cells.[7] The system usually consists of the M43A1 detector, up to five alarm units and a variety of power supplies. Detector cells are connected to the alarm units via telephone cable. This unit is slated to be fielded in July 1998. It offers greater sensitivity than its predecessor (M8A1) with significantly less interference. Its disadvantages are that its configuration and wiring requirements are ill-suited for detection in a civilian setting. Although chemical detection instrumentation is well advanced, its cost, portability and reliability make its implementation for first responders largely impracticable. The JCAD, which is slated for fielding this summer and is a small portable device, achieves the same objectives as the M8A1 and could overcome these weaknesses.

Simulation and Modeling Capabilities

In all cases of NBC weapons, the duration, scope and intensity of the danger they may present are subject to the conditions under which they are disseminated. For this reason, a critical aspect of our defense capabilities is the ability to model chemical or biological clouds, levels of airborne activity and contamination conditions at the location during the time of "detonation."

Current technology is capable of detecting only a limited number of agents with multiple point sensors at limited distances (1–5 km for chemical). Digitized data is only available in some cases. Projected advances in five years will achieve increased detection of agents at greater distances with fewer point sensors, greater portability and early-warning detection. Moreover, there will be a significant increase in the availability of digitized data. In 10 years, research and development will realize person-portable biodetection systems, chemical detection at a range of 20 km and real-time data and time-projection access for areas of concern. Fifteen years from now technology could provide integrated person-portable chemical and biological detection and global access to virtual-reality simulations.[8]

It should be noted that the best detection equipment is a primary requirement for mitigation of the potential consequences. However, effective response after detection will rely on coordination and communication among responsible agencies and local first responders. Not solely, but at least partially, the gaps in our technical capability to prevent WMD attacks underscore the need for adequate coordination of intelligence capabilities and awareness at all levels of involvement in responding to these threats.

For radiological, chemical and biological weapons, effective detection inherently must be coupled with capabilities for mapping of agent contamination and clouds in a given area to mitigate potential damage. Mapping and simulation capabilities that incorporate data collected in the field with atmospheric, meteorological and terrain information specific to the area at hand can greatly enhance consequence management capabilities.[9] Technical capabilities for simulation are particularly critical in light of the sensitivity of chemical and biological agents to these conditions. These assumptions dictate the direction of research and development efforts for NBC defense.

Sophisticated technology, however, is only one part of the solution. Effective implementation of the available and next-generation technologies requires more attention to the actual risks and greater coordination among the entities involved in all four strategies to attain counterproliferation capabilities.

Significant advances in detection and identification capabilities must be coupled with miniaturization, digitization and lowered costs for these technologies to make them applicable to the needs of the civilian response community. Digitization of the data gathered makes communications for further analysis of the data feasible and fast.

The Technical Is Organizational

Soldiers confronting WMDs on the battlefield have an impressive array of detection, protection and decontamination technologies. Battlefield scenarios, however, offer specific advantages for technical solutions that are not present in the case of a civilian setting. Vaccines can be administered to soldiers that provide an effective layer of immediate defense; secondly, a battlefield precisely limits the area to be monitored. Nuclear, chemical or biological threats in civilian settings extend to all citizens, and the battlefield — especially for the terrorist — is unlimited. Technology only offers limited solutions in a defined set of circumstances. In many respects, these circumstances are not present for domestic counterproliferation efforts.

Intelligence Needs, Information Analysis and Risk Assessment

International regimes are the first line of prevention in controlling access to weapons materials. Increasingly, however, the threat of terrorist attacks using WMDs controls our perception of domestic security. Controlling access to materials and detection/interdiction efforts are largely the responsibility of intelligence and law enforcement agencies: FBI, CIA, National Security Agency, local police, etc. Real-time communication and analytical tools to facilitate the work of these agencies are available. What is lacking is coordination.

Recent reports on counterproliferation efforts state that analytically sound threat and risk assessment is requisite to making sound policy decision about domestic preparedness investments.[10] Along these same lines, renewed thought is necessary to address the real utility and implementation potential of better instrumentation. Equipment with battlefield applications may be wholly unsuited for first responders in a domestic setting.

Portable, reliable, sensitive and less expensive detection devices will undoubtedly enhance crisis and consequence management capabilities, especially if these devices are integrated with modeling capabilities that afford accurate determination of factors related to dissemination and fallout. Digitization and communications advances make these possibilities readily feasible.

More important, however, is to recognize that many of the technical issues are also organizational. The foremost example is that biological detection requires coordination between individual medical professionals and agencies responsible for environmental sampling in the field. Similarly, intelligence agencies should be constantly involved in risk and threat assessment in order to facilitate the work and minimize the element of surprise for response efforts by other agencies. Evaluation of the threat and risks would not only offer better orientation as to where, when and by what means a terrorist attack might occur, but it would also provide necessary information for deployment of expensive detection assets.

In order to achieve focus in our counterproliferation efforts, policy makers, scientists and field operations personnel must be provided with a forum to discuss both technical and organizational issues. Such opportunities would greatly facilitate understanding of the technical issues confronted at the level of local first responders; simultaneously, policy and organizational concerns of federal, state and local representatives could be addressed. While the Chemical and Biological Defense Command has an excellent track record of incorporating state and local officials in awareness training and formulation of its training course for a specific municipality, only minimal opportunities exist for persons involved in international nonproliferation to coordinate with those involved in the Domestic Preparedness Program. Even more significantly, insufficient fora exist for coordination among agencies responsible for the separate strategies (controlling access, detection/interdiction, crisis management and consequence management) for a layered defense against WMD threats.

Conclusion

Admittedly, the threat is amorphous. Technical achievements can and will continue to enhance the ability to quickly detect and identify agents, as well as offer proficient tools for modeling the potential damaging consequences to be countered. In conjunction with and in implementation of the technical capability, the response involves the engagement and coordination of an inordinate number of private, local, state and federal agencies. Unfortunately, the effort spent on the development of equipment greatly outweighs those focused on achieving adequate cooperation and integration between responsible agencies and independent actors. Risk and threat assessment must rely on a broad base of input at all levels. The direction provided by these analyses can greatly facilitate effective deployment and technical development. It can aid in guiding cooperation among the actors involved. Only through a deliberate combination of reliable and readily employable equipment and streamlined coordination among those responsible for these strategies can the amorphous threat be more clearly defined and counterproliferation efforts attain the desired outcome.

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3. The Radiac Set (AN/PDR-77) can detect and measure nuclear radiation from nuclear accidents and other sources, and it has stable calibration and high reliability. Unlike earlier radiation-detection devices, it can also measure alpha, beta, gamma and low-energy X-ray radiation, while also measuring environmental levels. The Pocket Radiac is a hand-held device capable of measuring prompt gamma/neutron dose from an event, plus gamma dose and dose-rate from nuclear fallout. The Radiac Set AN/PRD-77 has already been fielded and is the first unit to measure an individual's total dose.
4. Other indicators would include large casualties within 48–72 hours, illness type that is unusual for the specific geographic area, illness occurring in an unnatural epidemiological setting, casualty distribution aligned with wind direction and lower attack rates among those working indoors.
5. These are three specific systems: (1) The Biological Integrated Detection System is vehicle-mounted and tests environmental air samples by concentrating on relevant aerosol particle sizes in the air samples and subjecting samples to both generic and antibody-based detection for selected agents. Planned upgrades and expansion of point detection on the BIDS should enhance its capability. (2) The Long-range Standoff Detection System provides a first-time biological standoff detection capability for early warning. It utilizes infrared laser to detect aerosol clouds from a distance of up to 30 km. Development is underway to extend the range to 100 km. This system will be available for fixed-site applications or inserted into various transport platforms such as fixed-wing or rotary aircraft. (3) The Short-range Biological Standoff Detection System employs ultraviolet- and laser-induced fluorescence to detect biological aerosol clouds at distances up to 5 km.
6. "Medical Management of Chemical Casualties," Medical Research Institute of Defense, September 1995, pp. 9–11.
7. Detection papers can identify (M8) or merely detect (M9) the presence of chemical agents. Such papers, which are similar to litmus paper in their application, and simulator detector kits are being made available to first responders through the Domestic Preparedness Program. The alarm draws samples into a cham-

ber and ionizes airborne agent molecules. A detector cell analyzes the resulting ion clusters, comparing their masses and charges with electronically stored standards to detect any presence of nerve agent vapor.

8. Adapted from *Defense Technology Area Plan*, Chapter II "Chemical/Biological Defense and Nuclear." http://www.dtic.mil/dstp/97_docs/dtap/cb/ch0201.html, July 11, 1998, p. 3.

9. The Joint Warning and Reporting Network combines field information from NBC detectors with command-post units housing meteorological and terrain information. Through digitized communications between field detection units and command post analysis capabilities, direction, degree and type of contamination can be quickly evaluated and consequence management can be implemented.

10. Davis, Richard. *Combating Terrorism: Observations on Crosscutting Issues*. USGAO, April 1998, p. 1.

James Brown is the conference chair of the International Arms Control Conference and is a principal member of the technical staff of Sandia National Laboratories. He is also a member of the Institute for Strategic Studies. Brown served as foreign affairs specialist to the director of the U.S. Arms Control and Disarmament Agency. His publications in the areas of arms control and disarmament and civil-military relations are extensive. These include 10 authored and co-authored volumes and more than 35 articles. Brown received a doctorate from the State University of New York at Buffalo.

Steven P. Kadner is president of Aquila Technologies Group. He directs research, development and manufacturing efforts in international safeguards containment and surveillance technologies. Kadner holds a master's degree in mechanical engineering from New York University and also presently serves as vice chair of the United States Industrial Coalition, a group of U.S. companies assisting the U.S. Initiatives for Proliferation Prevention program.

Ann Reisman is head of the International Projects Division of Brookhaven National Laboratory. The IPD supports U.S. policy objectives abroad by providing scientific, engineering and policy expertise to improve the safety of nuclear and fossil energy systems across the international community and by supporting verification of nonproliferation treaty obligations. Since 1977, the International Safeguards Project Office of IPD has administered the U.S. Program of Technical Assistance to IAEA Safeguards, the primary source of technical assistance to the IAEA's Department of Safeguards in Vienna, Austria. The program provides safeguards equipment to the IAEA, as well as assistance in inspector training, development of safeguards implementation and evaluation approaches, data processing and analysis, procedure documentation, and quality assurance.

Before assuming her present position, Reisman served as ISPO liaison officer to the IAEA and was based at the U.S. Mission to the U.N. Organizations in Vienna. Prior to joining ISPO in 1985, she contributed to a series of projects related to energy conservation, energy systems analysis and computer modeling, the most recent as principal investigator of a project to assess the technical and economic feasibility of cogeneration and district heating in the United States. Other projects included participation in the development of energy technology and environmental assessment tools used to support the U.S. national energy plan and energy analyses of International Energy Agency countries. Reisman joined Brookhaven National Laboratory in 1974. She obtained her undergraduate degree from Cornell University and her graduate degree from the University of California at Los Angeles.

Elizabeth Turpen is a legislative assistant for foreign affairs, nuclear issues and defense policy in the office of Senator Pete Domenici. She formerly provided policy analysis for Aquila Technologies Group related to U.S.-Russian initiatives, international safeguards policy and WMD proliferation threats. She holds a master's degree and doctorate in international affairs from the Fletcher School of Law and Diplomacy at Tufts University.

IAEA Photo Surveillance: The First 30 Years

Edward Kerr
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Abstract

This partly anecdotal history of the IAEA's use of photo surveillance is largely the story of the twin Minolta photo unit. It began in a haphazard manner as a stopgap system in the early 1970s and continued developing over the next two decades into a major surveillance program. The Minolta's two predecessors were the ROBOT and the Contarex. Events in 1978 concerning video development are described at some length because they set back the routine use of video surveillance by about 10 years, thus protracting the use of the twin Minolta systems. At their peak, around 1990, these Minolta units were producing approximately 2,000 inspection films per year with an average of about 5,000 frames per film.

The first IAEA surveillance camera was installed in the Bradwell Nuclear Power Station in 1969, just 30 years ago. The camera chosen was produced by ROBOT, a German firm specializing in equipment for bank surveillance. It was a 35mm camera with a fixed aperture and magazine of 2,000 frames. The project was under the supervision of T. Otomo, a Japanese member of the IAEA Department of Safeguards' newly formed Development Division.

The United Kingdom had placed Bradwell under safeguards in 1966 to provide the IAEA with some direct experience with on-power fueled stations. While initial efforts to safeguard this station involved the determination of quantities of plutonium produced for later comparison with the quantities of plutonium recovered from reprocessing, it was nevertheless felt that there should be some means of ensuring that discharged fuel bundles followed the regular route from the reactor charge floor to the spent fuel pond. For this purpose, the camera was installed to survey the charge area on the top of the reactor.

The author in 1971 installing a Contarex camera in one of the units of Tokyo Electric Power Co.'s Fukushima Dai-ichi Nuclear Power Station. Supervising from a lower level is safeguards veteran Cal Solem.

This first photo surveillance attempt was a failure. Without strict measures to control lighting, a fixed-aperture camera cannot do the job. While the lighting appeared to be constant to a short-term observer, there were times when the illumination was reduced to the point where the chosen aperture for the camera was far too small. The need for an automatic exposure-control camera was thus firmly established.

Such a camera was the 35mm Contarex, which was the agency's next choice and was installed in a few Japanese facilities in the early 1970s. Also of German manufacture, this camera had excellent optics and delivered good quality pictures. Its weaknesses were a small magazine (450 frames) and high current consumption. This meant that the interval between camera servicing was, of necessity, short. They were thus limited to short-term applications such as LWR refueling. Still, they were the first cameras to be used in routine safeguards situations.

By 1971, it was recognized that safeguards needed a camera with picture capacities of thousands of frames rather than hundreds, and the only likely candidates were cine cameras running in a single-frame mode. There was also concern about finding a suitable timer to operate a cine camera. Then the Minolta Co. marketed the Intervalometer for adapting their Super-8 cine cameras to time-lapse applications. We thought the problem was solved, and we bought an Intervalometer and one Minolta camera (model Autopak 8 D4) to see how it worked. As it turned out, the Intervalometer used far too much current to permit battery operation for periods of a few months, but all was not lost. Minolta turned out to be the right camera for our needs. The reason that only Minolta marketed an Intervalometer was because, at that time, only Minolta had a solenoid shutter release. So we had chosen the right camera but for the wrong reason, and we still did not have a timer to run it.

In 1972, we discovered a French-made timer called FLASH. It was primarily intended for turning lights on and off unattended, e.g. the lights in a store window that are turned on at dusk and turned off at 10 or 11 p.m. when all the window shoppers have gone home. It was battery-operated and worked on the tuning-fork principle, so it kept accurate time. It was quite large. On its face was a wheel with a diameter of about 10 cm (4 in) that rotated once every 24 hours. There were provisions for attaching clips or riders on the outer edge of this wheel, and these activated a relay by means of a connecting lever as the wheel turned. The riders could be placed as close as five minutes apart, so the interval between frames was some multiple of five minutes. Fifteen-, 20- and 30-minute intervals subsequently became popular.

A circuit to interface the FLASH timer and the Minolta camera was developed by the Development Division and the electronic workshop of the IAEA's Seibersdorf Laboratories, and the first unit was assembled. An agreement was negotiated for its installation in a Japanese facility that was about to shutdown for refueling. (Before NPT, safeguards agreements had no provision for the installation of any equipment, and when the agency did so it was only in cases where the national authority was prepared to be lenient.)

It was September 1972. The inspector in charge of the camera installation was Djali Ahimsa. (Later, he became head of the Indonesian Atomic Energy Agency.) With him was a newly recruited inspector on his very first trip. His name was Leslie Thorne. Ahimsa arrived in Japan on a Thursday evening. On Friday, he set up the camera in his hotel room. In the early hours of Saturday he woke up and wondered what had awakened him. Then he realized that the clicking from the camera had stopped.

There followed a very busy weekend, visiting the Tokyo electronics area in Akaibara, purchasing a test meter, a relay and a soldering iron, and redesigning the interface circuit. The camera and timer with the new interface circuit was installed on schedule on the Monday and functioned satisfactorily.

Back in Vienna, a member of the Development Division, on hearing this story, wrote a memorandum to Operations complaining that the activities performed in Tokyo were not the business of Operations and, further, that the newly designed circuit was not as good as the original because it drew more current. Operations' answer to this possibly set a new record for acrimonious content of an interoffice memorandum. I mention this because it was symptomatic of the relations between Development and Operations at the time. It reflected a conflict that was going on at the top of the management pyramid. Operations felt that Development staff members were totally lacking in any sense of urgency and did not realize that the inspectors needed equipment immediately. When this equipment was not forthcoming, Operations proceeded independently. Both the Contarex and the Minolta camera installations were Operations initiatives.

Development, for their part, felt that Operations was going off half-cocked and was involved in work that was not in their jurisdiction. In this they were perfectly correct. At the time, I was one of the Operations agitators, but I realize today with the benefit of a quarter-century's hindsight that both sides had a fair degree of justification. Operations had no business doing what it did, but, when we review the pitiful efforts of member states support programs to develop a photo surveillance unit, we see that Operations had no choice but to develop a stopgap method.

During 1973 more Autopak 8 D4 cameras went into service, triggered by FLASH timers. One special unit was installed to oversee the whole top area of the Taiwan Research Reactor, with three cameras directed at different locations over the entire fuel-handling area. One of the three cameras failed, but fortunately the cameras' fields of view were wide enough that they overlapped, and so the entire area remained under surveillance.

Thus the twin Minolta unit was born. The incident made us realize that the only way we could get the reliability we needed was through the use of redundant cameras. Admittedly, the practice of installing a second camera in every enclosure did not take place immediately. It was not until 1978 that enclosures were built with two cameras mounted rigidly in parallel, forcing both to have the same field of view. The point that should be noted is that once again, as with the initial choice of camera, the twin-camera photo unit happened largely by accident.

In the next two years there were three more developments. Minolta replaced the Autopak 8 D4 with a new model, the XL400. XL stood for extra low light because these cameras had a lens of f:1.2. This permitted the cameras to operate in practically all facilities without problems of illumination. A wide-angle lens adaptor for the Minolta cameras came on the market, giving them a field of view of over 100 degrees. And Kodak introduced a new thin film, 30 meters of which could be contained in a standard Super-8 film cartridge. (This represented 7,200 single frames in a single cartridge; for standard film it was 15 meters, or 3,600 single frames.) At last, the problem of film capacity was solved for most applications. And a new problem was born: the time and manpower needed to review the photographic record.

As safeguards subject to NPT agreements increased, so did the number of photo installations, and member states' support programs started to take note. While most support programs' surveillance activities were concerned with video, some efforts were directed to photo, presumably wishing to replace the inelegant IAEA units with something a bit more professional. To their surprise, it proved more difficult than it first appeared. One prototype unit came with a field effect transistor and the instructions that the inspector should ground himself by touching a water pipe or whatever before servicing it. Considering that many cameras are in spent fuel stores where staff must wear cotton or rubber gloves, this would not be easy. Another candidate unit came mounted on a heavy wet storage battery that required special handling equipment to raise it into place. Yet another potential successor to the twin Minolta had an enclosure that was defeated in about 30 seconds with a Swiss army knife.

One support program development project that deserved to succeed was that of Karlsruhe. Theirs was a photo unit able to operate in very low light with a capacity of more than 10,000 frames. However, fate dealt the project one setback after another, the worst being that the Austrian firm EUMIG, which built the camera on which the design was based, went out of business.

At this point we will digress for a little bit and talk about video, because events in the mid-1970s had a disastrous effect on the development of video surveillance and extended the use of photo surveillance by about a decade.

The IAEA installed its first video surveillance unit in the mid-1970s. It was built by the electronic lab at Seibersdorf, with the involvement of the Safeguards Development Division. We referred to it as Unit No. Zero.

Video recorders do not record in a sequential manner along the tape as do audio recorders. The high frequency of a video signal would result in tape being transported at impossibly high speed. Instead, the signal is recorded in parallel stripes running diagonally across the tape. When the recorder is first switched on, nothing useful is recorded until the heads which are moved by a mechanism independent from the tape transport mechanism are spinning at the right speed. This was a problem since we wished to make a series of short recordings of a few video frames each.

For Unit Zero, Seibersdorf's solution to the problem was simple and effective. Their circuit delayed switching on the tape transport until the heads were spinning at the required speed. It worked fine. However, the mass production of surveillance units was not the business of the Seibersdorf Laboratory, and so a Viennese firm named Psychotronic was given a contract to manufacture these systems using the Seibersdorf circuit.

What happened next was incredible. In 1978 Psychotronic applied for an Austrian patent on the Seibersdorf circuit. Named as inventors were two members of the Psychotronic staff and the Development Division staff member who was our liason with that company. The agency was at a complete loss. Its legal division, while experts in international law, knew nothing about Austrian patent law. While we were extraterritorial, we did not know how the patent would apply to activities outside IAEA headquarters. Seibersdorf had not documented its circuit sufficiently to contest the Psychotronic patent application. Nothing in the staff rules, unlike most scientific organizations, covered patents and inventions of staff members. There were fears that any conflict between the big IAEA and a tiny Viennese company would be used by the Austrian press, which frequently voiced anti-U.N. sentiments. And the agency staff member in question was a Soviet citizen, which further muddied the waters.

Rather than waiting for the agency to resolve the matter, member states' support programs developed video systems that avoided the Psychotronic patent. The U.S. STAR system reversed the tape after every recording and then, to make the next recording, advanced it again, thus bringing the heads up to speed before laying down video. The effect was not unlike a succession of running broad jumps with the take-off point for one jump being the landing place of the previous jump. A Canadian system, developed for CANDU reactors, recorded a large number of frames on a video disc, then transferred these to tape when the disc was full. A third system, which Euratom developed for its own use, was a cheaper version of the U.S. system.

In retrospect, the Canadian video system was arguably better than the American because it was so impossibly bad that we did not waste a lot of effort and time trying to make it work. Even worse, the preoccupation with bringing the STAR's performance up to an acceptable level deferred the start of efforts to develop a good video system by a number of years.

As a result, instead of the demise of photo surveillance, the 1980s saw the twin Minolta program increase even further, not only in terms of the number of installations but in the activities which supported it.[1]

- The mechanical FLASH timers were replaced with solid-state quartz timers.
- The Department of Safeguards acquired a darkroom with a cine film-developing machine.
- The staff was augmented by two mechanics who were trained by Minolta in cine camera repair. A good supply of spare parts was acquired. Procedures for repair and maintenance were established.
- The inventory was increased to about 1,000 cameras. These were Minolta model XL401, which had replaced the XL400 model in the late 1970s. This inventory included those cameras provided to Euratom to carry out its own photo surveillance program.
- IAEA implemented a Sandia recommendation to make the enclosures from deep-drawn aluminum, anodized inside and out to obtain a high degree of tamper-resistance.
- A compact enclosure designed by Gary Dillon of the Toronto field office was adopted by everyone and later modified for eventual use as a video-camera enclosure.
- We constructed film review stations from 16mm film editors, with computer codes to convert frame numbers to give the date and time when each photo was taken.
- For those locations where we were not allowed to remove the surveillance record from the facility, we put together a simple developing process that produced negative photos. These were projected through a video camera with the polarity reversed to give a positive image.
- Perhaps the most significant step was establishing a good database with a consistent system for classifying surveillance failures.[2] The first classifications were "equipment failure" and "other." Facility lighting was the biggest single contributor to this second category. There were also failures caused by radiation fogging of film, film run-out due to scheduling errors, a few inevitable inspector errors and acts of nature. In this last category was the snowstorm that closed a railway line and prevented the inspector from reaching the facility before the film ran out. There was also the failure caused by a conscientious painter who put a cover over the enclosure so it would not be splattered by paint.

The program reached its peak in 1989. In that year, just over

2,000 inspection films were developed. With an average of 5,000 frames per film, that meant roughly 10 million individual frames. Of course, we only needed to review half of them for safeguards purposes, but all films were given a technical review to determine if the equipment functioned correctly. In that year, the probability of a single camera failure in a two- or three-month surveillance period was 0.1, or 10 percent. The probability of a failure of a two-camera system was the square of this, 0.01, or 1 percent. A reduction of this failure rate by another order of magnitude could have readily been achieved through the use of a third camera, but this would not have been sensible, because the failure rate from "other" causes was about 4 percent.[3]

Today, film usage has dropped to about 1,000 inspection films per year. (In addition, there are films used for camera testing.) Some of these are used in standard twin Minolta units, which are still in regular service. Some are used in three-camera systems with staggered intervals between exposures to increase the time between servicing. (Kodak discontinued the 7,200-frame film some years ago.) And quite a few are used in units that back up video surveillance systems, which are not without reliability problems of their own.

The last of the twin Minoltas will be removed from service in one or two years. They will have been in use for about three decades, which is comparable to the life of telex or IBM cards. All in all, that is really quite impressive for a stopgap surveillance system.

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Ed Kerr graduated from the University of Toronto in 1959 with a degree in engineering physics. He worked for Atomic Energy of Canada Ltd. in reactor operations and later in reactor design. In 1967 he joined the IAEA Department of Safeguards as a safeguards inspector. He became head of the Section for Technical Services in 1977, a position he held until his retirement in 1991.

IAEA Announces New Appointments

Mohamed ElBaradei, director general of the International Atomic Energy Agency, announced three new appointments to agency posts March 12.

Pierre Goldschmidt is deputy director general and head of the Department of Safeguards. Goldschmidt graduated with a doctorate in electromechanical engineering from the Free University of Brussels in Belgium and, in 1979, was awarded a diploma in marketing and management from the Solvay Ecole de Commerce. From 1966 to 1971, Goldschmidt was employed as an engineer at Belgonucléaire. In 1971 he joined Electrobel Engineering in Belgium as an engineer and then chief engineer. In 1977 he joined SYNATOM in Brussels, where he has held the position of general manager since 1987. Since 1978, Goldschmidt has been a member of the Advisory Committee of the EURATOM Supply Agency as well as of the Executive Committee of the Uranium Institute in London. Since 1993 he has been a member of the Executive Committee of EURODIF, France, and for the last three years he has been chairman of the Organisation des Producteurs d'Energie Nucléaire in France.

Arnold Bonne is the director of the Division of Nuclear Fuel Cycle and Waste Technology in the Department of Nuclear Energy. Bonne studied geology as well as business administration at the University of Louvain, Belgium, and graduated with a doctorate in natural sciences from the universities of Louvain, Belgium, and Toulouse, France. He held various posts in the Belgian National Nuclear Research Establishment (SCK/CEN) at Mol, where he became head of the Research Unit on the Disposal of Radioactive Waste in 1984. In 1993 he joined the IAEA where, in 1996, he was appointed head of the Waste Technology Section in the Department of Nuclear Energy.

Shuja Nawaz is the director of the Division of Conference and Document Services in the Department of Administration. Nawaz studied economics and English literature at Gordon College in Rawalpindi, Pakistan, and graduated with a master's degree in journalism from Columbia University (U.S.A.) His first assignment was as a newscaster and producer at the Pakistan TV Corp. in Islamabad, Pakistan. In 1972 he became a news assistant at the New York Times, and in 1974 he accepted a position as assistant editor at the World Health Organization in Geneva, Switzerland. In 1975 he joined the International Monetary Fund in Washington, D.C., where he was an editor. Since 1992, Nawaz has been chief of the IMF Division of Conference and Training Support Services.

DOE Fills Key Management Positions at Hanford Site

Secretary of Energy Bill Richardson announced March 23 his selections for two key management positions at the Department of Energy's Hanford site located in Southeastern Washington. Keith Klein will become the manager of the Richland Operations Office, and Richard T. French was selected as the manager of the Office of River Protection, a newly created office at Hanford.

Klein will be responsible for the Department's mission at the 560-square-mile Hanford Site. The Hanford mission is to clean up the site's environmental legacy from past defense production, to provide scientific and technological excellence to meet global needs, and to partner in the economic diversification of the region. In October 1998, Klein was named acting manager for the Department's Carlsbad Area Office. From September 1994 to October 1998, he served as the deputy manager for technical programs at the Rocky Flats Field Office, managing the efforts to clean up and make safe several hundred facilities that contain or are contaminated with plutonium and highly enriched uranium. Other assignments have included various positions within DOE headquarters in the areas of environmental management, nuclear safety, quality assurance and nuclear energy. He began his federal career as an intern with the former U.S. Atomic Energy Commission in 1973. Klein has a master's degree in nuclear engineering from the Massachusetts Institute of Technology and a bachelor's degree in electrical engineering from Cornell University.

In late 1998, the Office of River Protection was created by congressional mandate to manage the Department's largest and most complex environmental cleanup project — Hanford's underground tank waste. The mission of ORP is safe storage, retrieval, treatment, immobilization and disposal of the untreated waste in the tank farms at the Hanford site. French will be responsible for the successful execution of the site's Tank Waste Remediation System Project and managing all aspects of the project, including the tank privatization program.

French has spent most of his 30-year career working at the Department's Idaho and Hanford facilities. In 1994, he founded RFT Services Inc., a company that provides engineering, construction and project management services. From 1988 to 1994 French was general manager and president of Kaiser Engineers Hanford, and from 1974 to 1988 he was with EG&G at DOE's Idaho facility. His experience includes facility engineering, construction, site operations, infrastructure services and facility closures at both sites. French is a graduate of the University of Colorado, where he earned a bachelor's degree in aeronautical engineering.

Carlsbad Site Receives First Radioactive Waste Shipment

On March 22, U.S. District Judge John Garrett Penn of Washington, D.C., lifted a seven-year-old injunction prohibiting the shipment of transuranic waste to the Waste Isolation Pilot Plant outside Carlsbad, N.M. The first shipment of defense-generated transuranic nuclear waste from Los Alamos National Laboratory arrived safely at the site — the nation's first deep nuclear waste disposal site — on March 26. The WIPP, a cornerstone of the DOE's national clean-up strategy, is designed to permanently dispose of and to provide long-term, safe management of transuranic waste generated by defense-related activities. Project facilities include disposal rooms excavated in an ancient, stable salt formation almost one-half mile underground. Transuranic waste consists of clothing, tools, rags, residues, debris and other disposable items contaminated with radioactive elements.

"My record on WIPP is clear — I have always insisted this facility should be opened only if scientific studies found it to be a safe and suitable repository for transuranic wastes," said U.S. Secretary of Energy Bill Richardson at the official opening of the site April 17. "I believe this is a world-class facility, and the people who have worked on it are world class. After more than 25 years of roadblocks, delays and hiccups, the WIPP is a success story.

"This is truly a historic moment — for the Department of Energy and the nation. Opening the WIPP represents the beginning of fulfilling the long-overdue promise to all Americans to begin closing the circle on the splitting of the atom."

Transuranic waste began accumulating in the early 1940s with the beginning of the nation's nuclear weapons program. A by-product of this program, this waste remains radioactive for thousands of years. As early as the 1950s, the National Academy of Sciences recommended disposal of radioactive waste in stable geologic formations, such as deep salt beds. Scientists searched for an appropriate site during the 1960s, testing the area of southeastern New Mexico in the 1970s. Congress authorized the WIPP in 1979. DOE completed construction of the facility in the late 1980s. Originally scheduled to begin receiving waste in 1988, the WIPP's opening was delayed because of several lawsuits and the lack of a specific regulatory framework. That changed in 1992 when Congress named the U.S. Environmental Protection Agency as the WIPP's primary regulator. The EPA certified in May 1998 that the DOE met all applicable federal standards for disposing of radioactive waste at the WIPP.

Westinghouse Government Environmental Services Co. is the management and operating contractor for DOE's Carlsbad Area Office at WIPP. Commodore Advanced Sciences Inc. is the DOE's technical assistance contractor at the site, providing assistance in areas such as technology evaluation, environmental compliance, quality assurance, project controls, permitting, and public involvement support.

MCS Awarded Contract for Nevada Test Site TRU Waste Characterization

Mobile Characterization Services LLC was recently awarded a contract by Bechtel Nevada to characterize 1,150 TRU waste drums at the Nevada Test Site, 60 miles north of Las Vegas. This contract follows a competitive demonstration project funded by the Carlsbad Area Office of the Department of Energy. During the project, MCS successfully demonstrated the ability to characterize TRU waste drums in preparation for shipment to the Waste Isolation Pilot Plant. This contract award represents 100 percent of the TRU drums remaining at the NTS.

Characterization of the drums involves three MCS key technologies: nondestructive assay for radionuclide qualification and quantification, nondestructive evaluation using real-time radiography, and drum venting/headspace gas analysis. MCS also offers services such as RCRA analysis, drum coring, and segregation/repackaging of waste.

The MCS principals are Canberra Industries, BNFL Instruments and V.J. Technologies.

Canberra Announces Acquisition of Nuclear Measurements Group

Canberra Industries, a division of Packard BioScience Co., announced March 5 that it has agreed to purchase the operating assets of the Nuclear Measurements Group of Oxford Instruments, a British corporation with headquarters in Eynsham, U.K. The Nuclear Measurements Group is located in Oak Ridge, Tenn. Prior to acquisition by Oxford Instruments, it was formerly Tennelec/Nucleus Inc., two U.S. companies that had been in operation since the early 1960s.

The Nuclear Measurements Group manufactures Tennelec low background alpha beta systems, nuclear electronics, high purity germanium material and detectors, alpha spectroscopy and gamma spectroscopy systems. In addition, the group also manufactures the Nucleus family of radionuclide calibration sources and educational nuclear instruments.

Canberra is the world's leading supplier of nuclear measurement instrumentation, which performs critical services in waste characterization, nuclear research, nuclear energy, decommissioning and decontamination, environmental monitoring and restoration, worker health and safety, as well as special nuclear material safeguards.

University of Missouri–Rolla Researcher Receives Recognition

Shahla Keyvan, an associate professor of nuclear engineering at the University of Missouri–Rolla, has received an invitation to present a paper on her research efforts at the 1999 International Work-Conference on Artificial and Natural Neural Networks in Alicante, Spain, in June. IWANN is a biennial interdisciplinary congress in the field of biological and artificial neural networks.

Keyvan has gained international recognition on her work in Adaptive Resonance Theory, one of the most complex patterns of the artificial neural networks. Her work in this area was also praised in 1993 by Gail Carpenter, who is the co-founder of ART. According to Keyvan, who also is the graduate program director in UMR's nuclear engineering department, members from about 20 countries will take part in the June conference.

In addition, Keyvan's work in the area of monitoring and diagnostics has gained recognition. In 1998, she was invited to provide an article on computerized monitoring for the John Wiley Encyclopedia on Electrical and Electronics Engineering, published by John Wiley & Sons Inc. The encyclopedia was released in March.

MC&A Seminar Held at Obninsk RMTC

A Tripartite Seminar on Nuclear Material Accounting and Control at Radiochemical Plants was held in Obninsk, Russia, Nov. 2–6, 1998. It was jointly organized by the Ministry of Atomic Industry (Minatom) of the Russian Federation, the European Commission and the U.S. Department of Energy at the Russian Methodology and Training Center, which was set up with the cooperation of the European Commission (the TACIS program and the Joint Research Center). The seminar was attended by representatives from the United States, the European Union and Russia. In particular, there were 51 participants from the Russian Federation, coming from 13 facilities, Minatom and the Federal Safeguards Authority (Gosatomnadzor). During the seminar, Russian and foreign specialists gave 37 presentations on the topic of nuclear material control and accounting at radiochemical and reprocessing plants. These presentations dealt with the development and performance of MC&A systems and their basic components. Individual presentations covered:

1. General aspects of State MC&A systems; requirements, regulatory aspects, and discussion of the nuclear fuel cycle in Russia, particularly of reprocessing;
2. MC&A at the various stages of the radiochemical process;
3. Quantitative and qualitative aspects of measurements for MC&A at reprocessing plants, including methods of destructive and nondestructive assay, density and volume measurements, requirements for accuracy of measurements and measurement quality assurance;
4. Continuity of knowledge of measurement data, including use of tamper-indicating devices and of containment/surveillance systems.

The amount of time taken for questions and discussion after each presentation demonstrated the strong interest of the participants in the subject matter. This was the second NMC&A Tripartite Seminar at the RMTC, the first having been conducted in 1997 with the title "NMA&C in Fuel Fabrication Plants." A third seminar dealing with enrichment facilities is planned for the year 2000.

RMTC Hosts Grand Opening Ceremony

The Russian Methodological and Training Center of Obninsk, Russia, organized a grand opening ceremony Nov. 4, 1998, to celebrate its establishment and recognize its training accomplishments in the field of nuclear material control and accounting. The ceremony was attended by numerous experts in nuclear materials accountancy and control from the Russian Federation, the European Union and the United States, as well as representatives of the media. Distinguished guests included E. Adamov, minister of Atomic Energy of the Russian Federation; the president of the Kaluga Region; M. Shubin, mayor of the City of Obninsk; G. Adam, member of the European Parliament; H. Allgeier, director general of the Joint Research Center of the European Commission; A. Dimitriev, deputy head of the Gosatomnadzor of the Russian Federation; P. Ek, representing the Swedish control authority SKI; P. Gourlez, representing the French control authority IPSN; K. Sheeley, deputy director of the Office of Arms Control and Nonproliferation of the U.S. Department of Energy.

Over the past three years, courses were established at the RMTC covering nuclear material control and accountancy in the entire spectrum of facilities of the nuclear fuel cycle and the relevant training facilities were completed. More than 40 courses are now taught annually at the RMTC, attended by more than 1,000 students from Russia, Lithuania, Ukraine and Kazakhstan.

ADVERTISER INDEX

June 20–23
Health Physics Forum, Indian River Plantation, Stuart, Florida, U.S.A. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.

June 21–23
1999 EPRI Plant Maintenance Conference, Grand Hyatt Hotel, Atlanta, Georgia, U.S.A. Sponsor: Electric Power Research Institute. Contact: Russ Pflasterer; phone, 650/855-2541; fax, 650/855-8759; e-mail, rpflaste@epri.com.

June 27–30
Executive Conference on Nuclear Power Plant Decommissioning and Spent Fuel Management, Park Place Hotel, Traverse City, Michigan, U.S.A. Sponsor: ANS. Contact: Ken Powers; phone, 616/547-8388; fax, 616/547-8187.

June 28–July 2
10th Annual Engineering and Science Conference, Obninsk, Russia. Sponsor: Nuclear Society of Russia. Contact: S.V. Kriukov, Nuclear Society of Russia; phone, 095-196-73-00; fax, 095-196-18-36.

July 14–15
IEST Seminar on New International Standards (ISO 14644, Application of IC/TC 209), Omni Inner Harbor, Baltimore, Maryland, U.S.A. Sponsor: Institute of Environmental Sciences and Technology. Contact: Joan Harpham; phone, 847/255-1561; fax, 847/255-1561; e-mail, iest@iest.org; Web site, http://www.iest.org.

July 25–29
INMM 40th Annual Meeting, Pointe Hilton Resort at Squaw Peak, Phoenix, Arizona. Contact: INMM; phone, 847/480-9573; fax, 847/480-9282; e-mail, inmm@inmm.org; Web site, http://www.inmm.org.

July 28
Nuclear Fuel Supply Forum, Willard Inter-Continental Hotel, Washington, D.C., U.S.A. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.

August 30–September 3
International Symposium on Technologies for the Management of Radioactive Waste from Nuclear Power Plants and Back-end Nuclear Fuel Cycle Activities, Taejon, Korea. Sponsor: IAEA. Contact: IAEA; phone, +43 1 2060 21270; fax, +43 1 2060 29610.

September 6–12
International Symposium on Research Reactor Utilization, Safety and Management, Lisbon, Spain. Sponsor: IAEA. Contact: IAEA; phone, +43 1 2060 21270; fax, +43 1 2060 29610.

September 20-24
6th International Conference on Facility Operations-Safeguards Interface, Jackson Hole, Wyoming. Sponsor: ANS. Contact: Mike Ehinger; phone, 423/574-7132; fax, 423/574-3900; e-mail, mhe@ornl.gov.

September 26-29
INFO/Crisis Communications, The Pfister, Milwaukee, Wisconsin, U.S.A. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.

October 3-6
NEI International Uranium Fuel Seminar 99, The Sagamore on Lake George, Bolton Landing, New York. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.

October 17-22
NEI Training Seminar: Fundamentals of Nuclear Communications, Hyatt Regency Bethesda, Bethesda, Maryland, U.S.A. Sponsor: Nuclear Energy Institute. Contact: NEI; phone, 202/739-8000; fax, 202/872-0560.

October 18-21
Fire Protection Information Forum, The Don CeSar Hotel, St. Petersburg Beach, Florida, U.S.A. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.

October 18-21
Decommissioning Planning Forum, Marriott at Sable Oaks, Portland, Maine, U.S.A. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.

October 27-30
EP Shanghai '99 (2nd International Exhibition on Electrical Power Equipment and Technology) and Electrical Shanghai '99 (International Exhibition on Electrical Engineering, Electrical Equipment and Contractors' Supplies), Shanghai Exhibition Centre, Shanghai, China. Sponsor: State Power Corp. Contact: Eric Shew or Rebecca Fung; phone, 852 2811 8897; fax, 852 2516 5024; e-mail, aes@adsaleexh.com; Web site, http://www.adsaleexh.com.

November 30-December 3
EP Vietnam '99 (4th Vietnam International Exhibition on Power, Electrical Equipment and Contractors' Supplies), Kasati Centre, Ho Chi Minh City, Vietnam. Sponsor: Electricity of Vietnam and Adsale Exhibition Services. Contact: Anita Fong; phone, 852 2811 8897; fax, 852 2516 5024; e-mail, aes@adsaleexh.com; Web site, http://www.adsaleexh.com.

January 19, 2000
Nuclear Fuel Supply Forum, Willard Inter-Continental Hotel, Washington, D.C., U.S.A. Sponsor: Nuclear Energy Institute. Contact: Conference Office; phone, 202/739-8000; fax, 202/872-0560.