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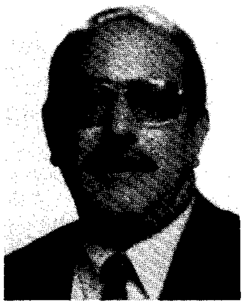
INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

Facing Change and Challenge: An INMM Tradition



The world in which we live is constantly changing, and the INMM is no exception when it comes to change. This is one of those years when the membership has elected a new president and vice president to serve with the treasurer and secretary as the officers of the Institute. The officers, Executive Committee members-at-large, and past president are entrusted by and therefore responsible to you, the members, for conducting the business of the INMM. I am honored to serve as the president and will strive to meet the high standards set by my predecessors.

Fortunately there is a wealth of talented individuals who comprise the entire operating team. Having worked closely with the Executive Committee, technical division chairs, and committee chairs for a number of years, I recognize and am thankful for the depth of experience and ability they lend to the operation of the Institute. I am especially pleased to have the continuing assistance and tremendous institutional knowledge of Treasurer Bob Curl and Secretary Vince DeVito available to continue keeping the INMM on the right track. The Institute's survival and continued growth is also very much dependant on the continued support of the numerous other volunteers who make valuable contributions. Your comments and suggestions are always welcome and valued. For your reference and so you can contact us regarding INMM business, our numbers and addresses are listed at the end of this column.

This past year has been one of change for the INMM as well. In addition to the technically rich traditional workshop/conferences that were conducted by the technical divisions, a couple of notable new endeavors were successful. The Packaging and Transportation Division orchestrated a very well attended Third International Uranium Hexafluoride Conference on Processing, Handling, Packaging, and Transporting. This was the first of these conferences to be held under INMM sponsorship. In addition, the Waste Management Division organized a European Low Level Waste Seminar, which was held in France. These two activities demonstrate the proactive approach the INMM has taken with respect to meeting the needs of the worldwide nuclear materials management community.

As I reflect on some of the accomplishments of our Past President Jim Tape, his efforts to increase the number of chapters and encourage international participation stand out. A Russian Federation Chapter has been fully established and the Charter for a Korea Chapter has been approved by the Executive Committee. The addition of these chapters will strengthen the organization and highlight the Institute's role as an international, professional, and technical organization. A Charter has also been approved for the formation of a Southwest Chapter in the United States. With the large number of individuals engaged in aspects of nuclear materials management in this region, the new chapter should soon be well established and very active.

What should we do next to serve our membership and the broader nuclear materials management community? This question is one the Executive Committee wrestles with each year. We believe that we are structured in a manner to address the broad range of materials management issues and to provide an international forum for the exchange of technical information in these areas. During the last couple of years many changes have been initiated to address the needs of the membership and we are constantly striving to meet member expectations. The real difficulty lies in the formulation of a strategic plan that enables the INMM to maximize its contribution to solving the many issues facing the international materials management community. The Institute is comprised of members with demonstrated technical competencies who have a desire to see integrated, multidisciplinary knowledge applied to improve the management of nuclear materials. What we should do next is a question that the Executive Committee must face head on again this year. I am confident that the new officers and Executive Committee will achieve positive results.

As the Institute begins a challenging new year, I join the membership in thanking Jim Tape for his tremendous leadership as chair during the last two years, Denny Mangan for his continued support as past chair, and Dave Crawford and Jill Cooley for their service as members-at-large. I look forward to working with new Vice President Debbie Dickman, as well as Mike Ehinger and J.D. Williams who join Marcia Lucas and Scott Strait on the Executive Committee.

Obie P. Amacker, Jr., INMM President
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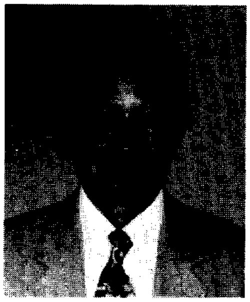
A Potential Safeguards Technique?



The answer is no. I believe that I can categorically state that the subject of the next few paragraphs cannot be used to increase our capability to safeguard nuclear material. However, its discovery does represent a very elegant milestone in physics.

This year marks the 40th anniversary of the discovery of the neutrino. Postulated in 1930 by Wolfgang Pauli to ensure conservation of energy and momentum in nuclear beta decay, the neutrino has little or no mass and no charge. It is therefore exceedingly difficult to detect. Its existence can only be inferred from its interactions with matter, such as its reaction with protons to yield a neutron and a positron. However, the mean free path for reactions with hydrogen is about 1,000 light years of liquid hydrogen. Pauli, himself, said the neutrino "... cannot be detected."

But detected it was. Using a detector comprising 300 liters of liquid scintillator, 92 photo multiplier tubes, and hundreds of tons of lead shielding, a Los Alamos research team lead by Fred Reines and Clyde Cowen first observed neutrinos at a Hanford reactor and later confirmed the neutrino's existence at Savannah River using a larger detector and a more powerful reactor. The definitive paper on the subject was published in the July issue of *Science*. Authored by Cowan, Reines, Harrison, Kruse, and McGuire, it was titled "Detection of the Free Neutrino: A Confirmation."

Long ago, in my early years at Los Alamos, I had the privilege of meeting Fred Reines and enjoyed several discussions with Fred and other research team members on various physics topics. But I still can't see any way to exploit the properties of the neutrino for safeguards.

As I write this column, it is a little more than a month since the 37th Annual Meeting of the Institute of Nuclear Materials Management. It was, in my opinion, a very successful meeting; it began with a most interesting plenary address by Hiroyoshi Kurihara, senior executive director of the Nuclear Material Control Center in Tokyo, Japan. Titled "Toward Better Management of Nuclear Materials in Japan and Asia," Kurihara's presentation addressed three topics: (1) the history and the present status of Japanese nuclear energy development and nuclear materials management, (2) Japan's efforts to strengthen international nonproliferation efforts, and (3) nuclear energy in the Asia region in general and specifically the concept of ASIATOM or PACIFIC ATOM, which might be similar to EURATOM. Kurihara's address is printed in this issue.

This issue also contains the transcript of the Monday afternoon roundtable discussion between officers of the INMM and Kurihara. We are most grateful to him for his participation.

In addition to Kurihara's keynote address and the roundtable discussion, we have, in this issue, four contributed papers on a variety of topics. The first, by Jared Dreicer and Debra Rutherford, discusses the proliferation risk of nuclear material in terms of material attractiveness, the level of safeguards, the socioeconomic circumstances of the State that owns the material, and the threat to the environment. The paper describes a disposition and proliferation risk systems analysis capability, the Global Nuclear Material Control model, which has been developed to study the elements and factors that affect and are associated with the inventory of nuclear materials.

In a paper titled "Verifying the Absence of Undeclared Activities," Morton Canty and Rudolf Avenhaus address the distribution of resources available for arms control, disarmament, and nonproliferation in terms of noncooperative game theory. Such resources will always be limited, and any insights on how to "get more bang for the buck" are more than welcome.

The third paper, by Alison Dove, George Eccleston, and Doug Reilly, gives a timely history and current status of the biennial international training courses on the implementation of state systems of accounting for and control of nuclear materials. These courses, which are sponsored by the International Atomic Energy Agency in cooperation with the U.S. Departments of Energy and State, are directed primarily to helping countries with developing nuclear programs to establish effective safeguards over their nuclear materials. The courses bring together participants and lecturers with diverse cultural, technical, and esoteric backgrounds. These highly successful courses to have satisfied both national and IAEA safeguards needs.

Dana Christensen, Mark Dinehart, and Stephen Yarbro discuss — to me the most frustrating — interaction between public expectations, political policy, and technical capability for plutonium management. The goals and requirements have changed rather considerably over the last few years. Today, the challenge is focused on isolating plutonium from the environment and preparing it for permanent disposition while protecting the material from theft and providing for international inspection. In addition, there is — at least outside the United States — a continuing interest in using plutonium as an energy source. The authors suggest some technical solutions to the seemingly insoluble problems.

I abstracted much of the information above about the neutrino and its discovery from an article written by Los

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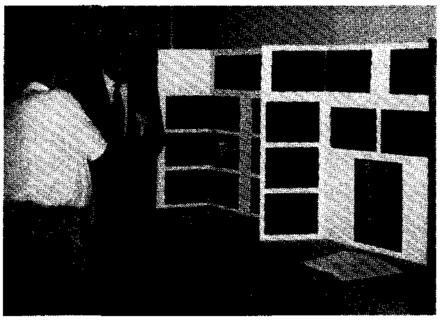
INMM Annual Meeting: Striving to Do It All

It is reported, by somewhat unreliable sources, that following the 37th Annual Meeting of the Institute of Nuclear Materials Management, a weary and bedraggled (but happy!) contingent of meeting participants departed for home after a week of intensive involvement in the cutting edge of nuclear safeguards activities. "The price of the Institute's success," President Jim Tape said, "is that there is more information disseminated in one week than one person could possibly absorb." We noted the popularity of supplementary and complementary meetings by various committees, working groups, and training groups during lunchtime, evening, and prior to and after the Annual Meeting, all of which made for very long days (and evenings). What can one expect when most of the world's experts on nuclear materials management are assembled at one location! The most common "complaint" from attendees was that there was so much to do that there was little time for fun.

Outgoing Chair Jim Tape addresses the audience at the plenary session.

Fortunately, the purpose of the Annual Meeting is to provide a professional forum for exchange of information, potential resolution of issues, and development of new ideas and initiatives. So, just because we have a Annual Meeting Program showing surfing on its cover doesn't mean we went to Naples, Florida for fun alone — besides everyone knows there's no surf in the Gulf! And the only reason we held the golf tournament prior to the meeting was to get some of the attendees in shape for an intensive meeting schedule.

If papers presented is an indicator of interest and success of the meeting, we certainly achieved new heights with a record of 262 papers. (Last year I said our optimum level was 210 papers with a 5% variance. Well, that goal went up in flames this year!) There were 34 sessions including a great poster session with 25 posters chaired by Sharon Jacobsen. Two premeeting training sessions were held by Central Training Academy on the Tamper Indicating Device Program and on Statistical Concepts in MC&A. Also held were 28 other committee and special-event meetings such as Dave Crawford's Fissile Material Assurance Working Group and Ron Cherry's IAEA Safeguards in the DOE Complex meeting. No wonder some attendees felt overwhelmed — many worked from 7 a.m. to 10 p.m.! Of course, once again, the success of the Annual Meeting is credited to the authors and speakers who made major professional contributions to the nuclear materials management community, to the Session Chairs who helped manage the meeting program, and finally to the Technical Program Committee and our INMM headquarters staff who tolerate my badgering them each year to achieve that elusive goal of perfection.

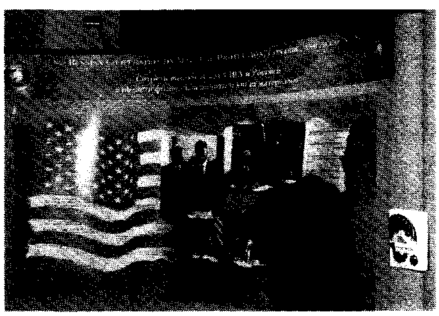


The Poster Session featured 25 displays.

At the plenary session this year, we heard Hiroyoshi Kurihara, senior executive director of the Nuclear Material Control Center in Tokyo, Japan, speak about approaches to better management of nuclear materials in Japan and Asia. Since the Asian region will have a significant future role in worldwide civilian nuclear energy development, Kurihara's talk was another important milestone in the Institute's efforts to take a leadership role in identifying and promoting early discussions of significant initiatives in a professional environment of the Institute's *Journal*. For a revealing discussion of the subject, see page 25 in this issue for a transcript of Kurihara's remarks at the INMM Roundtable.

Hiroyoshi Kurihara addresses more than 600 people at the plenary session.

The Institute is pleased to report that the Proceedings of the Annual Meeting this year will be distributed on CD-ROM for the first time this October. (Last year the printed copy of the Proceedings totaled 1,300 pages for 230 papers; this year two volumes would have been required, and the shipping costs alone would have approached, or even exceeded in some instances, the cost of printing.) However, a limited supply of hard copies of the Proceedings are available if INMM Headquarters is notified in advance. For those few readers who may not have computers, you are reminded that many organizations, such as public libraries and business groups, provide access to



One of 10 exhibits, the U.S.-Russian Cooperation

CD-ROM capabilities. Of concern regarding these Proceedings are the few speakers who did not provide written papers for publication. Speakers are reminded that papers for presentation are required to be published in the Proceedings. A procedural change is anticipated for 1997 whereby a written paper will be required prior to the Annual Meeting to insure compliance with the publication policy.

Looking forward to the 1997 Annual Meeting at the Pointe Hilton Resort at Squaw Peak, Phoenix, Arizona, be sure to check for early notification of the Call for Papers on the Internet at http://www.inmm.com. We also plan to post the speakers manual, meeting registration forms, and other information. (For those of you who feel that the use

The MC&A division discusses new initiatives for the upcoming year.

of a "resort" hotel for our Annual Meeting might give the impression to outsiders that the Institute's meetings are only "fun and games" sessions, please refer to the previous comments and information about the current meeting. The truth is that the Institute gets the best rates, accommodations, and services from this type of hotel during the off-season.)

Each year we do a customer survey, written and verbal, at the meeting to determine the level of satisfaction of our attendees. Responses were overwhelmingly positive but some unexpected criticism was received, too, such as the individual who wanted all meals and refreshments to be provided daily. This year, in addition to the "complaints" of an intensive week of information exchange stemming from a strong technical program, we heard concerns about a perceived overemphasis on the golf tournament and the "resort" image, lack of cold drinks in the afternoon breaks, lack of current meeting registrant information, and requests for INMM T-shirts, coffee mugs, and other mementos. Of course, the continuing growth of the Institute's Annual Meeting, with the resulting compression of so many papers and meetings into a few days, has been a concern of the Executive Committee for the past few years. Rearranging the technical program, increasing the number of meeting days, and limiting the number of papers, sessions and external meetings will be a subject for discussion again for 1997. But there's no easy answer to managing success. Our growth is also causing a meeting-space problem. With so many sessions needed to accommodate speakers, hotels capable of meeting our needs are becoming scarcer: the Annual Meeting is too large for the smaller hotels and too small for the conference center types!

The number of "no-show" speakers — (those who did not notify INMM of withdrawal of their paper and did not appear at the meeting) diminished this year but is still a concern. We continue our policy of not accepting papers from these contributors in the future if an adequate reason for their absence is not provided to INMM. Unfortunately, there was the usual 10% withdrawal of papers during the two months prior to the meeting. Hopefully, the withdrawals were not based on frivolous commitments to present a paper. We are very concerned about withdrawals after the Final Annual Program has gone to press!

On a personal note, you should know that I, after many years with the

INMM recognizes a sustaining corporate member during the awards banquet.

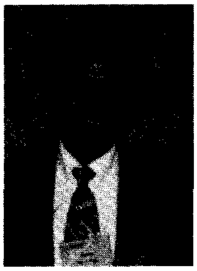
Department of Energy, its predecessor agencies, two of its laboratories (Oak Ridge National Laboratory and the Savannah River Site), have retired effective September 30, 1996. However, I plan to remain with the Institute until we do achieve a perfect Annual Meeting! You can reach me at 5506 Grand Ave., Western Springs, IL 60558; phone/fax: 708/246-8489; e-mail: cpietri@aol.com.

The Technical Program Committee has already started its planning for next year and solicits your comments, suggestions, and session topics. (One contribution already received consists of a session on the smuggling of nuclear materials, chaired by a expert in the field, whose name will not be divulged until next July). If you would like to propose a topic or arrange a session and chair it, we would be pleased to hear from you soon. Other potential speakers for the 1997 meeting should be starting preparations for their papers now to meet the February 1, 1997 deadline for submitting abstracts. It will be a great meeting and in addition to all the hard work, we'll still manage to have fun (despite those few nay-sayers)!

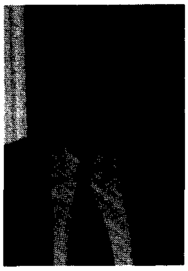
Charles E. Pietri, Chair
INMM Technical Program Committee
Annual Meeting

INMM Honors Award Winners, Fellows

Richard Schneider



Dennis Mangan



Andre Petite

At its 37th Annual Meeting in Naples, Florida, INMM honored two of its members with service awards and named two members fellows of the Institute. Richard Schneider received the Distinguished Service Award, which recognizes long-term service to the nuclear materials safeguards and management profession, while Dennis Mangan was the recipient of the Meritorious Service Award, which recognizes long-term outstanding commitment to the INMM.

Schneider has served more than 45 years in professional and management positions in the nuclear industry, applying technical expertise in nuclear materials safeguards research and development, analytical chemistry research and development, separation processes, and applied analytical chemistry. He is author of the plutonium/uranium ratio method of input accountability to a chemical processing plant, the "Cesium Index" method for coating waste, and was a principal developer of the use of isotopic correlations for verifying the plutonium content of spent power fuels.

From 1976 until his retirement in 1993, Schneider was a safeguards specialist for the then Exxon Nuclear Co. Inc., working in safeguards for reprocessing, centrifuge enrichment, laser enrichment, and fuel fabrication. Schneider has been an active participant in the Institute's annual meetings since 1960, a continuous member since 1967, and a fellow since 1984. He is a former board member and chairman of the Pacific Northwest Chapter of the INMM.

Dennis Mangan is manager of the Nuclear Materials Management Systems Department at Sandia National Laboratories, Albequerque, New Mexico. He is presently responsible for the Materials Management and Control Program at Sandia. Prior to his current assignment, he was responsible for the Technical Support Program that Sandia provided to the Department of Energy's Office of Fissile Materials Disposition. He was manager of the On-Site Monitoring and Applications Department where he had programmatic responsibility for the DOE's International Safeguards Program at Sandia, as well as DOE's On-Site Monitoring Program. Mangan is the immediate past chair of the INMM, having served as chair during the 1993 and 1994 fiscal years. He has been a member-at-large of the Executive Committee and has served on several committees of the Institute, including the Certification Committee and Annual Meeting Program Committee.

New INMM Fellows

Andre Petite, a Paris-based consultant, and Thomas Shae, International Atomic Energy Agency in Vienna, Austria, were named fellows of the INMM, recognizing their contributions to the profession and their service in the Institute. To achieve fellow status, individuals must have established a specific record of contribution to the nuclear materials management profession, have at least 15 years of active experience in the profession, and have been in good standing in the grade of Senior Member for at least five consecutive years prior to the proposal for their advancement to fellow.

Executive Committee Reports 1996 Activities

The INMM Executive Committee met July 26 before INMM's Annual meeting to hear updates on committee and division activities from the past year.

Finances

The INMM balance sheet as of July 28 showed total assets of $413,641. The operating account is $182,556 and the Merrill Lynch Trust account is $110,308.

Technical Division Reports

The International Safeguards division sponsored a workshop with ESARDA in Verona, Italy, October 28-31, 1996.

The Material Control and Accountability Division and Nonproliferation and Arms Control Division planned a workshop on International Inspection of Excess Fissile Materials in Washington DC. The original dates of the workshop were changed to February 19-21, 1997.

The Physical Protection division is considering a workshop in the spring. Debra Spencer, Sandia National Laboratories, has agreed to serve as the physical protection division contact on standards.

The Waste Management division reported on its activities for the year. These included the spent fuel management seminar held this year in Washington, D.C. and the Low-Level Radioactive Waste Technical Seminar held last April in France. Publication of the INMM Spent Fuel Storage monograph is scheduled for this fall.

Technical Committee Reports

ANSI N-14 (Packaging and Transportation of Radioactive and Non-Nuclear Hazardous Materials) Chair John Arendt reported on Public Law 104-113, the Technology Transfer and Advancement Act that requires national and international standards be used by government agencies and their contractors where applicable.

INMM Elects New Executive Committee and Approves Bylaw Changes

Committee Reports
Communications Committee Chair Debbie Dickman reported that an INMM Operations and Procedures Manual has been developed and will be published in November.

The Constitution and Bylaws Committee reported on the approved resolution from the membership that will replace the terms for chair and vice chair with president and vice president. The Executive Committee also passed a resolution that established new requirements for prospective Senior Members and redefined designations for Emeritus Members. A complete version of the approved INMM Bylaws will be printed in the 1997 Membership Directory.

In other business, Korea petitioned the INMM to form a chapter of the Institute. The petition was presented at the Annual Meeting. Also, a number of members in Russia are considering petitioning the INMM for a second Russian chapter from the OBNINSK region. Discussion ensued regarding the hesitancy to join the Russian Federation Chapter due to location, other nuclear facilities and other influences in Russia.

A copy of the complete meeting minutes can be obtained from INMM headquarters, 60 Revere Dr., Suite 500, Northbrook, IL 60062 U.S.A.; tel.: 847/480-9573; fax: 847/480-9282.

Membership Report

Regular Members	
Domestic	376
Foreign	68
Japan	147
Vienna	56
Korea	19
Senior Members	67
Emeritus	20
Fellow	21
Corporate (250)	3
Corporate (500)	3
Corporate (750)	18
Total	798
New Members	9

According to INMM bylaws, "the Secretary shall notify each member in good standing of the results of the election before October 1 of each year." This notice in the Annual Meeting Report and in the INMM Journal meets that obligation.

In accordance with the bylaws, the Nominating Committee selected candidates, and ballots were mailed to each of the 739 Institute members. In response, INMM received 195 ballots for Executive Committee candidates and 183 ballots for the Constitution and Bylaw changes.

The new officers and members-at-large elected to INMM Executive Committee are listed below. Their terms began October 1, 1996

President	Obie Amacker
Vice President	Debbie Dickman
Secretary	Vincent DeVito
Treasurer	Robert Curl
Members-at-Large	Marcia Lucas (9/30/97)
	Scott Strait (9/30/97)
	Mike Ehinger (9/30/98)
	J. D. Williams (9/30/98)
Immediate Past President	James Tape
Japan Chapter	Designate
Vienna Chapter	Designate

INMM also received write-in votes for the following:

President	Dave Crawford
	Richard Greene
	Charlie Pietri
Vice President	Ken Byers
	Vince DeVito
	Paul Ebel
	Marcia Lucas
	Debra Rutherford
	Don Six
	Barry Slotnick
Members-at-Large	Vanice Perin
	Charlie Pietri
	Brian Smith
	Tom Williams

Each year write-in votes are received for the elective positions. INMM believes that this represents a sincere effort by the members to recognize their write-in candidates as potential leaders and policy makers of the Institute. We do not wish to discourage or diminish your interest in seeing your candidates on the ballot. However, a more effective way to get your responsible choices elected to the Executive Committee is by recommending your candidates to the Nominating Committee. The Nominating Committee is the immediate Past President of INMM.

Also, the bylaws stipulate that "candidates may also be nominated for any of the elective offices or positions by fifteen (15) members who submit to the secretary in writing over their signatures a petition naming the candidate and the office or position to which that candidate is thus nominated. Such petitions shall be submitted to the secretary on or before April 1 preceding the election."

Generally, it is the practice of the Nominating Committee to select candidates who have been involved in INMM committees or chapters, who are generally familiar with the overall operations of INMM and have a working knowledge of the Executive Committee.

Constitution and Bylaw Changes
The Constitution and Bylaws changes replacing the titles of Chair and Vice-chair with President and Vice-president received 179 votes in favor of the change and 4 votes against it. The bylaws changes regarding requirements for senior membership received 178 votes in favor of the changes and 5 votes against them.

INMM 5.1 Subcommittee on Analytical Chemistry Laboratory Measurement Control Meeting

At its meeting on August 1, 1996, in Naples, Florida, the INMM 5.1 Subcommittee met to discuss the reaffirmation status of ANSI Standard N15.51 "Measurement Control Program — Nuclear Materials Analytical Chemistry laboratory," upgrades to this standard (sample exchange program, references, statistical statements, and measurement assurance programs), and assistance to the DOE Fissile Material Assurance Working Group (FMAWG). The N15.51 Standard was approved by ANSI just prior to the Subcommittee meeting. Next steps are to revise the document to conform to current practices and references that would enhance its value to the nuclear materials measurement community.

There is a continuing need to maintain a level of expertise and technical capability in the U.S. nuclear community. Much of the concern regarding proper nuclear materials management can be traced to diminishing domestic technical skills and facility infrastructure to support adequate measurement and control of nuclear materials. In our very cost-conscious society today, it appears that the proper processes painstakingly taken over the past several decades to assure reliability of measurements have slowly been eroded. Evidence that this condition exists is our apparent waning ability (and even interest and knowledge) to properly plan and execute programs without taking on unnecessary risks and repeating the mistakes of the past. INMM 5.1 is one of those very few remaining professional organizations at the working level that is contributing to the effort to reverse this trend. In fact, the technical expertise of the Subcommittee was offered to the FMAWG in their initiative to accurately quantify nuclear materials in the United States prior to long-term storage.

Welcomed back to active participation in INMM 5.1 were: Darryl Jackson, Los Alamos National Laboratory, after a long illness, and Peter De Regge, SCK-CEN, chairman of the European Safeguards Research and Development Association (ESARDA). Three new members joined the group: Jay Armstrong, LANL; Dennis Wilkey, LANL; and Timothy Gaines, Department of Energy, Office of Safeguards Evaluation.

New members are continually solicited, especially from contractor and licensee facilities, agencies, and other organizations currently not represented in the group. Other changes noted: Donald Joy, NRC, retired at the end of August but, fortunately, will continue to work with the group from his Myrtle Beach, South Carolina home; and Charles Pietri, DOE, retired at the end of September and will also continue his activities with the Subcommittee but in the somewhat cooler environs of Western Springs, Illinois. The Subcommittee, like other consensus standards organizations, continues to suffer from insufficient resources to support travel, meetings, and working time to meet its goals. (Of course, David Crawford, DOE-HQ, MC&A, continues his strong support for the efforts of INMM 5.1 in the development of consensus standards which can be used to replace DOE directives.)

Detailed minutes of the INMM 5.1 Subcommittee meeting and a membership mailing list are available in hard copy or preferably by e-mail by contacting Charles Pietri at cpietri@aol.com (tel./fax 708/246-8489).

Charles E. Pietri, Chair
Analytical Chemistry Laboratory Measurement Control Subcommittee

INMM N14 Standards Committee Meeting

The annual N14 Standards Committee meeting for 1996 will be November 7, 1996, at the Nuclear Regulatory Commission (NRC) Headquarters, 2 White Flint North, 11545 Rockville Pike, Rockville, Maryland. A preliminary agenda, attendance form, and other meeting details have been distributed.

ANSI N14.1 - 1995 — American National Standard for Nuclear Materials-Uranium Hexaflouride Packaging for Transport, has been published. Committee members can receive complimentary copies of this published standard by writing Charles T. Zegers, Program Director, ANSI, 11 West 42nd Street, New York, NY 10036. Additional copies of the standard can be obtained from ANSI for $60 per copy by calling 212/642-4900, or writing to the address above.

ANSI Standard report N14.1 - 1995 was approved by ANSI December 1, 1995, and published by ANSI in July.

The status report for N14 Standards Activities was updated July 9, 1996.

There are currently 91 members, including 10 alternates and 31 designated "Information Only." There are two organization vacancies.

The following ANSI Procedures were recently published: Procedures for the Development and Coordination of American National Standards, Operating Procedures of the Executive Standards Council, Constitutions and By-Laws, Operating Procedures of the Board of Standards Review, Appeals Board Operating Procedures, Auditing Policy and Procedures.

The procedures are available from the American National Standards Institute, Inc., 11 West 42nd Street, New York, NY 10036; tel.: 212/642-4900; fax: 212/398-0023.

John Arendt, Chair
INMM N14 Standards Committee
John Arendt Associates Inc.
Oak Ridge, Tennessee, U.S.A.

Status Report — N14.1 Standards Activities

Document Number, Title & Project Number	Brief Summary and Objective of Project	Project Status and Estimated Completion
N14.1 - 1990 - "Packaging of Uranium Hexaflouride for Transport" R.I. Reynolds, Chair	Standard provides criteria for packaging of uranium hexaflouride for transport. Update and maintain	N14.1 - 1995 Approved by ANSI December 1, 1995.
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 non-accident events of highway transportation. In accidents, packages secured as prescribed in this standard may come off their vehicle.	A revised draft 6/25/96 was sent to Writing Group. Balloting by N14 should start in early fall. Estimated Completion Date: 1996
N14.5 - 1987 - "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 (IAEA) Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6, 1985, or verification, and periodic verification.	Final draft is being prepared for N14 balloting. Estimated Completion Date: 1996
N14.6 - 1993 - "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500kg) or More for Nuclear Materials" George Townes	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 (4500 kg) or more for radioactive materials.	Revision of N14.6 - 1986 was approved June 28, 1993. Published and for sale. Estimated Completion Date: Complete
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.	N14.7 Draft sent to Writing Group for comments. Comments are being reviewed and incorporated in a revised draft. Writing Group has been expanded. PINS form has been sent to ANSI. Estimated Completion Date: 1996
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.	Currently not active. Will be activated when documents are received for standards consideration. Completion dates will be set for each document received. Dave Dawson coordinating standard. Recommendation in process. 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.	May be reactivated. Estimated Completion Date: N/A
"Ancillary Features of Irradiated Shipping Casks"	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.	Standard has been withdrawn. Status of this standard is being evaluated based on ballot results. Need for standard is questionable. Possible adoption of ISO standard on trunnions. Estimated Completion Date: 1997
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.	Writing Group meeting held at PATRAM. (ANSI technical document still a consideration.) Final draft ready to send to N14. Estimated Completion Date: 1996

Status Report — N14.1 Standards Activities continued from previous page

N14.24 - 1985 (R1993) - "Domestic Barge Transport for Highway Route Controlled Quantities of Radioactive Materials"	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 (RAM) on inland waterways and in coastwise and ocean service.	Reaffirmation was approved June 28, 1993. New Writing Group chair is needed. Plans to prepare revised standard are contingent on NRC NuReg Document for LSA. LSA reactor components will be considered. Writing Group chair appointed and new scope prepared by January 1, 1996. Estimated Completion Date: N/A
N14.25 "Tiedowns for Rail Transport of Fissile and Radioactive Material Containers"	This standard applies to attachment or tiedown of containers of radioactive materials to railroad cars where the gross weight of the containers exceeds one ton.	Initial proposed draft standard prepared 6/26/96. Estimated Completion Date: 1998
N14.26 "Fabrication, Inspection, and Preventative Maintenance of Packaging for Radioactive Materials" Ray Hahn, 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.	Writing Group formed. First rough draft completed. Awaiting adoption of the 1985 IAEA regulation by U.S. before distribution of draft for review. Estimated Completion Date: 1996
N14.27 - 1986 (R1993) "Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents: Brady Lester, Chair	The scope for 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, the actions of governmental authorities, or the specific responsibilities of the carrier or shipper during recovery operations.	Reaffirmation was approved June 28, 1993. A Writing Group chair has been appointed. Planning will now start on a new scope and an extensively revised standard in 1996. Estimated Completion Date: 1999
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.	Writing Group completed draft standard for Writing Group consensus. Estimated Completion Date: 1997
N14.30 - 1992 "Design, Fabrication, and Maintenance of Semi-Trailers Employed in the Transport of Weight-Concentrated Radioactive Loads"	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 1000 pounds per lineal foot over any portion on the semi-trailer. In addition, the standard provides detailed procedures for inservice inspections, testing, and quality assurance.	Standard approved by ANSI October 1, 1992. Published and available for sale from ANSI. Ralph Best is the new Chairman of Writing Group, replacing Dan Huffman. Revision of standard has started. Estimated Completion Date: 1999
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. It describes general requirements for tiedown securing hazardous materials packages to conventional trailers. The packages have a suitable base plat (pallet or skid) or flat base, and appropriate size arrangement of tiedown assemblies for packages that are within weight and dimensional limits of the equipment.	In final format; Writing Group will review and validate one more time. Estimated Completion Date: 1996

Divisions:
International Safeguards

On July 28, 1996, the Institute of Nuclear Materials Management's (INMM) International Safeguards Division (ISD) met during INMM's 1996 Annual Meeting in Naples, Florida, U.S.A. Fifty-six members of the International Safeguards Community, from the IAEA, CEC/EURATOM, CEC/JRC-Ispra, ABACC, Australia, Canada, China, Finland, France, Germany, Japan, Kazakstan, Netherlands, Russian Federation, South Korea, UK, Ukraine, and the United States participated in the meeting.

Sonnier opened the meeting with expressions of regret from Paul Ek and Steve Dupree who were not able to attend. As in previous meetings, a wide range of current international safeguards topics and issues were discussed, including the IAEA 93+2 Programme, Remote Monitoring, and Safeguards in an Openness Regime. As in the past, it was recognized that many factors must be considered before the introduction into routine safeguards activities of the many changes currently under consideration, as well as the vast array of new technology required to support these changes.

There continues to be a very positive response to the activities of the ISD on the part of the division participants as well as the INMM membership at large, particularly in view of the numerous significant events that have occurred in the recent past. The Division has been very supportive of and instrumental in the development of the International Safeguards portion of the INMM Program for the Annual Meeting. The ISD will attempt to hold at least two meetings each year, one in the United States at a location where a number of members of the community are meeting for other reasons such as ESARDA or IAEA meetings.

Cecil Sonnier, Chair
INMM International Safeguards Division
Consultant
Albuquerque, U.S.A.

Physical Protection

The activities of the Physical Protection Division presently in progress or recently completed are given below.

We had a very successful series of sessions at the INMM 36th Annual Meeting held at the Marriott Desert Spring Resort, Palm Desert, California. On July 9, 1995, we held a Division Meeting, which was attended by about 15 persons. A Physical Protection Division Meeting was held July 18, 1996, in Naples, Florida.

A Physical Protection Workshop originally planned for the spring of 1996, has been delayed until at least the Fall of 1996.

A quick look at the abstracts for papers for the annual meeting indicate that we will continue to have a number of very interesting papers in Naples.

Debra Spencer, Sandia National Laboratories, agreed to serve as the Physical Protection Division contact on the Standards Committee. Her address is Advanced Systems Applications Department 5861, Albuquerque, NM 87185-0762; tel.: 505/845-8280; fax: 505/844-0708.

J.D. Williams, Chair
INMM Physical Protection Division
Sandia National Laboratories
Albuquerque, New Mexico, U.S.A.

MC&A

The INMM Division of Materials Control and Accountability held the "Plutonium Inventories: Growing Challenges in MC&A and Nonproliferation," workshop May 1-2, 1996, at the Washington Hilton and Towers, Washington D.C. The workshop was attended by over 55 people, representing a broad cross section of views. Sessions covered plutonium inventories, near-term approaches and safeguards issues associated with plutonium inventories, and long-term approaches and safeguards issues associated with the question "Is the accumulation of plutonium a growing proliferation risk or is separation of plutonium followed by its burning in nuclear systems a greater risk?" A detailed summary of the workshop was published in the July 1996 issue of the *JNMM* along with several full papers from the meeting. Co-chairs of the meeting were Chad Olinger and Ed Arthur, Los Alamos National Laboratory.

A second workshop related to DOE excess materials was proposed by the International Safeguards Division to be co-sponsored by the MC&A and the Nonproliferation and Arms Control Division.

Rich Strittmatter, Chair
INMM MC&A Division
Los Alamos National Laboratory
Los Alamos, New Mexico, U.S.A.

Waste Management Division Update

The following summarizes the activities of the Waste Management Division (WMD) for the period July 1995 to July 1996.

The WMD conceived, organized and conducted the first INMM Low Level Waste (LLW) Technical Seminar, which took place in Troyes, France on April 23-25, 1996. The LLW seminar brought together approximately 60 participants from all over the world including representatives from France, United Kingdom, Netherlands, Spain, Germany, Japan, Sweden, Canada, Belgium, Czech Republic, Australia, Austria, Switzerland, Cuba, and the United States. The LLW seminar's purpose was to foster communication within the international technical community on issues surrounding storage and disposal of low level radioactive waste. An additional objective was to build a common understanding of the performance, economics, and maturity of the disposal technologies.

This first INMM LLW seminar was highly successful in accomplishing its objectives. The seminar's technical success was linked to the quality of the presentations, the discussions, the provocative questions from the participants during the sessions, and a comprehensive visit to the world's largest disposal facility in operation (Centre de 1'Aube Low Level Waste Disposal Facility). The WMD has invited five of the LLW seminar speakers to provide to the WMD a full paper for publication in the winter issue of the *JNMM*.

The WMD organized and conducted the INMM Spent Fuel Management Seminar XIII on January 24-26, 1996 at Loew's L'Enfant Plaza Hotel in Washington, D.C. Approximately 160 attendees enjoyed the seminar — topics included overviews of spent fuel management programs and policies; spent fuel storage technology; MPC technology; spent fuel transportation issues; and special considerations related to spent fuel management. The attendees represented a broad range of companies, both government and civilian, and included approximately 10 utilities, numerous vendors, and technical and consulting firms. Foreign countries were also well represented with attendees from France, Spain, Japan, South Korea, Austria, Italy, Germany, Canada, and the United Kingdom. This annual seminar has become very successful over the years and is widely recognized by the industry.

The WMD organized five sessions, and solicited papers for the 37th INMM Annual Meeting. The five sessions were: Waste Management I, Waste Management II, Waste Management III, Waste Management — Reprocessing, and Packaging and Transportation.

The INMM Spent Fuel Storage Monograph has been undergoing final editing. The manuscript is scheduled for publication in October 1996.

Glenn Vawter of TRW accepted the chair of the Spent Fuel and High Level Radioactive Waste Packaging and Disposal Committee of the WMD in late 1995. Since that time Vawter has recruited members for the committee and encouraged involvement within the WMD. Three papers that focus on the repository and waste package design elements of the Yucca Mountain Project, as well as a briefing on the status of the project, were prepared for this years' INMM Annual Meeting.

Planning for the Spent Fuel Management Seminar XIV has commenced. The seminar will be held again at Loew's L'Enfant Plaza Hotel in Washington, D.C. on January 29-31, 1997.

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

Southeast Chapter

The following chapter report was prepared for presentation at INMM's Annual Meeting.

Five members of the INMM Japan Chapter visited the Savannah River Site August 5, 1996, to tour the facilities after attending the INMM 37th Annual Meeting in Naples, Florida. The visit also included a tour of the Defense Waste Processing Facility, the Savannah River Ecology Laboratory, and a bus tour of the site.

The chapter also hosted a dinner meeting in the evening and heard a guest speaker discuss the Accelerator Production of Tritium Project.

Lori Brownell, Chair
INMM Southeast Chapter
Savannah River Site
Aiken, South Carolina, U.S.A.

Pacific Northwest Chapter

The Pacific Northwest Chapter (PNC) began this year's activities with a half-day technical paper presentation seminar to allow Hanford Staff members unable to attend the 37th Annual INMM (1995) meeting with the opportunity to hear papers given by Hanford presenters. A social and dinner meeting followed the seminar, at which time the new PNC officers and executive board members were announced.

The PNC officers for the 1995/1996 fiscal year were:

Chair	Scott Gority
Vice-chair	Donald Six
Secretary /treasurer	Gary Fetterolf
Executive Committee	James Andre
	Cindy Parnell
	Dan Noss
	Dean Scott (Past Chair)

Two standing committees were established to provide adequate organization to the chapter. The Seminar Committee, chaired by Cindy Parnell, PNNL, was established to coordinate presenters at quarterly meetings, and Membership Committee, chaired by Jim Andre, PNNL, was established to promote the PNC and expand membership. Both committees were very successful in their endeavors.

The February general meeting features a presentation by William Cliff, Ph.D., Manager, International Affairs, National Security Division, PNNL, titled "Smuggling in the Former Soviet Union and Eastern Bloc Countries." Cliff provided insight into an area that was of great interest to the audience.

The PNC Bylaws and Constitution were reviewed and revised and will be sent to its members for voting and approval in the near future.

The PNC supported various community science efforts this past year. Along these are the Engineers Week and related school activities, and Mid-Columbia Regional Science Fair, and the Tri-Cities Technical Council.

The annual PNC barbecue was held Aug. 7, 1996, at Leslie Groves Park in Richland, Washington. Members of the Japan Chapter of the INMM attended. In addition, Obie Amacker and Scott Gority provided a Hanford site tour prior to the event.

Scott Gority, Chair
Pacific Northwest Chapter
Pacific Northwest National Laboratory
Richland, Washington, U.S.A.

INMM Vienna Chapter

The Vienna Chapter continued its participation as an active chapter of the INMM during the 1995-96 fiscal year. The Chapter Executive Committee held monthly planning meetings. Chapter Executive Committee members for 1995-1996 were:

Chair	Martha Williams
Vice Chair	Mark Killinger
Secretary	Susan Pepper
Treasurer	Michio Hosoya
Past Chair	Jim Larrimore
Members-at-Large	Shirley Johnson
	Jill Cooley
Special Event Chair	Ed Kerr
Symposium Chair	Pricha Karasuddhi

Luncheon meetings were held in November, February, and April. Guest speakers and their topics were:

Roy Simpkins, Counselor for Nuclear Policy, U.S. Mission to the U.N. Organization in Vienna, "Brazilian/Argentine Nuclear Program from a U.S. Perspective," Ambassador Oleg M. Sokolov, Resident Representative of Russia to the IAEA, "Current Russian Arms Control Policy," Sonia Fernandez Moreno, Head of Safeguards and Physical Protection, Argentina National Board of Nuclear Regulation, and Argentine Representative to SAGSI, "The SSAC of Argentina — Nonproliferation and Safeguards Aspects."

More than 100 people attended a half-day international safeguards seminar sponsored by the Vienna Chapter in March. Richard Hooper, director of the IAEA Department of Safeguards Concepts and Planning, was the keynote speaker and he presented "Program 93+2, An Update." The following papers were presented:

"An Information System for

Chapter News

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Analysis of Environmental Measurements," Jack King;

"An Overview of IAEA Remote Monitoring Activities," Mark Killinger;

"The IAEA Safeguards Research & Development and Implementation Support Program," Ron Liikala;

"Using NMAX to Select a Random Sample of Items," Marian Russell;

"Gamma and X-ray Measurements of Nuclear Material Element Mass Fraction," T. Dragnev;

"Technique for Automated Energy Calibration and Stabilization of Seeded NaI Detector Spectra," Bernard Wishard, Martin Moslinder and Gary Gardner.

The election of Chapter officers was held this summer. Revisions to the Chapter Constitution and Bylaws, which will bring chapter practices in agreement with the international organization, were also voted on.

The Vienna Chapter will continue to sponsor luncheon meetings and the annual seminar during the coming fiscal year. Plans are also underway to participate in planning and carrying out a Science Fair for the International schools in Vienna.

Martha Williams, Chair
Vienna Chapter
IAEA
Vienna, Austria

Japan Chapter

The six meetings of the Executive Committee of Japan Chapter (72nd - 77th) were held at the Nuclear Materials Control Center in Tokyo from October 1995 to June 1996 and the following major topics were discussed and adopted,

1. The chapter's business report for 1995 fiscal year.
2. The chapter's business plan and financial budget for 1996 fiscal year.
3. The 17th annual meeting and appointment of chairman of the meeting.
4. Approval of the amendment of the Japan Chapter's Constitution and Bylaws based on the vote by the membership.
5. Approved 1997-1999 Japan chapter's officers candidates.

The Planning Committee completed the following tasks:

1. Prepare proposed amendment of the Japan Chapter's Constitution and Bylaws.
2. Set up group and plan for the Japan Chapter's Workshop.
3. Set up the group tour plan on nuclear-related facilities in the United Sates.
4. Translation of the Chair's Message, Technical Editor's Note and abstract of the technical papers in the *JNMM* into Japanese.

The 16th Annual Meeting
The 16th Annual Meeting was held in Tokyo on Dec. 7-8, 1995, in commemoration of the chapter's 20th anniversary. T. Michima, Power Reactor and Nuclear Fuel Development Corp. served as a program chairman of the meeting. A total of 148 people and nine guest speakers participated in the conference. A simultaneous interpretation service was provided during the meeting since guest speakers were invited from the United States, Korea, Australia, ESARDA, and the IAEA. A total of 20 technical papers were presented.

Annual Business Meeting
The 1995 Annual Business Meeting was held following the Annual Meeting. Following reports were given and approved.

The 17th Annual Meeting Programming Committee
The Programming Committee for the 17th Annual Meeting was organized by T. Mishima (PNC), Program Chair, and overall an annual meeting plan was discussed including invitation of an overseas speaker.

Workshop
The 6th workshop was held on June 28, 1996 in Tokyo, in which 65 people participated.

Membership
The membership status of the Japan Chapter as of July 30, 1996, is as follows:

Regular Membership	170
(This figure represents an increase of five members since January 1996.)	
Sustaining Membership	
Japan Atomic Energy Research Institute	2
Power Reactor and Nuclear Fuel-Development Corporation	3
Nuclear Material Control Center	1
Utility Companies	10
Nuclear Industries	3

Note: The annual sustaining membership fee is 100,000 ¥ per unit.

INMM thanks the following sponsors of its 37th Annual Meeting

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Canberra Industries
E.R. Johnson Associates Inc.
Los Alamos National Laboratory
Radia Corp.
RussTech

President's Message

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Technical Editor's Note

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Alamos National Laboratory Director Sig Hecker from the August 30 News bulletin. Sig's article describes the physics of the neutrino and its discovery in much greater detail than I was able to give here. If you are interested in more information, please let me know.

Darryl Smith
Los Alamos, New Mexico, U.S.A.

Obituaries

Tom Beetle died June 8, 1996, in Oceaside, Calif., at the age of 68. Following a tour in the U.S. Marine Corps, Tom attended Cornell University, graduating with a master's degree in mathematics, and followed on graduate work in statistics. He joined the Battelle Northwest Laboratory, where he worked until 1974, when he started work at the IAEA in Vienna, Austria.

During his tenure at the IAEA, Tom provided valuable support to Agency inspectors in the statistical analysis of measurement data, especially tank calibrations. He retired from that organization in 1988. He was a charter member of the Vienna Chapter of the INMM, which was organized in 1979.

To those who knew Tom, he is remembered as a friend who always had a good word, and who was always ready to do anything he could to help out. Tom, with his wife Jean, was known for his hospitality and fun-loving friendship. He will be missed by his many friends around the world.

The following resolution was unanimously adopted by the membership at their Annual Meeting, July 30, 1996, in rememberance of **Kathie Mangan.**

WHEREAS our friend, associate, and a "First Lady of the Institute" has passed from this life on June 28, 1996, and

WHEREAS her many hours of unselfish devotion to the Institute as a patient and supportive spouse to Dennis, as a helper during the Annual Meeting, especially at the Registration Desk and Spouses Breakfast, and as a cheerful greeter to new members and their spouses, and

WHEREAS she will be missed and always remembered with great respect and admiration by all of us,

Now therefore be it RESOLVED that we tender to her family our sincere condolence in their sorrow, and pray that they shall be comforted by the memory of her unselfish support of Dennis during his executive tenure in the Institute, and for her many contributions to the success of the Annual Meetings.

INMM 37th Annual Meeting Keynote Presentation

Toward Better Management of Nuclear Materials In Japan and Asia

■

Hiroyoshi Kurihara
Nuclear Material Control Center
Tokyo, Japan

■

Introduction

Thank you, Mr. Chairman. Ladies and gentlemen, it is a great honor for me to present the keynote speech on the situation of nuclear materials management and associated movements in Japan and Asia at this 37th Annual Meeting of the Institute of Nuclear Materials Management.

Nowadays, the Asian region is drawing a great deal of attention from all over the world regarding its possible future role as the core of worldwide peaceful nuclear energy development. Northeast Asia, Japan, Korea, and Taiwan already have a significant amount of nuclear power generation. Furthermore, these countries together with China have expansion plans. Southeast Asia is just beginning to plan and construct civilian nuclear power stations. Among these Asian countries, Japan can be regarded one of the most developed nations as far as peaceful nuclear energy is concerned. Within Japan several nuclear fuel cycle facilities, including reprocessing and uranium enrichment facilities, are in operation. Research and developmental activities on fast breeder reactors are continuing. Such facts explain why I was chosen as the keynote speaker at this Annual Meeting.

On this occasion, I would like to explain three topics in general. The first is the history (which should be brief) and the present situation of Japanese nuclear energy development and nuclear materials management. The second topic is Japan's efforts to strengthen international nonproliferation efforts, which include: various assistances in the dismantling of the former Soviet Union's nuclear forces; Japan's participation in the Korean Peninsula Energy Development Organization (KEDO), which is responsible for the supply of two light water reactors to the Democratic People's Republic of Korea (DPRK); Japan's initiative and contributions to the establishment of guidelines for use and storage of separated plutonium; technical and financial support to the IAEA safeguards implementation; and the strengthening of the Japanese system of accounting for and control of nuclear materials (SSAC) in connection with the Agency's activity, Program 93+2.

The last topic that I will address is concerned with nuclear energy in the Asian region. The concept of ASIATOM, or PACIFIC ATOM is now being widely discussed in several countries in Asia. I would like to discuss this idea, especially regarding the objectives, possible contents and the structures.

Japanese Nuclear Energy Development and Associated Nuclear Materials Management and Control

For my first topic, I would like to explain the history and present situation of Japanese civilian nuclear energy. In Japan, there are currently 51 nuclear power stations in operation, and 2,583 billion watt hours of electricity were generated in 1994. This figure is the third highest in the world. The U.S.A. is first (6,394 x 10^{11} Wh) and France is second (3,418 x 10^{11} Wh). As for the fuel cycle facilities in Japan, the ones in operation are: two uranium enrichment facilities (one a demonstration plant, and the other a commercial plant); two commercial scale conversion facilities; six fuel fabrication facilities, of which two plants are for BWR fuel, two are PWR fuel and the remaining two are for ATR Fugen and FBRs (Monju and Joyo), specifically MOX fabrication plants; one reprocessing facility of prototype scale in operation has a production capacity of 0.7 tons heavy metal/day or 90 tons heavy metal/year; and a large-scale commercial reprocessing plant of 800 tons heavy metal/year is under construction. We have a storage site for low level radioactive waste in Aomori Prefecture. In Tokai-Mura a small-scale vitrification facility for high level radioactive waste has just started operation. Vitrified high-level waste will then be stored on site at the commercial reprocessing facility. However, there is not yet any designated site for the ultimate disposal of such vitrified waste in Japan.

Although we recently had an accident at the FBR in Monju (it was not a radiation accident but was concerned with sodium leakage), the performance of nuclear safety in connection with the operation of nuclear power reactors and fuel cycle facilities has been excellent in Japan. We have had no serious accident that might affect either the operators or the local population. The rate of unintended shutdowns of power reactors in Japan has been extremely low.

Japan is continuing its policy of recycling plutonium produced in the reactors of either light water reactors or fast reactors, though many other countries, including the U.S.A., have given up on plutonium recycling and reprocessing. The Atomic Energy Commission of Japan is an advisory body to the Prime Minister in the Japanese government. The AEC issues long-term programs for peaceful nuclear energy development in Japan that cover five years on average. The most recent long-term program was begun in 1994. This program reafffirmed the Japanese policy of recycling plutonium, which was established at a very early stage of development; however, the indicated schedule for its R&D has been delayed. This is due to the delay of the R&D on the fast breeder reactors, as well as increased uncertainty about cost problems. Since the accident at Monju, the reliability and credibility of the nuclear energy development program promoted by the government has been heavily damaged. One of the important policies in Japan in connection with plutonium utilization is to maintain the balance of supply and demand of plutonium to avoid an accumulation of excess stocks. If mixed oxide fuel cannot be used in the core of LWRs in the future, this supply-demand balance will not be maintained. Three governors of prefectures in which many nuclear power stations are sited have suggested to the Prime Minister and the Minister for Science and Technology that, unless the problems associated with the Monju accident are not successfully resolved, they cannot accept MOX fuels into LWRs in their prefectures. The Atomic Energy Commission is now holding a series of roundtable discussions to find ways to recover its reliability rating and credibility among the general public with respect to the government-sponsored civilian nuclear energy development.

There is not yet any indication whether the Atomic Energy Commission and the Japanese government will change their nuclear policy, notably the plutonium policy. So far, there is no indication that the national policy will change. Still, the majority of public opinion in Japan is that nuclear energy is important for Japan, and that it should be maintained. At the same time, however, the majority of people are uneasy about the safety of nuclear power reactors, and about the treatment and disposal of radioactive waste.

The following observations are purely my own and do not represent any organizations with which I am affiliated. After finishing the roundtable discussions, the AEC should decide on a policy regarding nuclear energy development in Japan, especially the policy on the future of fast breeder reactor development and plutonium recycling. I would guess that the AEC will not drastically change its already established policy of promoting plutonium. The AEC would recommend to the government, however, that more openness and transparency must be incorporated into the licensing and promotion activities of the government. At present, I would think Japan is not promoting early commercialization of plutonium economy. Rather, Japan appears inclined to keep and develop Pu-related technology, regarding which, experts in Japan believe that in the latter half of the 21st century it will become a very important source of worldwide energy supply.

So far, I have explained the present situation of peaceful Japanese nuclear activities. Here, I will go back to the beginning of nuclear energy development in Japan.

As all of you know, it was in December 1953 that U.S. President Eisenhower made his famous "Atoms for Peace" speech at the 8th General Conference of the United Nations. In the following year, 1954, the first budget on the development of peaceful uses of nuclear energy was approved by the Japanese Diet. The Japan Science Council declared in the same year that Japanese nuclear development must be limited solely to peaceful purposes, and that the way to conduct peaceful nuclear development must be democratic, self-dependent and open to the public. These policies were later inherited by the Japanese government.

The first governmental cooperation agreement between Japan and the U.S.A. came into force in November 1955. A new domestic legal system on nuclear energy was established from 1955 to 1957. The first research reactor in Japan (JRR-1), which was introduced through cooperation with the U.S.A., reached criticality in August 1957. Then, the Japanese government made five more cooperation agreements with other governments. When the International Atomic Energy Agency was established in 1957, Japan was a charter member. Japan wanted to accelerate the IAEA's safeguards implementation. Japan needed natural uranium for its first domestically produced research reactor, the JRR-3, at that time, so natural uranium was actually transferred from Canada to Japan. Japan and the IAEA had concluded a supply agreement for uranium (in today's terms, a "project agreement") in 1959, and the Japanese government gave the IAEA safeguards and inspection rights. The IAEA document number for this project is INFCIRC 3. As far as I know, this was the frst implementation of IAEA safeguards in the world.

As I mentioned earlier, Japan has insufficient domestic uranium resources. In addition, there was no technical basis for a nuclear development in Japan. Important technology, equipment, and facilities had to be imported under the terms and conditions of various bilateral cooperation agreements. Thus, the Japanese government had to establish a division within the government dealing with nuclear material accountancy to keep track of the movements of nuclear materials that were imported. The Japanese government promulgated "The Law for the Regulation of Source Material, Nuclear Material and Reactors" in 1957. The main purpose of this law is to maintain the safety of nuclear-related activities and to establish licensing procedures. However, measures to maintain an adequate level of nuclear material accountancy and to establish various controls on the materials imported under the governmental cooperation agreements are also incorporated in this law. Originally, all nuclear materials imported into or produced in Japan were government-owned materials. In 1961, some nuclear materials were privatized, however, so nuclear material accountancy at the facility level became more important. The Nuclear Fuel facility level became more important. The Nuclear Fuel Division of the Atomic Energy Bureau of the Science & Technology Agency was at that time the organization responsible for nationwide nuclear material accountancy.

Following the success of the Japan Power Demonstration Reactor (JPDR), which began generating electricity in October 1963, the first commercial power reactor, a gas-cooled reactor (GCR), located in Tokai-Mura and operated by the Japan Atomic Power Company (JAPCO), began operation in 1965. Since the nuclear fuels are of British origin, and are covered under the Japan-U.K. cooperation agreement as well as a Trilateral Transfer Agreement between Japan, the U.K. and the IAEA, transferring the rights and obligations for safeguards to the IAEA went into force in 1967. This Tokai No. 1 Power Reactor became the first commercial reactor with IAEA safeguards in the world.

The coming into force of the NPT (Non-Proliferation Treaty) was an epoch-making event in the field of nuclear disarmament and nonproliferation. I still remember vividly the discussions held at the Safeguards Committee during 1970 and 1971. This Committee was established under the Board of Governors of the IAEA to create a model Safeguards Agreement required by Article 3 of the NPT. I was a member of the Japanese Delegation to that Committee. The head of the Japanese Delegation was the late Mr. Tamiya, and Ambassador Imai was also a member of our delegation. If my memory is correct, Myron Kratzer was chief delegate of the U.S.A., and Jon Jennekens was in the Canadian Delegation (as the chief delegate, I believe). This model agreement (INFCIRC 153) is by now the most important safeguards document yet made.

Although the Japanese government had signed the NPT immediately before it came into force (February 1970), ratification had to wait until six years later (June 1976). In 1975 the Japanese government started preliminary discussions with the secretariat of the IAEA on the possible contents of the safeguard agreement. The ensuing negotiations resulted in the Japan-IAEA Safeguards Agreement based upon Article 3 of the NPT on March 1977. The coming into force of the NPT and of the NPT Safeguard Agreement had a great impact on nuclear material accountancy and the national safeguards.

In 1970, a Safeguards Office was created within the International Cooperation Division of the Atomic Energy Bureau, Science and Technology Agency. I was deputy director of that office at the time. The Safeguards Office was transferred from the Atomic Energy Bureau to the Nuclear Safety Bureau in 1976, then in April 1977 an independent Safeguards Division was established. I happened to be the first director of the Safeguards Division. It was a hectic, extremely busy time; we needed to discuss with the IAEA about the subsidiary arrangements and facility attachments (Japan already had more than 100 facilities with nuclear material, and each attachment was a document of more than 30 pages).

Our Safeguards Agreement with the IAEA is a unique one. It has a protocol, aiming at establishing a state system of accounting for and control of nuclear material (SSAC) with an independent verification capability. According to the protocol, Japan's SSAC could be called a National Safeguards System. Until then, we had a nationwide nuclear material control system for which the legal basis was the "Law for the Regulation of Nuclear Materials, etc." However, we did not implement independent verifcation. So we needed to amend the Law, and this required approval by the Diet. Extensive preparations were necessary for gaining the approval by the Diet.

On top of that, in March 1977, President Carter of the U.S.A. requested that Japanese government reconsider the reprocessing of U.S. origin spent fuel at the Tokai Reprocessing facility of the Power Reactor and Nuclear Fuel Development Corp. (PNC). Since these discussions were extremely complex and touched upon the basic policies of Japanese nuclear development, the Japanese government made very extensive efforts to reach a solution agreeable to both countries. The Minister for Science & Technology was then Mr. Sosuke Uno, who later became Prime Minister. Under the leadership of Minister Uno, the Ministry of Foreign Affairs, the Ministry of International Trade and Industry, and the Science and Technology Agency created a team to deal with this matter. Since I was the director of the Safeguards Division, and this matter was concerned with fuel cycle development on the one hand, and nonproliferation on the other, my involvement was necessary. (At that time we called these negotiations the "Tokai Affair.") After several hard discussions and negotiations between the U.S.A. and Japan, a set of compromise solutions was reached.

The negotiation team on the U.S. side was headed by Ambassador Gerald Smith and Dr. Joe Nye of the State Department. The crucial point in the whole negotiation period came during June and July 1977. The USA and Japan decided to send a joint fact-finding team to the Tokai-Mura Reprocessing Plant, where they stayed for about three weeks. The leader of the U.S. side was Dr. Larry Scheinman, who was then deputy assistant secretary in the DOS. I stayed at Tokai-Mura during the whole period and we discussed the various alternative operation modes of the reprocessing and conversion plants, including so-called "coprocessing and co-conversion" processes. In a way the discussions of that time were a precursor of INFCE (International Fuel Cycle Evaluation). The solution that we reached included the following elements: the reprocessing plant would be operated as designed, namely, by the usual Pulex-method. However, a conversion plant to convert plutonium nitrite into plutonium oxide should be operated by the co-conversion technique, aiming at no presence of plutonium alone but always in co-presence with uranium throughout the conversion process. And the reprocessing plant should be used as a test-bed for safeguards technology experiments. The last agreement materialized as the TASTEX program (Takai Advanced Safeguards Tests and Experiments).

We learned an imponant lesson during these long and difficult negotiations: the fact that we could reach a successful solution in any very difficult situation if we made sincere efforts with fairness and an understanding of the other side's position through continual dialogue.

of this busyness came from the negotiations on finalizing subsidiary arrangements and facility attachments for the Safeguard Agreement with IAEA. After we solved these problems, we changed our domestic regulations to meet the requirements stemming from the NPT and the NPT Safeguards Agreement. So I would say that the present structure of our national nuclear material management system was established by that time. Implementing national safeguards and nuclear material accountancy are jobs for experts. So the government asked the Nuclear Material Control Center, which was established as an independent nonprofit organization in 1972, to deal with a part of the government jobs, namely, the treatment and compiling of nuclear material information, the preparation of national reports to be submitted to the IAEA, the analyses of uranium and plutonium samples taken at Japanese nuclear facilities by national safeguards inspectors, and the calibration and maintenance of nondestructive assay equipment. National safeguards inspections are implemented by national inspectors who are government officials. In addition, the government checks the adequacy of a facility's nuclear material accountancy.

It has been 20 years since this type of structure for implementing national as well as facility-level nuclear material accountancy was formulated in 1976. During this period I believe that, in general, the system has worked relatively well. Two years ago, we had an incident in the PNC MOX fabrication facility. About 70 kg of plutonium oxide powder was accumulated in the glove boxes of the process line. At first it was reported by the mass media as 70 kg of MUF (Material Unaccounted For). Though this misinformation was later corrected, still, the fact that about 70 kg of plutonium was sitting idly in glove boxes was criticized. Apart from this incident, I would repeat that so far, the Japanese situation has remained relatively stable.

However, the surrounding circumstances are gradually changing, and at this moment we are seriously considering the strengthening of our national safeguards system. I would like to touch upon this a little later.

So I would summarize Japan's present situation as follows:

In Japan, there are 51 nuclear power stations in operation. About 30 percent of the total electricity generation comes from those nuclear power stations. We have complete nuclear fuel cycle facilities domestically, though part of that cycle is still on a relatively smaller scale. We have three more nuclear power stations which are under construction, and three more stations are now being planned. In addition to this, quite recently the Higashidori Site was approved as the future site of nuclear power stations by the Governor of Aomori Prefecture. A commercial scale reprocessing plant is now under construction in Rokkasho-Mura. It is expected to go into operation in 2003; however, a spent fuel pond, which is a pan of the total facility, is to be in operation by next year. The safeguards efforts of both the IAEA and the national authority will certainly increase significantly by the start-up of the whole facility in 2003.

Japan has a policy of plutonium recycling. This policy has to be checked again for its viability, adequacy, required time, etc., since the Monju accident. So far it seems, however, that no major changes are anticipated in the basic concept.

IAEA safeguards are implemented regarding all Japanese nuclear materials. The national safeguards system with an independent verification capability is also applied, and we have found no suspicious activities so far. At present, the facilities we have under national and international control are thc following: Power Reactors, Research Reactors and Critical Assemblies, 62; Commercial Fuel Fabrication and/or Conversion Facilities, 8; Reprocessing Facilities, 2; Other Nuclear Facilities, 172; of a total of 244 nuclear facilities. In addition to this number, we have in Japan 1,024 locations in which small amounts of nuclear materials are used or stored. These locations are also required to accept national regulatory controls, including nuclear material accountancy requirements.

Japan's Efforts to Strengthen the International Nonproliferation Setup

Now, I would like to go on to the second subject, namely Japan's efforts to strengthen the international non-proliferation regime.

Because of Japan's geopolitical situation, with our high level of development in peaceful nuclear energy and space technology and our holding of weapons-usable materials, Japan's intention for and direction of future development have drawn keen attention from abroad. In the latest "Long-term Program for Research, Development and Utilization of Nuclear Energy" of 1994, the Atomic Energy Commission has stated that Japan must seek greater openness and transparency to remove suspicions regarding the real intention of Japanese nuclear development, suspicions which seem to exist in some sectors abroad. Japan should also exert greater efforts to strengthen the international nonproliferation regime. To achieve greater transparency, the Japanese government is now disclosing annually the amounts of inventories and flows of plutonium and uranium in Japan. Details on the national safeguards implementation are also made public.

I can enumerate the following contributions to international nonproliferation: assistance to the Former Soviet Union States, participation in the Korean Peninsula Energy Development Organization (KEDO), contributing to the IAEA safeguards in various ways, an initiative to organize a multinational meeting to discuss a set of guidelines on plutonium, as well as various assistance to and cooperation with Asian countries. Japan's various contributions to the IAEA safeguards are the main subject of this speech, but I would like briefly to touch upon the other subjects.

First, our cooperation with and assistance to the Former Soviet Union States. In this field, U.S. assistance involves the major efforts, while our efforts are on a rather smaller scale than those of the United States. The Japanese government has set aside 100 million dollars for this program, and so far, Japan has provided assistance using these resources to construct a storage facility for storing nuclear material no longer needed for defense purposes; Japan has constructed storage activities to hold waste coming from dismantled nuclear submarines; and has assisted in the establishment of a national and facility material accountanhold waste coming from dismantled nuclear submarines; and has assisted in the establishment of a national and facility material accountancy system as well as a physical protection system in Kazakhstan, Ukraine and Belarus. With other resources, PNC of Japan is assisting the upgrade of nuclear safety at Leningrad Nuclear Power Station.

Japan is also an important contributor to the ISTC, the International Science and Technology Center, established in Moscow. So far, we are not really involved in upgrading Russia's MPC&A, Material Protection, Control and Accounting, which I consider a pity, but I do understand the principle behind the Japanese government's attitude on the matter. Specifically, Japan will not use nuclear energy for defense purposes. It has not in the past and will not in the future. The process of dismantling nuclear weapons is just the reverse process of manufacturing nuclear weapons. There is an old Chinese saying that "a gentleman will not adjust his hat under a fruit tree in the orchard," which means he doesn't want his action to be mistaken as stealing fruit from the trees. Likewise, the Japanese government never wants to be involved in any assistance or cooperation involving the process of dismantling nuclear weapons, so as to avoid any misunderstanding of the intention. However, I feel that there are many areas where Japan could assist without arousing unnecessary doubt. Improvement of the Russian nuclear material accountancy system would be one such example. I eagerly await increased efforts by the Japanese government in this field.

The Korean Peninsula Energy Development Organization (KEDO) was established to deal with the construction in the DPRK of two light water reactors, replacing frozen gas-cooled graphite reactors. Japan is one of the founding countries and together with the USA and Korea, Japan is a board member.

From 1994, a series of informal meetings among nine countries (the U.S.A., the U.K., France, Russia, China, Japan, Germany, Belgium and Switzerland) is going on. The purpose of this group is to issue a set of guidelines for the handling of plutonium in the civilian sector. The scope will include plutonium derived from dismantled nuclear weapons that is no longer needed for defense purposes. It is hoped that there may be a result by this September, which would be subsequently released to the public in one of the Information Circular Documents (INFCIRC) from the IAEA. Japan was one of the strong supporters of this movement. It could have been called at one time the "Japan initiative." Of course, now all participating countries are equally eager for and positive about meaningful results. It is expected that such results may contribute to the international nonproliferation scene with transparency on the real situation with regard to plutonium in each nation, and at the same time it could help further the development of nuclear energy. Indeed, nowadays no type of civilian nuclear development can be pursued without consideration of the safety and nonproliferation aspects. This group will take up the discussion of high enriched uranium (HEU) as its next subject.

Apart from the activities that I have mentioned, Japan is carrying out various activities to contribute to nuclear nonproliferation. Several organizations, such as the Japan Atomic Energy Research Institute (JEARI) and the PNC, are receiving trainees from Asian countries for courses on nuclear material control and accountancy. My organization, the Nuclear Material Control Center, has made an arrangement for technical cooperation with a Korean organization, the TCNC (Technology Center for Nuclear Control). This year, our Center invited three technical experts on nuclear material control in the Chinese Atomic Energy Authority to visit Tokyo. It is my strong intention to expand this kind of cooperation in the Asian region, to improve the level of nuclear material accountancy and to discuss the importance of public recognition of the subject.

Now, I would like to discuss our efforts to improve IAEA safeguards. From the beginning we have taken a favorable attitude towards the Agency safeguards. Together with other advanced nations, we have supported these by organizing and participating in multinational or unilateral forums for technical development. TASTEX, which I already mentioned, JASPAS (Japan Technical Support Program), HEXAPARTITE (a multinational project for uranium enrichment facilities), LASCAR (a multinational project for large-scale reprocessing plant) and the recent ITAP (a support program for information handling) are some of the Japanese contributions.

The Agency's Program 93+2 is intended primarily to strengthen the Agency's ability to detect undeclared nuclear material. However, the streamlining of the Agency safeguards activities is also an important element in the program. Indeed, without the streamlining of present activities, the Agency cannot take on new activities under the very stringent budget and human resources conditions. Several ways are suggested for further streamlining the Agency's activities. One is through technical development, and the other is through a more effective use of the SSAC, the state's material accountancy system. A good example of this latter case is the Agency's new partnership approach with EURATOM. The Japanese SSAC already has an independent verification system. This type of SSAC required almost the same types of NDA equipment on site, the same types of sample analyses at the Safeguards Analytical Laboratory; national inspectors are actually doing almost the same kind of jobs at the inspections (national inspectors must do additional jobs which stem from the obligations in bilateral agreements).

As a first step, Japan has started to establish a "joint use system" for the on-site equipment. This system helps both organizations from the financial perspective. Then, we are now considering further upgrading the quality of Japanese national inspectors. If we and the Agency recognize that the quality of national inspectors is the same as those in the Agency, some parts of the IAEA inspectors' jobs could be delegated to the national inspectors. At least this will save the Agency's resources. Our national authority is now seriously considering that some parts of routine inspection jobs could be delegated to more expert people rather than using government officials, who must unfortunately change positions every two or three years. By such delegating, Japanese inspectors would attain a level of experience such as we can find in the IAEA or EURATOM system. This domestic improvement requires amendments to our Law, so approval by the Japanese Diet is necessary, but under the present very unstable political condition, we are not sure when and how we can submit it to the Diet.

We in Japan have one problem in the movement to enhance nonproliferation efforts. This is lack of experts. Since Japan is totally devoted to the promotion of nuclear energy use for peaceful purposes, we tend to forget the other side of nuclear energy. At least, people involved in nuclear development in Japan do not want any knowledge of anything which smells of war, the military, or the like. Nuclear disarmament and nuclear nonnproliferation is a totally different area. Here, there is nothing about military activities. However, the Japanese people have had no interest in becoming deeply involved in this area. The situation is the same in the area of international political scientists. It is fortunate that, recently, the situation has been improving. However, we still feel that we are heavily underpowered. I would like to learn more of the situation in the U.S.A. and European countries in order to make useful recommendations to our government.

Here, I would like to summarize the second part of my talk. Japan is increasing its efforts to strengthen the international nonproliferation regime. Assistance to the FSU, participation in KEDO, and contributions to the IAEA safeguards systems are some of the examples. I personally, however, am not satisfied with the level of our assistance; there should be much wider possibilities.

Nuclear Energy in Asia, and the Concept of ASIATOM

Now I turn to the third topic of my speech. Compared with other regions of the world, it seems that the Asian region can be expectcd to make further developments in civilian nuclear energy. In the Northeast Asia region, Japan, Korea and Taiwan already have significant amounts of nuclear power generation. More importantly, these three countries have plans to expand their nuclear power. I have already explained the Japanese situation Korea has a plan to construct 13 more nuclear power plants, adding them to the present 10 reactors. Taiwan will add two more nuclear power stations in addition to the six power stations now in operation. China has decided to increase the number of its nuclear power stations from the present three to 18 more, according to some reports.

Southeast Asia has no nuclear power stations yet; however, it is reported that Indonesia, Thailand, and Vietnam have plans to build one or more nuclear power stations. In South Asia, India has 10 nuclear power stations in operation, and 12 more stations are either under construction or in the planning. Pakistan has one nuclear power plant and one more is under construction. Other nations in this subregion have no plans as yet. In the Pacific region, including Australia and New Zealand, there are neither plants in operation nor plans for any.

The Asian region is a very wide area in the geographical sense, and also widely different in the cultural sense. Heterogeneity applies to Asia not only in culture but also in religion, ethnicity, the social structure, the level of technical advancement, and nuclear development. However, even though recognizing this heterogeneity, the concept of an "ASIATOM" attracts some experts. As a matter of fact, this idea is not new.

More than 20 years ago, some Japanese experts called for consideration of an ASIATOM. However, recent increased interest in nuclear energy in Asia has accelerated the discussions. The Atomic Energy Commission organized a roundtable discussion on the future of nuclear fuel cycles and nonproliferation last year in Kyoto, Japan, where not only some Japanese experts including myself and Professor Suzuki of Tokyo University, but also several experts from Asian countries touched upon this theme. Ambassador Siason of the Philippines was one of these people. Early this year President Ramos of the Philippines, at a Tokyo conference, suggested that the creation of ASIATOM would have a better influence on the security situation in Asia, so he called for serious consideration of that idea. It seems that many nations in the region are considering such concepts more seriously.

Possible Asian regional cooperation could have various functions. In my view at least four different functions could be considered, namely (1) the promotion of nuclear industries in the Asian region, (2) the upgrading of regional non-proliferation and security considerations, (3) the upgrading of nuclear safety in the Asian region, and (4) the promotion of nuclear science and technology. Recent reports by the mass media seem to place importance on the second objective, namely, the creation of a regional safeguards system, which should contribute to regional security issues. EURATOM was mentioned in connection with these discussions.

Of course, the European situation is rather more homogeneous than that in Asia. EURATOM was established when Europe needed more unified efforts in the whole region. The ultimate aim at that time in Europe was a single unified community. So ASIATOM could not be an exact copy of EURATOM. We need more innovative approaches. The most important thing to do at this moment is, in my view, to discuss matters regarding various sectors in many countries. For example, there have already been discussions about whether we should aim for an "ASIATOM" or a "PACIFIC ATOM" and who would be the participating states in such an agreement, etc. I have developed my thoughts on the subject in a more detailed way, but I will present my detailed thoughts at a session on Tuesday. I would like to give a summary of my thoughts there.

I would prefer the name of PACIFIC ATOM, rather than ASIATOM. The name PACIFIC ATOM could indicate the more active involvement of the U.S.A., Australia (and Canada, probably). I do not want an ASIATOM to be a closed regional organization. It should be open to the other regions of the world. In particular, I think the involvement of the U.S.A., whether as an official member or as an observer, is very essential.

I am not keen on the early establishment of a concrete body. I prefer to take a more gradual approach. However, I would say that in the end we should aim for the establishment of a region-

Pacific region, at the same time it could contribute to enhancing the level of regional security.

Apart from safeguards and security aspects, this system should promote regional nuclear industrial activities and more basic research and development. The nuclear industry requires huge financial resources and careful long-range planning. Regional cooperation and coordination will provide good results in assisting such activities. Although Japanese authorities, including the Ministry of Foreign Affairs, the Science and Technology Agency, and the Atomic Energy Commission have not made any official comments on the ASIATOM concept, they are watching the movement keenly. The Atomic Energy Commission is already taking a positive role to enhance nuclear research and developmental activities in the Asia region. So in the near future, we may start a more substantial discussion of the ASIATOM or the PACIFIC ATOM concept with government officials.

Conclusion

In conclusion, I would like to emphasize the importance of carrying out communications with transparency and openness. The words transparency and openness seem to be quite fashionable now, and many people use these words with many different meanings. Here, I have used the words with a very simple meaning; namely, don't hide anything, be fair to one's counterpart, and so on. Japanese people in general are not good at communicating in foreign languages. The number of publications written in English or other foreign languages in each field of expertise is very small. In our country, there is a saying supposedly imported from the West, namely, "silence is gold and eloquence is silver." In a homogeneous society like Japan, this saying might be true, but between countries, eloquence must be the golden.

I urge our Japanese colleagues to exert more effort to communicate with other countries and work together to accelerate the disarmament of weapons of mass destruction, and to strengthen the non proliferation regime in the world, so that all of us in the world may have safer, happier lives in the future. Thank you very much.

Annual INMM Safeguards Roundtable

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Introduction

The purpose of this roundtable is to have a free-flowing discussion following Mr. Kurihara's Plenary Session presentation, which is also published in this issue of *JNMM.* Participants were permitted to review the transcript of this discussion.

Jim Tape: Thank you for an extremely interesting speech. In the spirit of what you talked about, it was very open and "transparent." You discussed a number of key issues, including the Monju accident and the 70 kg of holdup at the Plutonium Fuel Production Facility (PFPF), which I know are sensitive topics in Japan.

From my point of view and what we saw from the questions after your speech, there was great interest in the concept of ASIATOM or PACIFIC ATOM. Looking 25 or 50 years into the future, what do you think the nuclear activities will look like in the region and what role will that organization play?

Hiroyoshi Kurihara: We don't know yet what the role will be of the organization or the country even. So many people are saying different things. One thing that is clear is that future organizations will not be the same as EURATOM. That is the only thing the Japanese experts agree on. One of my friends, Prof. Kaneko, wrote about the draft charter for the regional cooperation agreement. Based on this agreement the participating countries are making some kind of activities with the regional secretariat for future safeguards implementation. Maybe this body will coordinate the national activities of nuclear development. This kind of idea is vague; it is only an idea. There are no concrete proposals other than Prof. Kaneko's.

Charles Pietri: What is the major advantage to having an ASI-ATOM?

Kurihara: The countries in the region understand each other. For example, we have some problems with the attitude of China. We have major problems with the Democratic People's Republic of Korea. We also have some slight uneasy feelings about the Korean and Taiwanese interests. And, for Southeast Asia, we don't know whether they would like to construct their nuclear economy. By having a regional organization, we have confidence building in the region, and that will help the entire region.

Pietri: Is it because there are more similarities than being under a broader IAEA-type umbrella?

Kurihara: Knowing each other through experience makes us more confident. If we don't know what they are going to do, we have suspicions.

Through the regional system we know each other, we have more experience and credibility. This is the method for the regional system. If the regional system is so strong and fixed, and North Korea is outside, what are they going to do? This is a kind of black box. I want to avoid its becoming a black box. I want to be able to see inside. The regional system is a very important step.

China is constructing more nuclear power stations. If there is a problem or an accident it affects not only China but everyone in the region. The nuclear safety of China for example is not only China's interest but is the whole region's interest. So if we have nuclear cooperation with China and we share the same level of safety standards, it all helps.

This approach can also apply to nuclear safeguards and nuclear control. It is my opinion that nuclear material control is a part of the quality control of the nuclear industry. Quality control and quality assurance concepts are well understood in modern industrial societies. Take the case of Russia. Before communism they were not experienced in the modern way of industry, so they didn't have any concept of quality assurance or nuclear material control. That is a weakness. So I am afraid that China has a problem understanding the concept of quality control. China is not based on notions of modern industrial society. We need to discuss with the Chinese the basis for nuclear material control and quality control. That is a reason why I want frequent contact with them, to upgrade their level of understanding. If we share this understanding of material control and accountancy safeguards and provide regional assistance, this will be a good step. If we are too hasty in establishing a regional safeguards office though, the results will not be good.

Tape: It has been observed in EURATOM that there has been a shift of the most sensitive activities, sensitive from a nonproliferation point of view, to the nuclear weapons states that are members of EURATOM. So we see reprocessing and MOX fuel fabrication occurring in the United Kingdom and France. In the Asia region or the Pacific region, we don't see it occurring that way because Japan already has these facilities and is not a nuclear weapons state. Do you anticipate a shift of these activities to China as nuclear activities grow in the region?

Kurihara: The Chinese authorities already informed us that they would like to construct reprocessing plants for civilian use. They want to start it as a small-scale project and progress to medium-scale and large-scale use. They intend to develop fuel-cycle facilities for civilian use because they already have the technology which is used for military purposes. In the future I suppose that China will be the center of nuclear fuel-cycle activities for civilian use. Japan will continue to be a nuclear fuel-cycle country because Japanese people don't have any other energy resources domestically. Plutonium will be very important 50 or 60 years from now.

You know that South Korea at one time wanted to have reprocessing because they have the pressure of dealing with spent fuel. They have a problem, but because of the political situation in the Korean peninsula, they don't want to move in this kind of direction. So the United States stopped this movement. The same thing happened in Taiwan.

So as a region we need to discuss what to do with spent fuels. Perhaps we deal with it by having a regional spent fuel site or storage stations. That might be one of the ways to create a regional fuel-cycle facility. Taking out sensitive materials from countries that are not as safe and keeping the activities within a safe country is one way of lessening proliferation problems. On the other hand, President Clinton doesn't want to accelerate the civilian use of plutonium. If a regional reprocessing facility increases the use of plutonium MOX fuel in other countries, it will receive an unwelcome reaction. Certainly this is a problem.

From the Japanese point of view, sometimes we feel that the U.S. president's intentions intervene too much in the policy of other nations.

Tape: Do you foresee in the future the possibility of a joint Japan and China initiative to construct a reprocessing plant?

Kurihara: I must say it might be a possibility, but the relationship between the two countries is rather complicated. I don't know whether we can accomplish it between the two countries alone. Certainly we need a third party, preferably the United States. If the United States will not participate, we could ask one of the European countries.

Vincent J. DeVito: There is still a possibility that the political atmosphere surrounding China and Taiwan could be a problem.

Kurihara: Apart from regional consideration, we have various problems. One problem is the nations participating in such a framework. China and Taiwan generally can't participate together. In the cases of some economic forums, China and Taiwan can participate together though. But it is only in such activities. If the forum includes some political aspect, China will say no to Taiwan. Taiwan, however, has a significant amount of nuclear activities already, and this is a very difficult problem. The other problem is North Korea, of course.

Tape: One of the other themes in your paper this morning was Japan's support to the international safeguards community, more broadly the nonproliferation community. It seems to me that Japan has made a very conscious effort to reach out more in these matters. Tell us about the work you are doing in Russia. I am aware of some activities you are pursuing in Kazakhstan.

Kurihara: Most contributions in the Ukraine and Kazakhstan are to assist the establishment of their national State System of Accounting for and Control of nuclear materials (SSAC). This is a joint activity of the U.S.A., Sweden, Germany, other European nations, and Japan. The activities are coordinated by the IAEA. In Kazakhstan there is a fast reactor and a plant that is making nuclear fuel pellets. Some of the equipment to be used for national material control was purchased from Japan and sent to Kazakhstan to be used to upgrade their national system. For Ukraine there is the Research Institute. The nuclear material control system of the Research Institute was designed by Germany. Based on this design, some of the equipment, again purchased by Japan, was sent to Ukraine. As for Belorus, there has been no Japanese involvement, but Japan is interested in the same types of activities.

As for Russia I must say that in nuclear material control Japan hasn't done anything so far. As for the contributions to Russia, there are the storage facilities of the nuclear material that came from dismantling nuclear weapons. They wanted containers for the storage of the nuclear material. This is a joint activity with Russia, United States, and Japan. Japan is contributing some financial aid because the United States wants some financial contributions from Japan. That is one area of assistance.

There is also assistance in the dismantling of nuclear submarines in the Japan Sea. They have a problem in where to store the nuclear waste from dismantling nuclear submarines. And they just discharged liquid nuclear waste into the Japan Sea. The Japanese government was very much surprised at that. So finally the Japanese government contracted with a Russian partner to construct a storage facility on their land to store radioactive waste materials from dismantled nuclear submarines.

The other contribution to Russia is in the area of safety. Part of the RMBK type nuclear power stations are not safe compared with Western standards. Japan wants to supply Russia with equipment that detects cracks in the pipes by "hearing" the sounds. This type of equipment was successful in our country in one of the advanced thermal reactors (Fugen). There are similarities in the designs of Fugen and Russian RMBK type reactors.

The equipment was used and demonstrated in the Leningrad nuclear power station and it worked quite successfully, so that the Russian government wants more equipment. Also, the fuel from dismantled missiles is toxic. A research institute in Japan has a very good method for decomposing this toxic fuel. This type of contribution is also going on. There are small efforts to identify to what extent the former missile sites (ICBM and so on) are contaminated. Japan has started to examine how much money is needed for surveys to tell how deeply the sites are contaminated, before restoration. This has already started.

Of course there is another effort, the International Science and Technology Center (ISTC), whose intention it is to find jobs for nuclear scientists in Russia. This is a joint effort of the United States, European Union and Japan. As far as I know, those are many contributions.

Tape: I think the activities of ISTC are potentially very important and Japan's contribution could be significant because you have such an active nuclear industry. There are opportunities for nuclear scientists from Russia to interact with experts who are working with peaceful applications. Within the United States our nuclear industry is much more narrowly focused these days, so you may have in fact a better opportunity.

Kurihara: I must confess that so far our contribution has not been so great. Some time ago, maybe one or two months, people from ISTC made some presentations to Japanese industries. They have some potential to generate support, but Japan is not very interested. Substantive contributions to ISTC were first made by the United States and then by the European Union countries. Japan is actually lagging behind.

Tape: How about Program 93+2 of the IAEA. Is that something you are making contributions to?

Kurihara: When it was discussed by the IAEA Board of Governors there was a rumor, which seemed to spread widely, saying that Germany and Japan are strongly opposed to taking new measures included in Part II of Program 93+2, which is not at all true. It is true that Japan's government has always made comments that we are very cautious about implementing new measures in Japanese facilities. Of course this program is aimed at finding out undeclared activities, especially in some suspected countries. But because it will be implemented by the IAEA, the IAEA must implement its new measures without discrimination among member states. So, you know that traditionally the aim was to watch countries like Iraq and North Korea, but this measure should be implemented in all countries that are party to the NPT, including Japan.

So to accept those new measures of the Agency implementation to apply to Japan, Japan must amend its domestic rules. Japanese domestic regulation does not permit Agency inspectors access to the facilities in which nuclear material is not used, although such facilities are within the nuclear industry. Typical cases are, e.g., zircalloy tubes fabrication plants, fabrication plants of centrifuge for uranium enrichment. If the international requirements of Program 93+2 are vague, the Japanese government has difficulty promulgating the domestic regulations. It stems from the type of national regulations that evolved 120 years ago when we were Westernized. We imported various systems from Western countries. I don't know why, but the legal system in Japan is imported from Germany, and the German legal system is different from the United States system. The German system is more rigid and the Japanese system is rigid too. So if you promulgate any kind of domestic rule in our country you have to define the boundary conditions within which the present rule will apply.

There is one more point that I would like to explain. Japan would like to see some streamlining in the Agency's safeguards implementation. At yesterday's International Safeguards Division meeting, some people made strong statements that the Agency is not adequately funded. I share that view. Compared with the total cost of international security — for example how much money is needed to make more war ships — the Agency's budget for administering international safeguards is very small. Some might say that it is peanuts. But still another problem is that the Agency is financially supported by member States' governments. I don't know why recently almost all governments have had deficient budgets. Compared with those of private industry, the government budgets are problematic.

Therefore, even if governments wish to increase contributions, they don't have any money. The Agency's budget will not increase. So if you want an increase of new measures, you must streamline the operations. There are two ways to do this. One way is with more technology for remote transmission of data without the presence of the Agency's inspector onsite. That reduces the Agency's staffing. This is a good direction and the Japanese government is willing to assist in implementing this type of new technology. The other way is using the manpower of other organizations effectively. Namely, a part of the Agency's inspection effort could be shared by a national safeguards system (SSAC). This is a very touchy point, and the European people don't like this idea because EURATOM is a regional safeguards system and Japan's is a national safeguards system. Politically and socially, the regional and national systems are different.

And what is the purpose of the Agency's safeguards if there is a national diversion? So that regional systems can check for national diversions, but a national government cannot detect national diversions by itself. However, I would say that any Agency safeguards activities are based upon information submitted by the Government. If the Agency does not believe the information came from the State at all, safeguards implementation cannot be realized. So, at least in some part, the Agency is to rely on the Government's activities. So, if technically the national government has very efficient or almost equivalent SSAC to the Agency, the Agency can have the same types of activities as the partners in EURATOM. One step further, the Agency can delegate some of the activities to the national system and the Agency could audit the activities of the delegated system. This concept is still being developed. The basis of the idea is that you must have a very effective national system. That is the reason we are intensifying the upgrading of the quality of the national safeguards systems.

Dennis Mangan: In the United States there is an initiative addressing chemical/biological weapons of mass destruction. Do the Japanese have an active program addressing the nonproliferation of other weapons of mass destruction?

Kurihara: There are two activities, neither of which are significant. But so far we had not been so attentive to these kinds of weapon of mass destruction: biological and chemical. But after the recent Onmu Super Truth cult activities, we are reminded that this is very dangerous. The Ministry of Foreign Affairs has an Arms Control and Disarmament Division. Within this division there is a newly created office called the Office of Nonproliferation. It does not refer specifically to nuclear weapons. The major part of its job is controlling chemical and biological weapons and the transportation of missiles. This is a new movement that the government undertook as it has become more interested in dealing with this problem.

There is also the Institute of International Studies, which gets most of its money from the Ministry of Foreign Affairs. Part of this institute, which will become independent in the near future, deals with nonproliferation of weapons of mass destruction. Although the number of people working for the Institute is very small, less than ten now, the Institute intends to increase its force.

You know Mr. Koyumaki has to retire from the job because he has reached retirement age. This is the center for nonproliferation. Major parties NBC (Nuclear Biological and Chemical), wanted to have nuclear scientist, so we recommended Mr. Koyumaki to go over there. Sometime this year he will move from JAERI to this new center.

Deborah Dickman: You were looking at ways of improving the quality of inspectors and training them ...

Kurihara: It is in our national interest to improve the quality of inspectors. You know that in our country safeguard inspectors are government officials. Our governmental official recruitment system is very peculiar — every one, two, or three years the government officials must change their jobs within the same ministry. So, when a young government official takes a post as a safeguards inspector, he must take a training course and have six months to a year of experience to be an experienced inspector. But after three years' experience, the inspector has to go to another division and learn nuclear safety licensing and so forth.

Dickman: So they wouldn't be available for inspections anymore?

Kurihara: Right. We have about 30 full-time inspectors and 90 part-time inspectors — all government officials, but they always rotate. This is the weakness of the government system, and it is one that we hope to rectify. A possible way to do so is to delegate the authority of safeguard inspection to the more expertised organization, in which safeguard inspectors can stay for a long time.

Dickman: After they rotate through the divisions do they come back into the safeguards division?

Kurihara: They almost never come back. I came back three times — that is why I am regarded as a safeguards and nonproliferation specialist, which is quite a rare case in the Japanese government. This is similar to the British governmental system. This system generally helps when an individual moves into a management job. If he has been rotating every few years and has experience in various jobs — although it is kind of being a non-expert — when he is the boss, he knows everything, at least from his point of view.

My remarks so far have related to safeguards jobs in the Japanese government. The same can also apply to the nuclear safety inspectors. The government is also the body to issue a license for construction and operation of nuclear facilities. The government requires a workforce of nuclear safety experts. However, governmental safety examiners are also to rotate every two or three years. We must have more specialists in the field — we need to escape from the amateurism. Our Nuclear Material Control Center (NMCC) is an independent, nonprofit organization. We have people who are trained to be safeguards experts. At this moment the government intends to ask the NMCC to implement routine safeguards inspection jobs. By doing so, the NMCC inspectors can stay at their jobs for 10 or 15 years. This is the process of upgrading the quality of the national inspection system.

Dickman: Do your inspectors get the training they need in Japan or do they go to the [International Atomic Energy] Agency?

Kurihara: No. This is a kind of on-the-job training. Already we talked to Mr. Perrios of the IAEA — he is the director of SGOA. Once the government delegates the authority to our center, we would like to make some kind of arrangement with the ministry so that some of the inspectors will go to the IAEA for the training. The agency inspectors are frequently in Japan and could be lecturers for our national inspectors.

Tape: I see that it is time for the afternoon sessions to begin, so we must conclude this interesting discussion. Thank you very much.

Kurihara: It has been my pleasure.

Fissile Material Proliferation Risk

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Abstract

The proliferation risk of a facility depends on the material attractiveness, level of safeguards, and physical protection applied to the material in conjunction with an assessment of the impact of the socioeconomic circumstances and threat environment. Proliferation risk is a complementary extension of proliferation resistance. We believe a better determination of nuclear proliferation can be achieved by establishing the proliferation risk for facilities that contain nuclear material. Developing a method that incorporates the socioeconomic circumstances and threat environment inherent to each country enables a global proliferation assessment. To effectively reduce the nuclear danger, a broadly based set of criteria is needed that provides the capability to relatively assess a wide range of nuclear related sites and facilities in different countries and still ensure a global decrease in proliferation risk for fissile material (plutonium and highly enriched uranium).

Introduction

As the quantity of weapons-usable nuclear material increases, the proliferation risk of that material increases. Recent proliferation events (FSU material smuggled to Germany) demonstrate that the proliferation of weapons-usable nuclear material and nuclear technologic capability and expertise has become one of the predominant threats to U.S. and global security. U.S. and international efforts must focus on the threat of global or regional proliferation now that the threat of a nuclear exchange no longer dominates our attention. Various individuals, groups, and nations have a strong motivation to acquire weapons-usable nuclear material rather than to produce it because there is significant cost and time expense related to the development of the necessary infrastructure for production. Nuclear proliferation risk is based on various material, protection, and socioeconomic related dimensions and the source, technical capability, and persistence of the potential purchaser. Some of the proliferation risk dimensions are material form; physical access to material during processing, storage, and transportation; the degree of safeguards and security applied; the economic conditions and pay for workers and guards; and the political stability of responsible government authorities. Potential purchasers (threat) are, for example, a terrorist group or national government. A national government may present a valid threat if it has demonstrated a desire and technical capability to develop a nuclear program. The dismantlement and disposal of fissile material must assure against the possibility of material proliferation.

In addition to studying the technologic feasibility and cost of various disposition options (vitrification, burial, conversion to MOX fuel, ...), the impact of proliferation risk requires investigation. Prioritizing which sites should initially contribute material for disposition and assessing the proliferation risk of any sites associated with the fuel-cycle process are important factors in decreasing the potential for proliferant activities. As indicated in Fig. 1, determining the proliferation risk of various facilities/sites before or during the disposition process requires the collection and correlation of all relevant information and data into a model capable of supporting systems studies and analysis.

Global Nuclear Material Control Model

During the last year we developed the foundation of a disposition and proliferation risk systems analysis capability, the Global Nuclear Material Control (GNMC) model. This prototype model, developed on a Sun workstation, permits us to conduct systems studies and analyses on the elements and

Fig. 1. Proliferation risk analysis depends on the distribution of nuclear material.

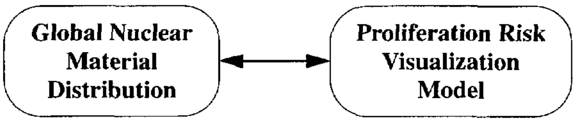
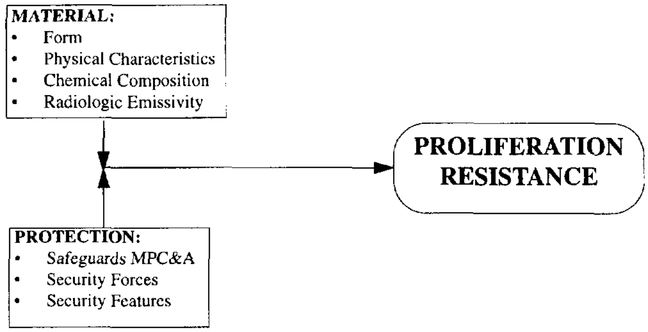


Fig. 2. Elements of proliferation resistance



factors that affect and are associated with the inventory of nuclear material. The GNMC has analytic computational capabilities in the following areas: management, protection, control, and accounting (MPC&A) of safeguards and security resource allocation, material disposition options, and material production and dismantlement (proliferation source). The GNMC provides a representation of this information and the data related to nuclear facilities/sites and the inter- and intra-country nuclear material distribution. The GNMC characterizes site and facility information, nuclear material inventory data, and nuclear material production capabilities. Specific analytic capabilities have been included to calculate the future production of nuclear material, to investigate alternative disposition options, and to estimate future inspection resource requirements for nuclear material MPC&A required to meet International Atomic Energy Agency (IAEA) safeguards and security criteria. In addition to the GNMC effort, we have been researching an analytical model for determining the proliferation risk of specific countries, sites, or facilities within the context of the GNMC.

Proliferation Risk Model

The distinction between proliferation resistance and risk requires clarification. The proliferation resistance of nuclear material depends on the material attractiveness in association with the level of safeguards and physical protection applied, is shown in Figure 2. The degree of safeguards and security applied domestically and internationally is related to a material attractiveness determination. Criteria have been developed by the IAEA, the Department of Energy (DOE), and the Nuclear Regulatory Commission (NRC) for evaluating the relative attractiveness of nuclear materials for use in weapons. These criteria are used for the purpose of applying a ranked safeguards approach so that materials that are most easily used for nuclear weapons purposes are assigned increased safeguards. Summarized in Table 1, these criteria are generally based on the time that would be required to process the material into weapons grade, the technical difficulty of that processing, and the quantity of material considered significant for the development of a weapon. Although the criteria differ slightly, especially for the significant quantity value, there is similarity and overlap amongst the related attractiveness concepts and levels. The 1994 National Academy of Sciences (NAS) study[1] suggested using the "spent fuel standard" as a metric for evaluating the proliferation resistance associated with options for the final disposition of plutonium from nuclear weapons declared excess to military purposes. The "spent fuel standard" simply stated means that excess weapons plutonium is made as inaccessible for weapons use as the large amounts of plutonium in commercial spent fuel. The spent fuel standard is a material attractiveness concept; it defines proliferation resistance in terms of the self-protecting attributes of the material and its need for chemical processing. Proliferation resistance neglects the impact contributed by the threat environment and the socioeconomic circumstances.

The proliferation *risk* of a facility depends on the material attractiveness, level of safeguards, and physical protection applied to the material in conjunction with an assessment of the impact of the socioeconomic circumstances and threat environment. Proliferation risk is a complementary extension of proliferation resistance. We believe a better determination of nuclear material proliferation can be achieved by establishing the proliferation risk for facilities that contain nuclear material. Developing a method that incorporates the socioeconomic circumstances and threat environment inherent to each country enables a relative global proliferation assessment. This is important if the criteria adopted by the United States is to be a model for global fissile material disposition. To effectively reduce the nuclear danger, a broadly based set of criteria is needed that provides the capability to relatively assess a wide range of nuclear related sites and facilities in different countries and still ensures a global decrease in proliferation risk for plutonium and other fissile material. The effectiveness of safeguards can only be determined when it is considered with respect to the current socioeconomic circumstances and threat environment; otherwise the level of safeguards only indicates the proliferation resistance of a nuclear facility. Depicted in Figure 3 are the four

Table 1. Materials Attractiveness Criteria to Determine Ranked Safeguards and Security

Criteria	IAEA	DOE	NRC
Significant quantity	8 kg	2 kg	2 kg
Attractiveness of material for weapon use	Difficulty and time of processing required for usable form	Amount of processing required for usable form	Quantity of material and degree of self protection
High and low of the attractiveness level range[a]	High - Separated Pu. Low - Fuel Assembly	High - Assembled weapon or device Low - Highly irradiated forms	High - Large qty. and low self protection[b] Low - Small qty. and high self protection

[a] The DOE range of levels in order of decreasing attractiveness are assembled weapons; directly convertible materials such as pits; high-grade materials such as oxides; low-grade materials such as process residues; and highly irradiated forms.
[b] High self protection for Pu is defined as Pu in radioactive material with a total external radiation dose rate in excess of 100 rems/h at 3 feet.

components that comprise the proliferation risk analytic model: material desirability, protection accessibility, socioeconomic stability, and threat capability.

Material Dimension of Proliferation Risk

The material dimension is determined by a number of components related to the physical attributes of the material. The form of the material with respect to the actual physical characteristics, chemical composition, and radiological emissivity influence the desirability of the material and hence the proliferation risk of that material. The physical characteristics, weight, and size affect a proliferator's ability to transport the material. For example, a plutonium pit resulting from dismantlement is more easily concealed and transported than a spent fuel assembly. The chemical composition of the material influences the level of technical knowledge and capability a proliferator must have, as well as the time it takes to produce a weapons-usable form. Plutonium metals, carbides, and oxides require no or little processing to manufacture enough material in a usable form; whereas plutonium in spent fuel requires time-consuming and complex processing to manufacture enough material. Finally, the radiological emissivity of the material imposes restrictions on handling and shielding requirements, which increase the time and complexity to process the material. Spent fuel requires remote handling equipment and shielding to prevent lethal radioactive dosing. Quantitative measures exist for this dimension, such as size, weight, and rems/h at 1 meter. The desirability of the material depends on the physical characteristics, chemical composition, and radiological emissivity of the material. Material resident at a particular facility that is desirable results in greater proliferation risk for that facility.

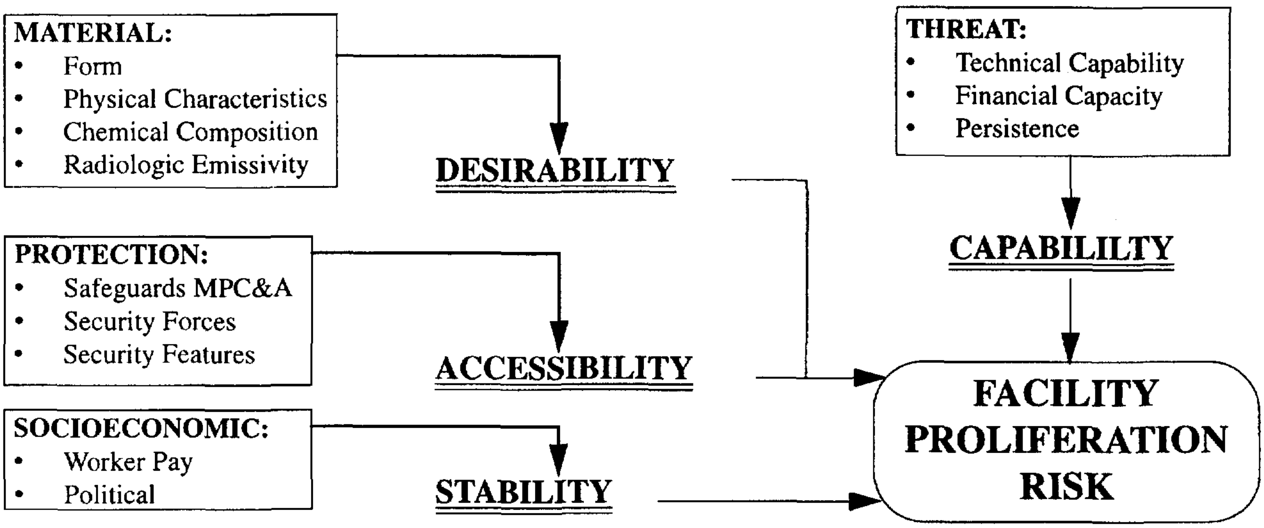
Protection Dimension of Proliferation Risk

The protection dimension is determined by the physical access to material during processing, storage, and transportation and the degree of safeguards and security applied. Physical access is related to the quantity and type of impediments imposed around the processing, storage, and transportation of the material and the degree to which these impediments can be defeated or compromised. Generally, the greater the number and type of impediments the less accessible the material becomes and the lower the proliferation risk. Some of the typical components to consider as part of physical access are gates, guards, monitors, physical structure, penetration difficulty, facility isolation, and for a processing facility, the degree it is automated (preventing worker access). Components to consider as part of safeguards are automated accounting systems and containment and surveillance systems. Quantitative measures exist for this dimension, such as type and quantity of barriers and quality and quantity of safeguards systems. Safeguards and security depend on the material accounting and control technology and the containment and surveillance technology. The more safeguards and security technology utilized at a facility the less accessible and, hence, the less likely material theft and diversion occurs. The less accessible material is at a facility the lower the proliferation risk for that facility.

Socioeconomic Dimension of Proliferation Risk

The socioeconomic dimension depends on the economic conditions and pay for workers and guards and the political stability of responsible government authorities. This is at least partially a subjective measure. However, by using it to conduct relative comparisons between sites and states, it is an important element in an assessment of proliferation risk. By including this dimension we are able to include assessments, evaluations, and information that exist and to provide a basis by which proliferation comparisons and ranking can be made. For example, one way to defeat or compromise the physical access impediment component of the protection dimension is to bribe workers or guards, which will occur with more success if the bribee is economically distressed. In politically unstable states, the proliferation risk increases due to the lack of authoritative control, the perception

Fig. 3. Dimensions and some factors of facility proliferation risk.



that there are no responsible authorities, and when there is no authority to impose punishment. Quantitative measures exist for this dimension, such as gross domestic product, per capita income, cost of living, and unemployment rate. The quantitative measures are supplemented by qualitative measures, such as political stability, level of civil strife, type of political regime, and political leadership assessments. Associated with decreased socioeconomic stability is increased proliferation risk.

Threat Dimension of Proliferation Risk

A proliferation threat can come from a criminal, terrorist, subnational organization, or national government. Nuclear facilities and sources for fissile material are of particular concern in, for example, the states of the FSU, the threshold weapon states (India, Israel, and Pakistan), and the potential weapon states (Iran, North Korea, and Iraq). In the FSU, accounting for nuclear materials has been limited, but physical protection measures have been strong. However, there are recent signs that the physical protection system may be eroding and that the criminal and terrorist threats in these countries have increased. All three of the threshold states are reported to have nuclear weapons production capability with a limited stockpile. The potential states, Iraq and North Korea, have clearly had proliferant activities, and Iran is suspected of having a clandestine nuclear weapons program. Associated with a threat is a degree of persistence or commitment and technical capability and financial capacity to successfully obtain and process fissile nuclear material into a usable form. The proliferation risk of a nuclear-related facility can be strongly affected by a broad spectrum of completely divergent threats: a well funded, organized, and technically capable terrorist group desiring fissile material or the political decision of a nation to initiate a weapons program. The complexity, time, and cost of the processes required to recover a significant quantity of material through chemical reprocessing or isotopic enrichment is a measure of the difficulty of processing and inversely, the isotopic quality of the material. This measure of difficulty indicates the level of technical capability and resources required by the threat to be successful. Quantitative measures exist for this dimension, such as chemical form, isotopic concentration, process facility needs, and time and cost to process a significant quantity, which can be utilized to determine the threat's required level of technical capability and financial capacity. Threats with technical capability, financial capacity, and political or ideological commitment increase the proliferation risk.

Interdependence of Dimensions

The components of the proliferation risk elements — material desirability, socioeconomic stability, threat capability, and protection accessibility — are interrelated. Variations in one component either necessitate a responsive change in another component or alter the proliferation risk assessment of a facility. The following variations in the proliferation risk dimension components illustrate some of these interdependencies. The material form influences the safeguards MPC&A; materials in item form are more readily safeguarded than materials in bulk form where measurement uncertainties complicate precise accounting for the material. Radioactive emissivity influences the technical capability and financial capacity required by the threat; radioactivity increases the self-protective nature of the material that makes theft and transport more complex. Economic deprivation of workers and guards influences the security features and security forces; unpaid workers are more likely to divert material for criminal or terrorist threats. Political agreements and policies are only valid if they are durable; political instability creates opportunity for proliferation threats. Examination of the interdependencies and trade-offs between all of these components is necessary to achieve a proliferation risk assessment and to determine the efficacy of safeguards.

Country Proliferation Risk

To obtain the proliferation risk assessment for a country, it is necessary to assess all the facilities at all the sites within a country. Figure 4 shows the hierarchical nature of proliferation risk at the country level. The aggregation of proliferation risk for countries and sites is straightforward. Analytically the country proliferation risk is represented by the following equation

$$CP = \sum_{i}^{s} SP_i . \qquad 1.0$$

The analytic equation for the representation of site proliferation risk is the summation of the proliferation risk for all facilities present at each site

$$SP = \sum_{i}^{f} FP_i . \qquad 2.0$$

where CP = country proliferation risk, SP = site proliferation risk, FP = facility proliferation risk, s = number of sites in the country, and f = number of facilities at the site. Both of these equations merely reflect the hierarchical structure. However, the most important assessment is at the facility level.

Analytical Model

The proliferation risk of a particular facility depend on the impact of the various dimensions. The material, protection, threat, and socioeconomic dimensions are each composed of specific factors that impact the proliferation risk of a facility. The facility proliferation risk is determined by the interdependency of these dimensions and the importance of their respective factors. Simplistically, facility proliferation risk is represented by

$$FP_i = MD - PA + SS + TC , \qquad 3.0$$

where FP = facility proliferation risk, MD = material desirability, PA = protection accessibility, SS = socioeconomic stability, and TC = threat capability. A first approximation of each of these dimensions is presented in equations 4.0–7.0

$$MD = \sum_i (MF_i \times Mwt_i) , \qquad 4.0$$

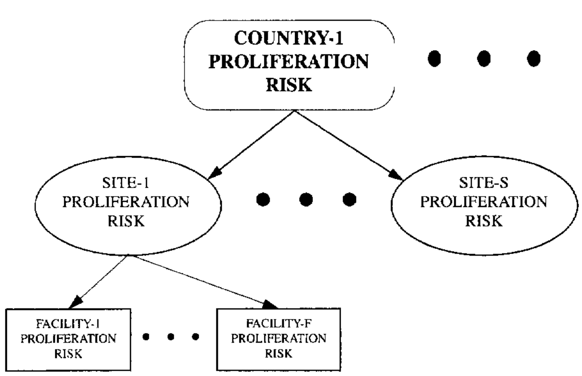
$$PA = \sum_i (PF_i \times Pwt_i) , \qquad 5.0$$

$$SS = \sum_i (SF_i \times Swt_i) , \qquad 6.0$$

and $TC = \sum_i (TF_i \times Twt_i)$, 7.0

where MF = material factors, PF = protection factors, SF = socioeconomic factors, TF = threat factors, and Mwt, Pwt, Swt, and Twt are the weights associated with each factor ($0 < wt \le 1$). To develop beyond the first approximation a number of methods, possibly including fuzzy logic and data fusion techniques, will be required to develop and implement the facility factors assessment.

Fig. 4. Country proliferation risk depends on proliferation risk at all sites and facilities.



Example Facility

An example of a representative facility is presented that demonstrates this methodology, using the dimensions and factors listed in Figure 3. The representative facility is a storage facility. The facility stores the following material: the form is separated reactor-grade plutonium (>18% ^{240}Pu), the material is physically packaged in individual containers, the material composition is plutonium dioxide (PuO_2), and the material has low radiologic emissivity. The facility inventories the containers on a regular schedule, the facility is protected by a domestic security force, and it is a modern cement structure with two rows of security fencing containing motion detectors. Socioeconomically, the workers are educated and well paid. The regional and national authorities responsible for this facility coordinate activities and provide regulatory oversight. Finally, there is little technical and financial capability required of a threat element (criminal, terrorist, or national government) because oxide is easily processed into a metal form.

The dimension, factors, factor descriptor, factor descriptor characteristic, maximum values, and values are presented in Table 2. The maximum values that each set of dimension factors

Table 2. Representative Facility Information and Data

Dimension	Factor	Factor Descriptor	Factor Descriptor Characteristic	Max. Value	Value
MD	MF_1	Form	Oxide	10	9
MD	MF_2	Physical Characteristic	Individual Containers	10	8
MD	MF_3	Chemical Composition	Reactor-grade Pu	10	7
MD	MF_4	Radilogic Emissivity	Low	10	10
PA	PF_1	MPC&A	Inventories	10	4
PA	PF_2	Security Forces	Domestic Force	10	6
PA	PF_3	Security Features	Structure & Fencing w/Sensor	10	6
SS	SF_1	Worker Economics	Educated & Paid	6	3
SS	SF_2	Political	Evident	6	3
TC	TF_1	Technical Capability Required	Minor of Threat	6	5
TC	TF_2	Financial Capability Necessary	Minor of Threat	6	5
TC	TF_3	Persistence	No Threat Perceived	6	0

can achieve are not necessarily the same, and neither are the factor weights. The maximum value possible reflects the significance of the dimension. The higher the MD the more desirable the material, the higher the PA the lower the material accessibility, the lower the SS the more stable the social circumstances, and the lower the TC the safer the environment. To simplify the example we have chosen factor weights of 1.

The dimension summation calculations (using Mwt, Pwt, Swt, and Twt all equal to one) give

$$MD = (9 + 8 + 7 + 10) = 34, \text{ a high value,}$$

$$PA = (4 + 6 + 6) = 16, \text{ a medium value,}$$

$$SS = (3 + 3) = 6, \text{ a medium value, and}$$

$$TC = (5 + 5 + 0) = 10, \text{ a medium-to-medium-high value.}$$

The resulting facility proliferation risk value is

$FP = MD - PA + SS + TC = 34 - 16 + 6 + 10 = 34$, a medium-high value (scale of -30 to 70). The renormalized value becomes 64 (the renormalized scale is 0 to 100).

Summary

Evaluating the proliferation risk of facilities or processes for fissile material needs to satisfactorily include the risks from the beginning to the end of the physical process. To determine these proliferation risks, it is necessary to include the threat environment and socioeconomic circumstances in each country. The "spent fuel standard" provides a proliferation resistance measure, but it does not consider the threat environment or socioeconomic circumstances in a country. The level of safeguards applied at a facility only indicates the resistance of the facility to proliferation. The effectiveness of safeguards systems is indicated by the proliferation risk of the facility. Proliferation risk can only be determined when it is considered with respect to the current socioeconomic circumstances and threat environment.

The GNMC establishes the framework and an analytical model for evaluating and assessing the global production, disposition, and international safeguards and security requirements for nuclear material. A benefit of this work is the resulting capability to establish and investigate proliferation risk. By exploiting and utilizing the GNMC framework as the foundation for the development of a proliferation risk system analysis capability, we have the ability to determine the proliferation risk of existing sites/facilities.

References

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Verifying the Absence of Undeclared Activities

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Abstract

The resource distribution problem posed to arms control, disarmament, and nonproliferation regimes by the extension of the rights of inspectorates to look for undeclared, illegal activities is analyzed in terms of noncooperative game theory. A general solution for the inspection of locations within a State subject to verification is derived, which relates quantitative, optimal inspection probabilities to a subjective assessment of of the importance of the locations.

Introduction

Recent developments in international arms control and nonproliferation regimes have focused attention on situations in which illegal action is postulated at certain locations which are not declared and therefore not subject to routine inspection. Important examples include the possible coexistence of undeclared and declared nuclear facilities under the Nuclear Non-proliferation Treaty (NPT), the potential misuse of industrial facilities to produce chemicals scheduled under the Chemical Weapons Convention (CWC), and undeclared strategic location of military equipment in the frame of the Conventional Forces in Europe (CFE) Treaty. While under the CWC the Inspectorate will essentially have the right to inspect any location it chooses and while the "open skies" extension of the CFE provides a similar capability, this freedom of choice is not yet provided for in international nuclear safeguards. In the 93+2 Programme for improving the effectiveness and efficiency of safeguards the IAEA has proposed measures that will considerably extend its right to access under the NPT and, furthermore, increase the amount of information made available to it through its member States.

In the hypothetical situation in which both routinely inspected as well as undeclared locations are available for clandestine misuse, it is reasonable to assume that a Treaty violator will first assess the attractiveness of his various options and act accordingly. However, the Inspectorate, on the basis of the increased information made available to it both through voluntary declarations and otherwise, may not only have some idea as to where undeclared activity might occur, but also be capable of reconstructing the violator's assessment. Given this, the question still remains as to how the Inspectorate should best apportion its limited resources among the various locations, declared or undeclared. We address in this paper a simple model that relates such inspection strategies to the subjective and technical parameters characterizing the locations involved.

The Model

We consider N locations subject to inspection, not necessarily declared. Let the number d_i represent the attractiveness or pay-off to the State, on an arbitrary scale on which legal behavior has attractiveness nil, of an undetected violation of the Treaty at location i. One might argue that in most cases $d_i < 0$, $i = 1 \ldots N$; that is, most Treaty States prefer legal behavior. This of course begs the question of a verification regime, so we must assume

$$d_i > 0, \quad i = 1 \ldots N$$

for all locations i that are considered to be liable for inspection. Furthermore we can prioritize the State's options by assuming, without loss of generality, that location 1 is at least as attractive as location 2, location 2 is at least as attractive as location 3, and so on:

$$d_1 \geq d_2 \geq \ldots \geq d_N.$$

Of course the State may get caught. If it does, it will presumably get a negative pay-off on the above scale (Iraq certainly did!), and we call this

$$-b_i < 0, \quad i = 1 \ldots N.$$

Just where it gets caught may well be immaterial, so that the b_i may all be equal. However we will distinguish them for the time being. Apart from its attributed attractiveness for violation d_i and the perceived sanctions b_i, each location has an important *technical* attribute, namely the *probability of detection* of an illegal act, provided the location is in fact inspected. We will denote this quantity, in accordance with standard notation, as

$$1 - \beta_i, i = 1 \dots N.$$

Unlike d_i and b_i, the probability of detection is, in principle at least, establishable on the basis of purely technical considerations, e.g., goal quantities, material accessibility, false alarm probability, facility design, etc. In order not to complicate the discussion here, we will ignore the possibility of false alarms, although their inclusion is neither trivial nor without consequence.[1,2]

It is tempting now to try to devise a formula involving the subjective and technical parameters $\{d_i, b_i, 1 - \beta_i\}$, that would allow the Inspectorate to apportion its resources among the N locations in some sensible way. In fact this is precisely what we shall do. However, it isn't possible to proceed without further parameterization, because we are dealing with a strategic situation; neither the Inspectorate nor the controlled State can act rationally without taking into account the options and utilities of the other party.

Consider then the preferences of the Inspectorate, which we normalize in a similar way. The pay-off is nil if the State behaves legally, and

$$-c_i < 0, \quad i = 1 \dots N,$$

for undetected violation at location i. What about detected illegal activity? Certainly the Inspectorate's first priority is to deter violation. This implies that its pay-off in this instance, which we call $-a_i$, should satisfy

$$-c_i < -a_i < 0, \quad i = 1 \dots N,$$

Now we are in a position to characterize the strategic situation. With respect to some reference period, such as a calendar year, let the probabilites of an inspection and an illegal activity at location i be given by p_i and q_i, respectively, $i = 1 \dots N$. Suppose that the State decides once and for all whether or not to violate and, should it do so, carries out its illegal activity at precisely one location. Its strategies are

$$\{q_i | q_i = 0, i = 1 \dots N\} \tag{1}$$

for legal behavior, and

$$\{q_i | 0 \le q_i \le 1, i = 1 \dots N, \sum_{i=1}^{N} q_i = 1\} \tag{2}$$

for illegal beahvior. The expected pay-off to the State depends on the actions of both parties. It is

$$\begin{aligned} S(\mathbf{p}, \mathbf{q}) &= \sum_{i=1}^{N} (1 - \beta_i) p_i q_i (-b_i) + \beta_i p_i q_i d_i + (1 - p_i) q_i d_i \\ &= \sum_{i=1}^{N} (d_i q_i - A_i q_i p_i) \end{aligned} \tag{3}$$

where $\mathbf{p}$ and $\mathbf{q}$ are the strategy vectors $(p_1 \dots p_N)$ and $(q_1 \dots q_N)$, respectively, and where for convenience of writing we have introduced

$$A_i = (b_i + d_i)(1 - \beta_i) > 0, i = 1 \dots N.$$

The Inspectorate verifies n locations randomly within the reference period, not inspecting any location more than once. Its strategies are, similarly,

$$\{p_i | 0 \le p_i \le 1, i = 1 \dots N, \sum_{i=1}^{N} p_i = n\}, \tag{4}$$

whereas its expected pay-off is

$$\begin{aligned} I(\mathbf{p}, \mathbf{q}) &= \sum_{i=1}^{N} (1 - \beta_i) p_i q_i (-a_i) + \beta_i p_i q_i (-c_i) + (1 - p_i) q_i (-c_i) \\ &= \sum_{i=1}^{N} (-c_i q_i + B_i q_i p_i) \end{aligned} \tag{5}$$

with

$$B_i = (c_i - a_i)(1 - \beta_i) > 0, i = 1 \dots N.$$

The parameter n is the expected number of inspected locations and might be thought of as a very rough characterization of the total inspection effort invested within the State over the reference period.

The Illegal Game

To determine the desired prescription for the Inspectorate, we clearly need a solution concept that will tell us which strategy $\mathbf{p}$ will optimize its pay-off, taking full account of the strategic alternatives $\mathbf{q}$ of the State. This is provided by Nash equilibrium.[3] A rational solution for both protagonists is a pair of strategies $(\mathbf{p}^*, \mathbf{q}^*)$ that satisfies the inequalities

$$\begin{aligned} &I(\mathbf{p}^*, \mathbf{q}^*) \ge I(\mathbf{p}, \mathbf{q}^*) \text{ for all } \mathbf{p} \\ &S(\mathbf{p}^*, \mathbf{q}^*) \ge S(\mathbf{p}^*, \mathbf{q}) \text{ for all } \mathbf{q}. \end{aligned} \tag{6}$$

These inequalities express Nash's fundamental criterion for rational behavior in a noncooperative situaton, namely that neither party can have an incentive to depart unilaterally from its chosen strategy. Athough there exists no other satisfactory solution concept for the resolution of conflict, Nash equilibria are not necessarily unique. One may at times be faced with a difficult equilibrium selection problem, the classic example being the game called "the battle of the sexes"[4] We will return to this point in the final section.

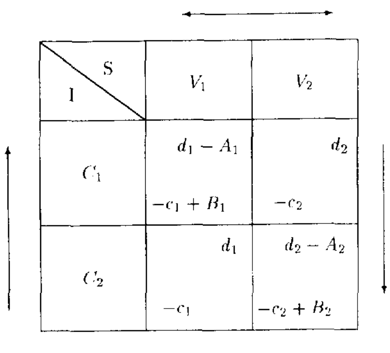

Figure 1. The 2 × 2 inspection game in bimatrix form. The pure strategies of the Inspectorate are C_i (control location i, i = 1, 2) and of the State V_i (violate at location i, i = 1, 2). The State's payoffs for any combination of pure strategies are shown upper left, those of the Inspectorate lower right. The vertical arrows show the preference directions for the Inspectorate, the horizontal arrows those for the State. For example, if the State considers the strategic situation (C_2, V_2), it has an incentive to deviate to V_1 as indicated by the arrow at the bottom of the figure.

Before presenting the general solution of the illegal game, that is, the game in which the State chooses to violate, it is illustrative to consider first a much simpler case in which only two locations exist and precisely one of them is inspected at random.

The Inspection of Two Locations

We consider the case $N = 2$ and $n = 1$. Then we can write $p_1 = p$ and $p_2 = 1 - p$, so that equations (5) and (3) reduce to

$$I(\mathbf{p}, \mathbf{q}) = p((-c_1 + B_1)q_1 - c_2 q_2) + (1 - p)(-c_1 q_1 + (-c_2 + B_2)q_2)$$
$$S(\mathbf{p}, \mathbf{q}) = p((-d_1 + A_1)q_1 - d_2 q_2) + (1 - p)(-d_1 q_1 + (d_2 - A_2)q_2)$$

We have avoided similarly replacing q_1, q_2 by q, $(1 - q)$ in order to maintain formally the legal option $q_1 = q_2 = 0$, although in the illegal game it is excluded from discussion. The situation can now be represented conveniently as the bimatrix game shown in Figure 1.

Use can be made of the preference directions (arrows) in Figure 1 to determine all of the solutions. With regard to the two-pronged arrow at the top of the figure, we must distinguish two cases:

1. $d_1 - A_1 > d_2$ (equivalently $(d_1 - d_2)/A_1 > 1$):
   In this case the topmost arrow points to the left and (C_1, V_1) is the unique Nash equilibrium; the corresponding payoffs for the two players at equilibrium are obviously

$$I^* = I(\mathbf{p}^*, \mathbf{q}^*) = -c_1 + B_1$$
$$S^* = S(\mathbf{p}^*, \mathbf{q}^*) = d_1 - A_1.$$

2. $d_1 - A_1 \le d_2$ (equivalently $(d_1 - d_2)/A_1 \le 1$):
   Now the topmost arrow is to the right and the preferences are cyclic. This means that the Nash equilibrium is in the domain of mixed strategies, i.e., probability distributions over the players' sets of pure strategies; both the Inspectorate and the State randomize. The equilibrium can be determined quite easily by requiring that each player choose his strategy so that his opponent is indifferent to the choice of his own strategy: We obtain

$$p^*(d_1 - A_1) + (1 - p^*)d_1 = p^* d_2 + (1 - p^*)(d_2 - A_2)$$
$$q_1^*(-c_1 + B_1) + q_2^*(-c_2) = q_1^*(-c_1) + q_2^*(-c_2 + B_2).$$

This leads to

$$p^* = (d_1 + A_2 - d_2)/(A_1 + A_2)$$
$$q_1^* = B_2/(B_1 + B_2),$$
$$q_2^* = 1 - q_1^*;$$

the corresponding equilibrium payoffs are

$$I^* = \frac{1 - c_1/B_1 - c_2/B_2}{1/B_1 + 1/B_2}$$

$$S^* = \frac{d_1/A_1 - 1 + d_2/A_2 - 1}{1/A_1 + 1/A_2}$$

It is an easy exercise to show that these solutions satisfy the Nash criteria.

The Inspection of N Locations

The following theorem generalizes the preceding special solutions to N locations and n inspections. The proof is given in the Appendix.

Theorem 1. *For the noncooperative two-person game ({**p**}, {**q**}, I, S) given by equations (2–5) in which, without loss of generality, the locations are ordered such that*

$$d_1 \ge d_2 \ge \ldots \ge d_N$$

let k, $n \le k \le N$, be chosen so that

$$\sum_{j=1}^{k-1} \frac{d_j - d_k}{A_j} \le n \qquad (7)$$

and

$$\sum_{j=1}^{k} \frac{d_j - d_{k+1}}{A_j} > n\,. \qquad (8)$$

If (8) is already satisfied for $k = n$, then (6) is omitted, whereas if (7) is still satisfied for $k = N$ then (7) is omitted. Furthermore define

$$i_m = \arg\max_i (d_i - A_i)$$

Then provided

$$\sum_{j=1}^{k} \frac{d_j - (d_{i_m} - A_{i_m})}{A_j} > n \tag{9}$$

the equilibrium payoff $I^* = I(p^*, q^*)$ to the Inspectorate is given by

$$\sum_{j=1}^{k} \frac{c^* + I^*}{B_j} = n \tag{10}$$

where c^* is defined by

$$c^* := \sum_{j=1}^{k} c_j \cdot q_j^* \tag{11}$$

and determined by

$$\sum_{j=1}^{k} \frac{c^* - c_j}{B_j} = 0. \tag{12}$$

The equilibrium payoff $S^* = S(\mathbf{p}^*, \mathbf{q}^*)$ to the State is given by

$$\sum_{i=1}^{k} \frac{d_i - S^*}{A_i} = n. \tag{13}$$

The Inspectorate's equilibrium strategy is

$$p_i^* = (d_i - S^*)/A_i \text{ for } i = 1 \ldots k, \text{ otherwise } 0 \tag{14}$$

and that of the State is

$$q_i^* = (c^* + I^*)/nB_i \text{ for } i = 1 \ldots \text{k, otherwise } 0. \tag{15}$$

Furthermore,

$$d_{k+1} \le S^* \le d_k \text{ for } k < N, \quad S^* < d_k \text{ for } k = N. \tag{16}$$

On the other hand, if

$$\sum_{j=1}^{k} \frac{d_j - (d_{i_m} - A_{i_m})}{A_j} \le n \tag{17}$$

the equilibrium pay-offs are

$$I^* = -c_{im} + B_{im} \tag{18}$$

$$S^* = d_{im} - A_{im}. \tag{19}$$

The State's equilibrium strategy is

$$\mathbf{q}^{*T} = (\overbrace{0, 0, \ldots 0}^{i_m - 1 \text{ times}}, 1, 0 \ldots 0). \tag{20}$$

An equilibrium strategy for the Inspectorate is to choose

$$p_i^* = \max\Big(0, (d_i - S^*)/A_i\Big), i = 1 \ldots k, \text{ otherwise } 0 \tag{21}$$

and, insofar as $\Sigma_i p_i^* < n$ to distribute the remaining inspection probability arbitrarily.

A number of remarks are worth making about this theorem:

1. To begin with, the optimal strategies have quite a rich structure. It is extremely unlikely that an ad hoc approach to the resource distribution problem, even with the same subjective and technical parameters as we have used here, would lead to anything like equations (13), (14), (19), and (21), which define the Inspectorat's optimal sampling strategies. Yet, being Nash equilibria, these strategies, and these alone, can be justified on the grounds of rationality.
2. The Inspectorate's solution, apart from the technical parameters $1 - \beta_i$, depends solely upon the subjective preferences of the State. This is characteristic of the solutions of two-person noncooperative games. The Theorem thus provides us with precisely the recipe involving $\{d_i, b_i, 1 - \beta_i\}$ that we sought. Note, however, that the subjective and technical parameters are inextricably bound up with one another. Given the existence of subjective preferences, the Inspectorate will not be able to implement an efficient verification stategy if it confines itself to technical considerations alone. This point is elaborated upon in some detail in reference 5.
3. When condition (17) is met, the pay-offs to both players have saturated to the values (18) and (19). Any inspection effort exceeding the threshold (17) is wasted. The theory thus recommends a value for n. If the option of legal behavior is considered, however, it may be advantageous to choose a different value, see Deterrents section.
4. The State's solution similarly depends on the utilities of the inspectorate. One might argue that the State would hardly be inclined to worry about such matters in choosing its plan of action, and therefore would be unlikely to arrive at its Nash equilibrium. While this is true, it in no way detracts from the validity of the Inspectorate's solution. According to the second inequality in (6), the State can only fare worse, provided the Inspectorate sticks to $\boldsymbol{p}^*$. The Inspectorate's equilibrium pay-off is guaranteed.
5. The State will be deterred from illegal action, opting for the strategy given by (1), when its equilibrium pay-off S^* in the illegal game is less than zero. We will be returning to this point in Section 5.

Simplifications

Some simplification results if, as suggested above, the b_i are all assumed to be equal. This means that the State perceives the consequences of detected violation to be equally severe regardless of where the detection occurs. Because the State's utility function is arbitrary up to a linear transformation which doesn't change the ordering of its preferences, we can simply say that

$$b_i = 1, i = 1 \ldots N.$$

On this scale, d_i becomes a measure of the perceived gain for undetected violation relative to the loss to be expected if the illegal activity is detected. A value $d_i \approx 1$ means that the possible gains and losses are assessed as being about equal. The Inspectorate's strategy under condition (9) is then

$$p_i{}^* = \frac{1 - S^*}{(1 + 1/d_i)(1 - \beta_i)},$$

$$i = 1 \ldots k, \text{ otherwise } 0. \tag{22}$$

The payoff S^* is determined by

$$\sum_{i=1}^{k} p_i^* = n, \tag{23}$$

the cut-off k by (7) and/or (8) and the best value of n is given by the equality in (17).

Going a step further and setting the d_i equal to one another as well, we can, without loss of generality, reorder the locations in increasing detection probablility, thus obtaining

$$b_i = 1, d_i = d, i = 1 \ldots N,$$
$$1 - \beta_1 \le 1 - \beta_2 \le \ldots \le 1 - \beta_N.$$

Then $i_m = 1$, $k = N$, and condition (9) reduces to

$$\sum_{i=1}^{N} \frac{1 - \beta_1}{1 - \beta_i} \le n.$$

Under this condition, with the notation

$$\frac{1}{1 - \beta^*} = \frac{1 + 1/d}{1 - S^*} = \frac{1}{n} \sum_{i=1}^{N} \frac{1}{1 - \beta_i},$$

we obtain the optimal inspection strategy

$$p_i^* = \frac{1 - \beta^*}{1 - \beta_i}, \quad i = 1 \ldots N.$$

This is a well-known solution to the zero-sum game in which only the a priori detection probabilities are considered and the payoff to the Inspectorate is the overall detection probability.[6]

Deterrence

As suggested in the fifth remark on Theorem 1, the State will be deterred from illegal behavior if, at equilibrium, its pay-off in the illegal game is negative. From the Nash condition and equation (3), this means that the $p_i{}^*$ must satisfy

$$0 \ge S(\underline{p}^*, \underline{q}) = \sum_{i=1}^{N} \left(d_i - A_i p_i^*\right) q_i \quad \text{for all } \mathbf{q}.$$

In other words

$$1 \ge p_i{}^* \ge d_i/\mathrm{A}_i, \quad i = 1 \ldots N, \tag{24}$$

which in turn implies

$$\sum_{i=1}^{N} \frac{d_i}{A_i} \le n \quad \text{and} \quad \frac{d_i}{A_i} \le 1, \quad i = 1 \ldots N. \tag{25}$$

From conditions (25) we see that deterrence is only possible if the "effort" n invested is large enough (first inequality) and under additional circumstances dictated by the model's parameters (second inequality). From (24) it is apparent that the Inspectorate's deterring equilibrium strategy, should one be possible, is not unique. Rather it lies within a "cone of deterrence," a phrase coined by Marc Kilgour some time ago.[7] Fortunately, the optimal inspection strategy for the illegal game lies within this interval, so the Inspectorate is best advised simply to stick with it whether conditions (25) can be satisfied or not.

For two locations and $n = 1$, the case treated in the section The Inspection of Two Locations, we obtain legal behavior at equilibrium if

$$d_1/A_1 + d_2/A_2 \le 1$$

and the Inspectorate's strategy p^* is given by

$$d_1/A_1 \le p^* \le 1 - d_2/A_2. \, .$$

Discussion

The achievement of a fair and efficient distribution of inspection effort among the various locations that may represent a risk to an arms control or non proliferation agreement is certainly no easy task. Extension of the scope of verification to undeclared locations clearly compounds the difficulty. Priorities that are subjective and perhaps even political in nature will have to be set and a considerable amount of good-will and compromise on the part of both inspector and inspectee will be needed to make the system a success. An in transparent approach will have a negative effect, both on the credibility of the verification regime and on the acceptance among participating States.

It is suggested here that the Inspectorate's equilibrium strategies (13), (14), (19) and (21) of Theorem 1, or the simplifications (22) and (23), are useful for assigning inspection probabilities on the basis of a subjective prioritization $d_1 \ldots d_N$ of the locations targeted for random inspection. We have seen that the relation between these priorities and the optimal inspection strategies is nontrivial. The solutions presented nevertheless have a solid foundation in the theory of economic behavior and are to be preferred to any ad hoc or arbitrary alternatives.

Routinely inspected, declared locations could be assigned similar or even equal d-values, whereas highly sensitive locations can be guaranteed an inspection probability of 1 by choosing their d-values sufficiently large. Extremely implausible locations, such as end users of Schedule 3 chemicals under the CWC, would be excluded from random inspection altogether if their d-values cause them to lie beyond the cut-off k. The actual choice of numerical values for the d_i is akin to the *fuzzification* of linguistic variables in fuzzy set theory.[8] There is no empirical basis for such a procedure other than the success of the resulting control or decision system. Nevertheless such systems often perform well. Based on experience, the subjective parameters can be adjusted iteratively.

An upper limit for the scale of the d_i might be obtained by the following "hard-line" argument. Suppose a high detection probability $1 - \beta$ can be uniformly attained at all N locations. The State knows this, but will nevertheless only be deterred from violation when all locations are inspected. This would mean that the first condition in (25) would hold as equality for $n = N$. That is, with $b_i = 1, i = 1 \dots N$,

$$N = \sum_{i=1}^{N} \frac{d_i}{A_i} = \frac{1}{1-\beta} \sum_{i=1}^{N} \frac{d_i}{1+d_i} \leq \frac{1}{1-\beta} \sum_{i=1}^{N} \frac{d_1}{1+d_1} = \frac{N}{1-\beta} \cdot \frac{d_1}{1+d_1}.$$

Thus

$$1 - \beta \leq d_1/(1 + d_1).$$

But, from the second condition in (25), we also require for deterrence

$$d_1/A_1 \leq 1 \quad \text{or} \quad d_1/(1 + d_1) \leq 1 - \beta.$$

Hence we must have

$$d_1/(1 + d_1) = 1 - \beta$$

and if, according to usual convention $1 - \beta = 95\%$,

$$d_1 = 19 \approx 20.$$

Thus we might choose the scale:

High risk locations:	$d_i = 20$
Medium risk locations:	$d_i = 2$
Low risk locations:	$d_i = 0.2$

The hard-liner approach becomes a little silly if $1 - \beta = 100\%$ since then $d_1 \longrightarrow \infty$. Of course if the State is only deterred from illegal activity when detection is an absolute certainty then its incentive to misbehave must indeed be limitless. Suppose $1 - \beta = 1, i = 1 \dots N$, but the number of inspections is limited by the Agreement to some value $n < N$. Then the same argument as above leads to the condition

$$n/N \leq d_1/(1 + d_1) \leq 1.$$

The right-hand inequality is satisfied anyway, so we should choose

$$d_1 \geq n/(N - n).$$

This obviously leaves some scope for the imagination. Note however that $d_1 \approx 20$ will satisfy this condition for $n \leq 0.95N$.

Two final remarks conclude this paper. First, it was mentioned previously that Nash equilibria need not be unique. The question arises whether there might exist solutions other than that of Theorem 1 or the legal version given in the Deterrence section. For the special $N = 2$, $n = 1$ game described earlier, one can in fact show that the illegal solution and the corresponding legal solution for $S^* < 0$ are in fact exhaustive.[9] Furthermore for $N = 3$, $n = 1$ it can similarly be demonstrated that the illegal solution of Theorem 1 is unique.[10] It seems plausible that these results hold also for the general case, but it remains to be proved.

Second, a similar analysis to that presented here may be applied to the inspection of N States by a single Inspectorate. The model is then an $N + 1$ person noncooperative game for which closed-form solutions exist only for $n = 1$, see reference 2. However much the same conclusions may be drawn regarding the interaction of subjective and technical parameters and the necessity to take both into account in order to achieve an efficient verification regime.

Appendix

Proof of Theorem 1: We begin by demonstrating that the conditions (7) and (8) on the parameters d_i, $i = 1 \dots N$, completely exhaust the parameter space, in other words that the solution is complete. To this end we write the two conditions in the form

$$\frac{d_1 - d_k}{A_1} \leq n - \sum_{j=2}^{k-1} \frac{d_j - d_k}{A_j} \tag{26}$$

$$\frac{d_1 - d_{k+1}}{A_1} \geq n - \sum_{j=2}^{k} \frac{d_j - d_{k+1}}{A_j} \tag{27}$$

Equivalently,

$$nA_1 + d_{k+1} - A_1 \cdot \sum_{j=2}^{k} \frac{d_j - d_{k+1}}{A_j} \leq d_1 \leq nA_1 + d_k - A_1 \cdot \sum_{j=2}^{k-1} \frac{d_j - d_k}{A_j}. \tag{28}$$

It therefore suffices to show that

$$nA_1 + d_{k+1} - A_1 \cdot \sum_{j=2}^{k} \frac{d_j - d_{k+1}}{A_j} \leq nA_1 + d_k - A_1 \cdot \sum_{j=2}^{k-1} \frac{d_j - d_k}{A_j}, \tag{29}$$

for then conditions (7) and (8) are equivalent to d_1 spanning the entire interval from 0 to ∞. Now, inequality (29) is equivalent to

$$d_{k+1} - A_1 \cdot \left(\sum_{j=2}^{k} \frac{d_j - d_{k+1}}{A_j} - \sum_{j=2}^{k-1} \frac{d_j - d_k}{A_j} \right) \leq d_k$$

or to

$$d_{k+1} - A_1 \cdot \left(\sum_{j=2}^{k} \frac{d_j - d_k + d_k - d_{k+1}}{A_j} - \sum_{j=2}^{k-1} \frac{d_j - d_k}{A_j} \right) \leq d_k$$

or to

$$d_{k+1} - A_1 \cdot \sum_{j=2}^{k} \frac{d_k - d_{k+1}}{A_j} \le d_k$$

which is fulfilled by the imposed ordering of the d_i.

Next we demonstrate that the given solution, under condition (9), satisfies (16). We have with (13)

$$\sum_{j=1}^{k} \frac{d_j}{A_j} = n + \sum_{j=1}^{k} \frac{S^*}{A_j} \ge n + \sum_{j=1}^{k} \frac{d_{k+1}}{A_j}$$

follows from (8). Hence,

$$(S^* - d_{k+1}) \cdot \sum_{j=1}^{k} \frac{1}{A_j} \ge 0$$

from which the left hand inequality in (16) follows. Furthermore (7), extending the summation trivially from $k - 1$ to k, is equivalent to

$$\sum_{j=1}^{k} \frac{d_j}{A_j} \le n + \sum_{j=1}^{k} \frac{d_k}{A_j}.$$

Again from (13)

$$n + \sum_{j=1}^{k} \frac{S^*}{A_j} = \sum_{j=1}^{k} \frac{d_j}{A_j}$$

or, with (30),

$$n + \sum_{j=1}^{k} \frac{S^*}{A_j} \le 1 + \sum_{j=1}^{k} \frac{d_k}{A_j}$$

or

$$(S^* - d_k) \cdot \sum_{j=1}^{k} \frac{1}{A_j} \le 0$$

from which follow the right hand inequalities in (16).

Now it will be shown that the solution given indeed satisfies the Nash equilibrium conditions (6). With (5) and (3) these are equivalent to

$$I^* \ge -\sum_{i=1}^{N} c_i q_i^* + \sum_{i=1}^{N} B_i q_i^* p_i = -c^* + \sum_{i=1}^{N} B_i q_i^* p_i, \quad \text{for all } \mathbf{p}$$

and

$$S^* \ge \sum_{i=1}^{N} d_i q_i - \sum_{i=1}^{N} A_i q_i p_i^*, \quad \text{for all } \mathbf{q},$$

respectively. Assume that (9) is satisfied and consider first the case $k = N$. Then, as indicated in the statement of the Theorem, condition (8) is to be omitted and only (7) remains. Using (15), inequality (31) may be written

$$I^* \ge -c^* + \sum_{i=1}^{N} \frac{c^* + I^*}{n} \cdot p_i = I^*$$

so that the first equilibrium condition is fulfilled as equality. Similarly, inequality (32) may be written with the help of (14) as

$$S^* \ge \sum_{i=1}^{N} d_i q_i - \sum_{i=1}^{N} (d_i - S^*) \cdot q_i = S^*$$

and again the equality holds. Now consider the case $k < N$. With (15) inequality (31) is equivalent to

$$I^* \ge -c^* + \sum_{i=1}^{k} \frac{c^* + I^*}{n} \cdot p_i$$

or

$$0 \ge -(I^* + c^*) + \frac{c^* + I^*}{n} (\sum_{i=1}^{N} p_i - \sum_{i=k+1}^{N} p_i)$$

or, because $\Sigma_i p_i = n$,

$$0 \le \frac{c^* + I^*}{n} \cdot \sum_{i=k+1}^{N} p_i.$$

But $c^* + I^* \ge 0$ according to (10), so this last inequality is fulfilled. Proceeding in the same way with (32), it may be written, using (14), as

$$S^* \ge \sum_{i=1}^{N} d_i q_i - \sum_{i=1}^{k} (d_i - S^*) q_i$$

or as

$$\sum_{i=k+1}^{K} (d_i - S^*) q_i \le 0$$

which is fulfilled by virtue of the left hand inequality of (16). Now assume that condition (17) holds. Then (31) is equivalent to

$$-c_{im} + B_{im} \ge c_{im} + B_{im} p_{im}$$

which is fulfilled. For any pure strategy $q_i = 1$, inequality (32) is equivalent to

$$S^* \ge d_i - \max(0, d_i - S^*).$$

If $d_i \ge S^*$, this is equivalent to $S^* \ge S^*$, while if $d_i \le S^*$ is equivalent to $S^* \ge d_i$. Thus, apart from the distributed excess inspection probability, the inspectee is indifferent to his strategy choice at equilibrium and (32) is fulfilled.

Finally it will be shown that the equilibrium strategies satisfy

$$0 \le p_i^* \le 1, 0 \le q_i^* \le 1, \text{ for } i = 1 \ldots k, \text{ otherwise } 0 \tag{33}$$

and the normalization conditions

$$\sum_{i=1}^{k} p_i^* = n, \quad \sum_{i=1}^{k} q_i^* = 1. \tag{34}$$

Assume (9) holds. Then equations (34) follow immediately from (10) and (11). Furthermore, from (15) $0 \le q_i^*$ and its normalization ensures that $q_i^* \le 1$. From the right hand inequality of (16) it similarly follows that $0 \le p_i^*$. With equations (13) and (14) the condition $p_i^* \le 1$ can be written as

$$p_i^* = \frac{d_i}{A_i} - \frac{1}{A_i}S^* = \frac{d_i}{A_i} - \frac{\sum_{j=1}^k (d_j/A_j) - n}{\sum_{j=1}^k (A_i/A_j)}$$
$$= \frac{\sum_{j=1}^k (d_i/A_j) - \sum_{j=1}^k (d_j/A_j) + n}{\sum_{j=1}^k (A_i/A_j)} \le 1, \; i = 1 \ldots k.$$

This is equivalent to

$$\sum_{j=1}^k \frac{d_i - d_j}{A_j} + n \le \sum_{j=1}^k \frac{A_i}{A_j}, \; i = 1 \ldots k,$$

or to

$$\sum_{j=1}^k \frac{d_j - (d_i - A_i)}{A_i} \ge n, \; i = 1 \ldots k,$$

which is fulfilled by virtue of (9). Thus conditions (33) are fulfilled.

Assume (17) holds. Then

$$0 \le p_i^* = \max\left(0, \frac{d_i - S^*}{A_i}\right) \le \frac{d_i - A_i - (d_{i_m} - A_{i_m}) + A_i}{A_i} \le 1$$

so that conditions (33) are fulfilled. Finally,

$$\sum_{i=1}^k p_i^* \le \sum_{i=1}^k \frac{d_i - S^*}{A_i} = \sum_{i=1}^k \frac{d_i - (d_{i_m} - A_{i_m})}{A_i} \le n$$

because of (17). Any excess probability can be distributed arbitrarily.

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A *JNMM* Series: Safeguards Innovations Through Global Cooperation

■

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■

In a global political economy where resources for the discovery of new safeguards innovations are extremely limited, the international safeguards community must establish partnerships for cooperation. This global cooperation will allow organizations with common goals to exchange ideas and expertise to develop safeguards solutions in a more economical and timely manner.

The U.S. Department of Energy's (DOE) International Safeguards Division (ISD) provides technical leadership to formulate and implement U.S. nonproliferation policy. ISD activities range from conducting nuclear safeguards training to developing safeguards techniques for the world's most advanced plutonium and uranium handling facilities. For more than two decades, ISD has entered into international partnerships and agreements for cooperation with other organizations to develop solutions that will improve safeguards. ISD has formal agreements for cooperation in place with 11 national and multinational organizations. These partnerships provide, a unique opportunity to augment DOE expertise with technical capabilities of other experts internationally.

One important example of these partnership efforts is the International Training Course on State Systems of Accounting and Control for Nuclear Materials. This training program was developed to conform with the mandates set forth in the 1978 Nuclear Non-Proliferation Act (NNPA), the 1986 Omnibus Diplomatic Security and Anti-Terrorism Act, and President Clinton's 1993 Non-Proliferation Policy, which require the strengthening of the International Atomic Energy Agency (IAEA) safeguards program and the prevention of nuclear weapons proliferation.

The SSAC course is offered every two years. The Tenth International Training Course was conducted in May 1995, and the eleventh course will be held in May 1997. The SSAC course requires a significant amount of global cooperation, with students and lecturers participating from IAEA Member States and organizations around the world. Without their diverse backgrounds, knowledge, and cultural exchange, SSAC training would not be nearly as effective.

The following paper, titled "SSAC: All the Basics" provides an overview of the standardized SSAC training program, course curriculum, and international lecturer and student participation.

SSAC Training: All The Basics

■

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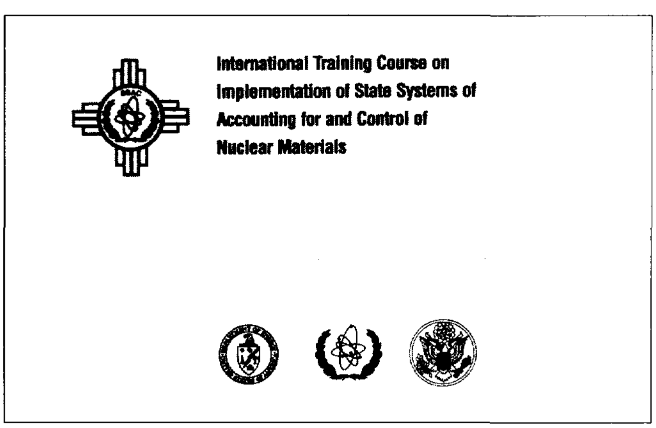
Introduction

The International Atomic Energy Agency (IAEA) in cooperation with the United States Department of Energy (DOE) and the United States Department of State (DOS) conducts biennial international training courses on the implementation of state systems of accounting for and control of nuclear materials (SSAC). A letter of announcement is sent by the IAEA to its Member States in all geographic regions inviting them to submit nominations for SSAC training.

Nominees can be from government agencies that regulate nuclear activities, from the management or nuclear material accounting offices of nuclear facilities, or from universities or institutes working within these areas. Preference is given to candidates from countries with developing nuclear programs, but candidates from countries with developed nuclear programs are also considered. Nominations are submitted through official channels to the IAEA. A committee selects a limited number of course participants, typically 40. The nominating Governments are informed of the names of their selected candidates and apprised of the administrative and financial procedures.



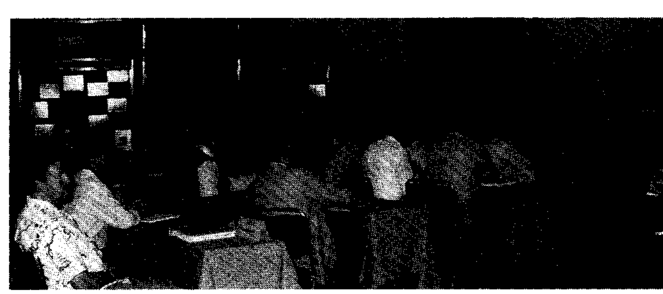
Manual cover with the SSAC logo in the upper left corner and DOE, IAEA and DOS logos at the bottom right.

Historical Perspective

The first SSAC course was given in Vienna, Austria in 1976, and the first U.S. courses in Richland, Washington, in 1979 and Los Alamos, New Mexico, in 1980. Courses have also been presented in the U.S.S.R., Australia, Argentina, Japan, and Brazil.

In 1978, the United States passed the Nuclear Non-Proliferation Act (NNPA) to, among other things, "strengthen the safeguards program of the IAEA by contributing funds, technical resources, and other support to assist in

Lecture by John McManus, IAEA Operations B Director, during 1987 course. Participants (L-R first row) Mirta L. Arestin (Argentina), Sonia F. Moreno (Argentina), and Carlo Bommarito(Italy).



Arnie Hakkila lecturing at the 1985 SSAC course.

Workshop presentation by Mirta Arestin (Argentina) in 1987. Listening in front row is Rongbao Zhu (China).

Bob Keepin leading a 1985 workshop discussion with (L-R) Jose F. Cabalteja (Philippines), Jianping Jia (People's Republic of China), Riyad Hasan Othman (Iraq), and Afroz Andalib Chowdhury (Bangladesh).

Subgroup discussing workshop functions and operation.

Carlos Buecher, IAEA Division Director of Development and Technical Support, providing a lecture in 1980 at the first U.S. SSAC course.

effectively implementing and improving the IAEA safeguards system." Section 202 of this act states that "DOE shall establish and operate safeguards and physical protection training courses for nationals of nuclear developing countries."

NNPA was followed in 1986 by the Omnibus Diplomatic Security and Anti-Terrorism Act which mandated the provision of "non-proliferation assistance to foreign countries and international agencies," and in 1993 by President Clinton's Non-Proliferation Policy, which established a foundation for U.S. "efforts to prevent nuclear weapons proliferation."

Instructional Methods

SSAC training is highly participative. Students explore issues and practice skills during group exercises and workshops. The curriculum addresses the methodologies used in establishing an effective national program to fulfill IAEA safeguards requirements by presenting example SSAC's from countries like the United States, Canada, Kazakstan, and Japan, and outlining the safeguards requirements in states with regional safeguards. Canada, Kazakstan, and Japan were invited to attend in 1995, but the list changes somewhat each year. A strong emphasis is placed on low enriched uranium fuel fabrication plants, and elements of Program 93+2 are being included in the upcoming course. The course consists of demonstrations, exercises, lectures, discussions, tours, and a visit to an operating nuclear facility. Lectures and written materials are in English. Students are given a comprehensive manual to use as a reference.

Lecturers from the United States are selected by DOE in consultation with the IAEA, and international lecturers are selected by the IAEA in consultation with DOE. Each lecturer is selected for specific teaching style and extensive national and international experience in the implementation of state systems of accounting and control of nuclear materials. Past lecturers have been associated with the DOS, IAEA, Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), DOE, Commission of the European Communities-EURATOM Safeguards Directorate, Atomic Energy Control Board of Canada, US Nuclear Regulatory Commission, Japan Nuclear Fuel Company, Ltd., and Kazakstan Atomic Energy Agency.

Course Content

Curriculum materials are drawn from years of experience. The SSAC course consists of three sections plus a design workshop.

Panel discussion at 1985 SSAC course (L-R): Carlos Buechler (IAEA), G. Robert Keepin (United States), Benson Agu (IAEA), Otto Lendvai (Hungary), Charles Smith (USNRC).

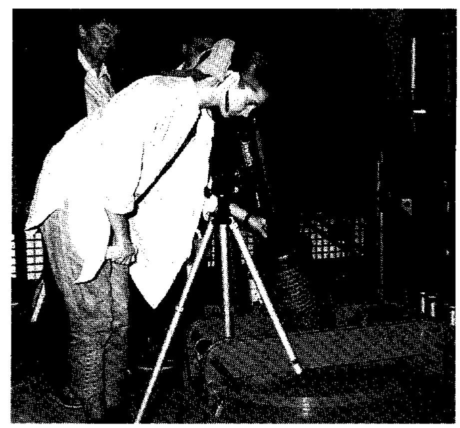
Howard Menlove demonstrating a neutron collar to measure fresh BWR fuel to (L-R): Howard Menlove, Juan Carlos Chavez (Chile), Rongbao Zhu (China), Sonia F. Moreno (Argentina), Ekaterina Gueorguieva (Bulgaria), and Ove Johnsson (Sweden).

The first section gives a history and overview of nuclear safeguards. This serves as the course introduction and provides the opportunity to emphasize the course informality and allow the students and instructors to become acquainted. During this section, initial subgroups are formed and their function and operation is established. The section ends with a subgroup meeting and panel discussion on the interface between the IAEA and the States. In 1997 this section will include Sessions 1 through 8 and Workshop A, listed in the agenda at the end of this article.

The second section covers the major elements of a state system (SSAC) including: a measurement system, procedures to evaluate measurement uncertainty, procedures to evaluate shipper/receiver differences, procedures for taking physical inventories, a system of records and reports, material accounting procedures, and procedures for submitting reports to the IAEA. In 1997 this will include Sessions 9 through 20 and Workshops B through E listed at the end of this article.

The third section covers safeguards at LEU fuel fabrication facilities and includes the IAEA safeguards approach, examples from a foreign fabrication plant, and tours and demonstrations of safeguards at an operating US fuel fabrication facility that is under IAEA safeguards.

1987 SSAC Attendees applying E-cup seal to five-gallon containers.



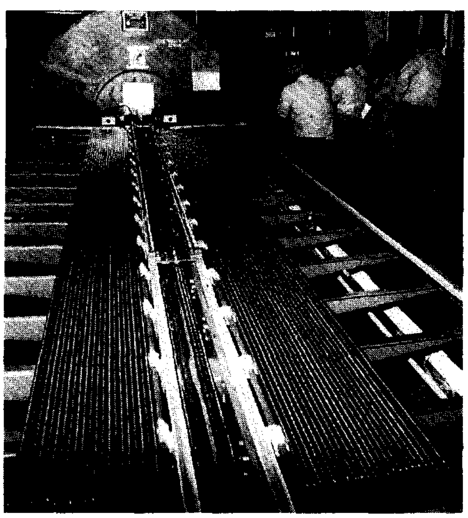
Heinz Kschwendt (Euratom) watches as Nina Danielsson (Sweden) observes the Cerenkov glow from spent fuel stored underwater during the 1989 course.

The MC&A design workshop is the culmination of the course, where individual subgroups design an SSAC for a hypothetical country with a LEU fuel fabrication facility. The design requested of the attendees has usually been limited to designing the MC&A system for the facility; however, in the future we plan to include design of the State Authority and simulate interactions between the Authority, Facility, and the IAEA.

Who Pays For SSAC Training?

The US Government defrays the costs of conducting the course including salaries and fees of US lecturers, laboratory assistants, field trips, reports/materials associated with the course, lab supplies, and administrative costs incurred by the IAEA. The US Government is responsible for making hotel reservations, providing ground transportation between the airport,

Jim Stewart demonstrates neutron coincidence counting in 1989. (L-R) Abdelaziz Hajjani (Moroco), Daniel H. Giustina (Argentina), Jim Stewart, Nina Danielsson (Sweden), Shaker Hamed Rayiss (Iraq), Yordan Harizanov (Bulgaria), Kin-Fu Lin (Taiwan), and Monzurul Haque.



Fuel Rod Scanner demonstration at the Exxon (now Seimens) Nuclear LWR Fuel Fabrication Plant in the 1987 SSAC course.

hotels, and teaching facilities, and providing the IAEA with funds for distribution to course participants from developing countries. They pay one half of the round trip (economy class) air fare for participants from developing countries; the other half is paid by the nominating country. Participants from developing countries are provided with per diem to ensure that accommodations, food, and incidentals are covered. There is no course fee.

International Flavor

The combination of lecturers and students guarantees that the SSAC program will continue to be infused with international ideas and concerns. All students bring alternative approaches to problem solving. Similarly, international lecturers demonstrate

Ken Sanders, DOE International Safeguards Division Director, and Arnie Hakkila Los Alamos Course Coordinator, 1991 SSAC course.

Ron Augustson demonstrating an Active Well Coincidence Counter in the 1987 SSAC course.

different methods and techniques for safeguards. Selected students return as instructors in later courses and, thereby, continue to affect the development of the course. The 10th SSAC course held in 1995 was attended by 39 participants representing 28 countries: Lithuania, Hungary, Bulgaria, Brazil, Israel, Kazakstan, Egypt, Armenia, Canada, Romania, Mexico, Indonesia, Czech Republic, France, Japan, Pakistan, Russian Federation, Latvia, Uruguay, Argentina, Syrian Arab Republic, South Africa, Thailand, Belarus, Korea, Malaysia, and China.

Student Feedback

Students provide an evaluation of the course each day to help overcome errors or problems associated with instructional materials or lectures, and aid in the continued development of training materials. Overall, participants have considered the lecture material to be clearly written and valuable to their work, instructors to be understandable, and the time allocated for training adequate. DOE and Los Alamos National Laboratory continue to assess resource materials and course content to provide the best educational opportunities for SSAC students.

Reactor control room tour during 1985 SSAC course with (L-R): reactor operator, Candida M. de Almeida (Brazil), Ryszard Zarucki (Poland), P.S.A. Narayanan (India), Amarof Lahcen (Morocco), Huie Zhuang (PRC), Stein Deron (France, IAEA), and Willie Theis (Austria, IAEA).

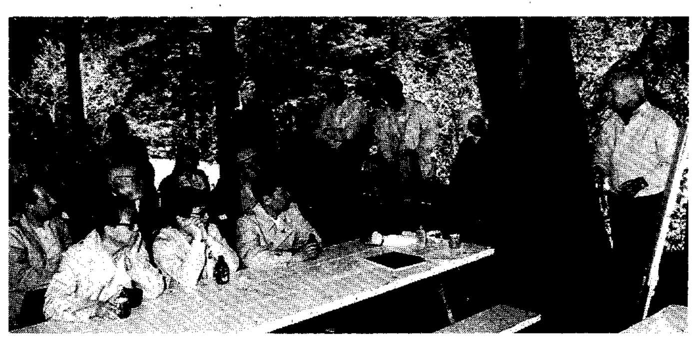
1987 SSAC course attendees (L-R): Miriam D. Pacheco (Brazil), Sonia F. Moreno (Argentina), Asmaa Selah Eldin Abdel Salam (Egypt), Mirta L. Arestin (Argentina), Hendaryah Sutanto (Indonesia), and Aysun Yucel (Turkey).

The SSAC course has provided a solid return on investment. By bringing together participants and lecturers with diverse cultural, technical, and esoteric backgrounds, the SSAC program is truly a global cooperation initiative. This course has satisfied both national and IAEA safeguards requirements.

Course Schedule

The Tenth International Training Course on State Systems of Accounting for Control of Nuclear Materials was conducted April 19 through May 5, 1995 in Santa Fe and Los Alamos, New Mexico, and Festus, Missouri. The first two weeks of training were held in New Mexico, and the third week the students were hosted by ABB Combustion Engineering in Hematite, Missouri, to visit an operating low enriched fuel fabrication plant where IAEA safeguards are applied.

Norris Bradbury, former Los Alamos Director, addressing the 1987 SSAC course attendees. The audience includes Bob Keepin, Hastings Smith, Tom Hirons, Gene Bosler, Glenn Whan and Howard Menlove (Los Alamos), Winston Alston (IAEA), Walter Rehak (DDR -Safeguards Head), Sonia Moreno (Director of Nonproliferation and International Relations ENREN), Aysun Yucel (Head of Safeguards Turkish AEC).



Walter Rehak, DDR Director of Safeguards, lectures to 1987 course participants on a pleasant afternoon in the hills above Santa Fe, New Mexico.

The Eleventh International Training Course is scheduled for May 6 through 17, 1997. The tentative agenda for this course is given at the end of this article.

Acknowledgement

The success of the SSAC course is attributed to close interactions between DOE, DO, IAEA and the Los Alamos National Laboratory staff who develop, coordinate and oversee the training program. The development and technical coordination that have been provided by Bob Keepin, Charlie Hatcher, Arnie Hakkila, Linda Robinson, Janet Sander, Ken Thomas, Gene Bosler, and Hiroshi Hoida have been invaluable to the Department of Energy and to the overall success of this course. This success has also been a direct result of the many dedicated people of the IAEA and its member states who have participated over the years as instructors and students.

Tentative Agenda, 1997 SSAC Course.

Enhanced Tentative Agenda

11th INTERNATIONAL TRAINING COURSE ON IMPLEMENTATION OF STATE SYSTEMS OF ACCOUNTING FOR AND CONTROL OF NUCLEAR MATERIALS

May 7 - May 23, 1997

REGISTRATION, Wednesday, May 7, 1400-1600

	WEDNESDAY 7 MAY	THURSDAY 8 MAY	FRIDAY 9 MAY	SAT. 10 MAYL & SUN. 11 MAY	MONDAY 12 MAY	TUESDAY 13 MAY	WEDNESDAY 14 MAY	THURSDAY 15 MAY
0830		WELCOME (Host Organizations)	5. THE U.S. SSAC	TOUR OF SANTA FE AREA	9. SSAC ELEMENTS-FACILITY/STATE VIEW	14. NON-DESTRUCTIVE ASSAY OF NUCLEAR MATERIAL	18. IAEA SAFEGUARDS AT POWER REACTORS	*BUS TO LOS ALAMOS (MEET IN LOBBY AT 0730)* D. WORKSHOP: NON-DESTRUCTIVE ASSAY OF NUCLEAR MATERIAL (Reilly)
		1. COURSE INTRODUCTION	6. The KAZAKHSTAN SSAC		10. EURATOM 'S COMPUTERIZED SAFEGUARDS INFORMATION SYSTEM	15. NON-DESTRUCTIVE ASSAY OF NUCLEAR MATERIAL IN BULK-HANDLING FACILITIES	19. Continuous Monitoring and MEASUREMENT OF REACTOR FUEL	
		2. HISTORY CURRENT TRENDS (Program 93+2) IN NUCLEAR SAFEGUARDS	7. THE CANADIAN SSAC			16. DESTRUCTIVE ANALYSIS OF NUCLEAR MATERIAL and Environmental Sampling	20. Enhanced Safeguards forReactors and Storage Facilities IRMP Project and Embalse	
1200								Lunch In Los Alamos
1330	REGISTRATION Badging Announcements Banking Group Photo Portraits	3. INTRODUCTION TO IAEA SAFEGUARDS and Implementation of Program 93+2	8. THE ARGENTINE-BRAZILIAN JOINT INSPECTION PROGRAM/ABACC		11. NUCLEAR MATERIAL CONTROL AND ACCOUNTING IN A JAPANESE FUEL FABRICATION FACILITY	17. SAFEGUARDS FOR REACTORS AND CRITICAL ASSEMBLIES	C. WORKSHOP: ACCOUNTING RECORDS AND REPORTS	D. WORKSHOP: NON-DESTRUCTIVE ASSAY OF NUCLEAR MATERIAL
		4. TECHNICAL SUPPORT FOR SAFEGUARDS (Program 93+2)	A. SUBGROUP PANEL: IAEA/SSAC INTERFACE		12. IAEA SAFEGUARDS AT FUEL FABRICATION PLANTS	B. SUBGROUP: NUCLEAR MATERIAL CONTROL AND ACCOUNTING		E. BRIEF PRESENTATIONS OF ATTENDEE INTERESTS
					13. STATISTICS APPLIED TO SAFEGUARDS			
1700								
1800		*IAEA RECEPTION AT PICACHO*						*LOS ALAMOS DINNER*

THERE WILL BE MORNING AND AFTERNOON BREAKS EVERY DAY AT APPROXIMATELY 1000 AND 1500

Tentative Agenda, 1997 SSAC Course.

Tentative Agenda

11th INTERNATIONAL TRAINING COURSE ON IMPLEMENTATION OF STATE SYSTEMS OF ACCOUNTING FOR AND CONTROL OF NUCLEAR MATERIALS

May 7 - 23, 1997

	FRIDAY 16MAY	SAT. 17 MAY & SUN. 18 MAY	MONDAY 19 MAY	TUESDAY 20 MAY	WEDNESDAY 21 MAY	THURSDAY 22 MAY	FRIDAY 23 MAY
0830	21. FUEL FABRICATION PLANT NUCLEAR MATERIAL ACCOUNTANCY SYSTEM ELEMENTS F. PRE-WORKSHOP: FUEL FABRICATION PLANT SAFEGUARDS	TOUR OF LOCAL POINTS OF INTEREST	WELCOME TO FACILITY 22. BASIS OF MODEL PLANT MATERIAL CONTROL AND ACCOUNTING SYSTEM 23. MODEL PLANT ACCOUNTING SYSTEM 24. DESCRIPTION AND EXAMPLES OF RECORDS, REPORTS, AND FORMS	26. PROCEDURE FOR TAKING PHYSICAL INVENTORIES 27. ANALYTICAL PROCEDURES, NDA METHODS, AND SEALS USED AT MODEL FACILITY	29. NUCLEAR REGULATORY COMMISSION SAFEGUARDS INSPECTION I. SUBGROUP: PLANT TOURS, ACCOUNTING SYSTEM, PIT, MEASUREMENT SYSTEM, SEALS	J. WORKSHOP: DESIGN OF NUCLEAR MATERIAL CONTROL AND ACCOUNTING SYSTEM	K. WORKSHOP: DESIGN SUBGROUP REPORTS
1200				Lunch in Festus			
1330	F. PRE-WORKSHOP: FUEL FABRICATION PLANT SAFEGUARDS	Travel to Facility	25. BRIEF PLANT DESCRIPTION G. GENERAL PLANT TOUR	28. ROLE OF STATISTICS IN FUEL FABRICATION PLANT SAFEGUARDS H. TOUR PLANT LABS	J. WORKSHOP: DESIGN OF NUCLEAR MATERIAL CONTROL AND ACCOUNTING SYSTEM	J. WORKSHOP: DESIGN OF NUCLEAR MATERIAL CONTROL AND ACCOUNTING SYSTEM	L. COURSE EVALUATION AND WRAP UP *END OF COURSE*
1700							
1800			*CHAMBER OF COMMERCE RECEPTION*			*AWARDS BANQUET*	

THERE WILL BE MORNING AND AFTERNOON BREAKS EVERY DAY AT APPROXIMATELY 1000 AND 1500

Technical Considerations and Policy Requirements for Plutonium Management

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Abstract

The goals for plutonium management have changed dramatically over the past few years. Today, the challenge is focused on isolating plutonium from the environment and preparing it for permanent disposition. In parallel, the requirements for managing plutonium are rapidly changing. For example, there is a significant increase in public awareness on how facilities operate, increased attention to environmental safety and health (ES&H) concerns, greater interest in minimizing waste, more emphasis on protecting material from theft, providing materials for international inspection, and a resurgence of interest in using plutonium as an energy source. Of highest concern, in the immediate future, is protecting plutonium from theft or diversion, while the national policy on disposition is debated. These expanded requirements are causing a broadening of responsibilities within the Department of Energy (DOE) to include at least seven organizations. An unavoidable consequence is the divergence in approach and short-term goals for managing similar materials within each organization. The technology base does exist, properly, safely, and cost effectively to extract plutonium from excess weapons, residues, waste, and contaminated equipment and facilities, and to properly stabilize it. Extracting the plutonium enables it to be easily inventoried, packaged, and managed to minimize the risk of theft and diversion. Discarding excess plutonium does not sufficiently reduce the risk of diversion, and as a result, long-term containment of plutonium from the environment may not be able to be proven to the satisfaction of the public.

Introduction

As a result of the Strategic Arms Reduction Treaties and unilateral offers and agreements made by Presidents Bush, Gorbachev, and Yeltsin, the United States and Russia will retire many thousands of nuclear weapons within the next decade. This will remove many metric tons of plutonium from military control. Plutonium is one of the essential elements of nuclear weapons, and physical controls on the access to plutonium historically have been the primary barrier to theft and/or proliferation of nuclear weapon material. Not so obvious today is the fact that surplus plutonium also exists in the form of raw metal and oxide, residues, transuranic (TRU) and low level waste (LLW), contaminated facilities and equipment, and spent nuclear fuel, each of which also represents a significant source for diversion. With the end of the cold war, the management of these categories of materials is fragmented; and, consequently, they are at increasing risk for loss of management control.

A recent National Academy of Sciences study on the "Management and Disposition of Excess Weapons Plutonium"[1] is quoted as saying that, with regard to the weapon-related materials: "The existence of this surplus material constitutes a clear and present danger to national and international security." This report defines the need to safeguard and more comprehensively manage surplus inventories until permanent disposition options can be selected. The state of technology to address this inventory will be explored.

Discussion

Recently, numerous studies have been published concerning the management of plutonium.[1-4] This fact indicates the keen interest that the international community places on managing this material safely and properly. Over the 50 years since the discovery of plutonium, the main use for plutonium in the U.S. was in national defense. A second major use of plutonium has been as an energy source in advanced fuel programs. At the time of the discovery, all plutonium work was conducted under self-imposed secrecy, as a result of the recognition that it was possible to produce a powerful explosive through the rapid fissioning of plutonium by neutron bombardment. This precedent was maintained during the cold war, and very little actual information concerning the use and inventories of weapons plutonium was published. Numerous physical security measures were deployed to protect against the diversion of either information or the actual material outside the nuclear weapon community. This was accomplished fairly easily because all the material was handled under the jurisdiction of the Department of Energy Office of Defense Programs (DOE/DP), and Office of Nuclear Energy (DOE/NE).

The New Requirements

The end of the cold war has brought about a significant change in how plutonium inventories are managed. First, the Secretary of Energy began an initiative to increase the quality of ES&H management within Department facilities.[5] This step exposed the nuclear defense community to a broader range of oversight organizations, most of which are outside the Department. At the same time, Congress established the Defense Nuclear Facilities Safety Board (DNFSB), with the charter to evaluate the performance of the Department of Energy (DOE) in the execution of its safety and health obligations.[6] This became a very public vehicle for bringing scrutiny on the Department's nuclear operations. Congress and the Department established the Office of Environmental Remediation and Waste Management (DOE/EM) with the charter to clean up excess cold war nuclear facilities and sites.[7] This resulted in the transfer of a significant amount of plutonium to the new DOE/EM in the form of residues, waste, and contaminated equipment and facilities. The DOE/EM Office is heavily involved in the privitization of facility clean up functions, and most of the new contractors are unaware of the historical basis of nuclear materials management. The Secretary announced the "Openness Initiative" wherein previously classified information was released for public consumption. This included the disclosure of quantities of plutonium that exist in the defense inventories.[8] Congress recognized the fact that plutonium would become an inventory challenge and initiated the DOE Office of Material Disposition (DOE/MD) to evaluate permanent disposition options for excess weapons materials. An additional dimension to the charter of DOE/MD was the opening of relations with the Russian Federation and the discussion of plutonium stabilization and disposition.[9] In 1995, the President announced that the U.S. would place 200 metric tons of special nuclear material under the International Atomic Energy Agency (IAEA) safeguards program.[10] This action exposed the DOE facilities to the potential for international safeguard controls over material. During 1994, two weapons DOE Complex-wide plutonium safety assessments were made; one by the DNFSB and the other by the Assistant Secretary for Environmental Safety and Health.[11,12] The latter assessment resulted from a 1993 Presidential initiative on nuclear nonproliferation and DOE's effort to develop strategies for the eventual disposition of excess fissile materials.[12,13] Both of these assessments identified the imminent dangers to workers, environment, and the public associated with the ever-deteriorating state of nuclear material packages, infrastructure, and nuclear facilities. This list of significant changes and actions has generated an increasingly more complex list of requirements for material management and facility operations. Globally, the new requirements include:

1. Theft protection of materials — The DOE published a minimum set of requirements and procedures for the control and accountability of nuclear materials.[14] In addition, a set of international standards has been proposed concerning storage, protection, and accountability of spent nuclear fuels in surface and geologic storage.
2. Long-term ES&H management — The DOE strengthened the role of its Office of Envirnoment, Safety and Health (DOE/EH) in performing its self-assessment responsibilities and has engaged other government organizations in jointly performing ES&H oversight to include the Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and others.
3. Cost of Material Management — The Department is embarking on the development of a uniform approach for the packaging and storage of excess nuclear materials and has published a standard for the handling of materials that have a plutonium (Pu) content of greater than 50%.[15] The Department is also working on a packaging and storage standard for lower-concentration materials.
4. Waste Management — The responsibility for the management and minimization of waste is distributed among a number of offices. Managing the source-term for materials considered for discard is the key to controlling the release of plutonium to the environment. The EPA, as well as state and local agencies, also have a role in the management, handling, transportation, and disposal of mixed waste.
5. Military Applications and Nonproliferation — Nuclear weapons continue to represent an aspect of national defense. The control of nuclear weapon technology and information, as well as the identification of the spread of such technology, is essential.
6. Energy Production — Countries having nuclear capa-

Table 1. Department of Energy Organizational Relationship versus Program Requirements for Nuclear Material Management

Organization	Theft	ES&H	Waste	Cost	Military	Energy	Policy
DOE/DP	X	X		X	X		X
DOE/NE					X	X	X
DOE/EM	X	X	X				X
DOE/MD		X	X			X	X
DOE/NN	X			X	X	X	X
DOE/EH		X	X				X
DOE/PO	X	X	X	X	X	X	X

bility are evaluating the use of excess plutonium and enriched uranium in future power production. A number of national studies have evaluated this approach and support it.[1-3] The current policy of the United States is not to reprocess and recycle spent nuclear fuels.

7. National Policy — The national policies concerning the use of plutonium in the fuel cycle, disposal of plutonium, control of weapon information, and other aspects of the problem, are in a dramatic state of flux. Understanding and managing these policy changes is an essential requirement.

These requirements are the major issues that are changing the organizations involved with and the approaches to managing nuclear materials. Establishing a uniform basis for managing these materials must take into account these requirements. Whereas in the past, most of the weapon nuclear materials were managed by the DOE/DP and DOE/NE, the significant changes discussed above have caused a rapid distribution of responsibility to include as many as seven DOE organizations, thus exacerbating the problem. Table 1 shows the various organizations who have responsibility over materials, technology, information, and/or operations involving nuclear materials. The Xs in the table indicate where each organization plays a role in implementing the various requirements. The very fact that so many Xs occur indicates the need to develop a uniform policy and approach for nuclear material management.

Of the new categories of requirements, the one involving the greatest concern is the Theft (anti-theft) requirement. In an effort to evaluate this category properly, the DOE Order on the Control and Accountability of Nuclear Materials[14] can be used to express the forms of plutonium according to their theft attractiveness. Table 2 is extracted from the DOE Order in terms of the Attractiveness Categories and the proliferation standpoint. Weapon assemblies and components are the highest and are therefore noted at level A. Plutonium pits, freshly separated plutonium metal and oxide, and recycled metal and oxide are slightly lower in attractiveness, and therefore fall into attractiveness level B. Residues, unirradiated fuel and some TRU wastes fall into attractiveness level C. Spent nuclear fuel and most (TRU) waste both fall into attractiveness level D. Finally, high-level waste (HLW) and LLW fall into the lowest level of attractiveness, level E. Added at the bottom of the table, although not specifically noted in the DOE Order, is a category titled "other". Within this category exists material such as Nevada Test Site debris. Although this is relatively difficult to obtain, nevertheless, it represents a source of plutonium for theft or diversion. In fact, in the old test locations, the materials have likely cooled sufficiently such that the nuclear materials are relatively desireable.

The plutonium weapon components, separated metal and oxide, and small portions of the residues are currently under the jurisdiction of the DOE/DP and are managed in a fashion consistent with national defense security activities. Similarly, the storage, protection, and accountability of spent nuclear fuel (SNF) falls under the jurisdiction of the IAEA and is managed in a consistent fashion. It is the materials that fall in the categories of residues, TRU waste, and LLW that are managed in a number of organizations that have less of an integrated focus.

Of particular concern, is the fact that the American Nuclear Society Special Panel on Protection and Management of Plutonium[3] reported that spent nuclear fuel is a continuing proliferation risk, that burial of spent nuclear fuel is not adequate to protect it from proliferation, and that spent nuclear fuel becomes more attractive over time because of the die-out of short-lived daughter products. These facts were reinforced by Dr. Glenn T. Seaborg in his plenary talk to the American Nuclear Society on October 30, 1995.[16] In looking at Table 2 and in reading reference 13, one clearly concludes that if spent nuclear fuel represents a continuing proliferation risk, then residues and waste (TRU and LLW) also represent a continuing proliferation risk. Therefore, consistency in nuclear materials management is becoming increasingly important.

Consequently, it is worthwhile to look at the history of categorization of these materials. During the cold war period, the United States hosted a program of nuclear weapon fabrication that included the making of new plutonium in reactors and, simultaneously, the recycle of manufacturing residues. The value of new plutonium was calculated based on the cost of nuclear reactor and separation canyon operations. The cost of recycle was then compared to the cost of new plutonium, and a decision was made concerning the discard of residues. Those with a cost of recovery that exceeded the cost of new plutonium

Table 2. Nuclear Material Safeguards Categories

Attractiveness Level[14]	Materials Categories[14]	Typical International and DOE Materials
A	Weapons: assemblies and test device.	Weapon assemblies and some components such as some pits
B	Pure Products: pits, major components, buttons, ingots, recastable metal, directly convertible materials	Most pits, freshly separated metal and oxide (IAEA) and recycled metal and oxide (DOE)
C	High-Grade Materials: carbides, oxides, solutions less than 25 g/L, nitrates, fuel elements, alloys	Unirradiated fuel, weapon manufacturing residues, some TRU waste
D	Low Grade Materials: solutions 1-25 g, process residues requiring extensive reprocessing, moderately irradiated materials	Old spent nuclear fuel, some weapon manufacturing residues, most TRU waste
E	All Other Materials: Highly irradiated forms, solutions greater than 1 g/L	New spent nuclear fuel, high-level waste, low-level waste
Other	Difficult to access materials	Nevada Test Site debris

(*The "Other" category is not specifically an aspect of reference 14).

were categorized as waste and packaged for disposal. Those with a cost of recovery less than new plutonium were saved for recycle. This concept was referred to as the "Economic Discard Limit." In addressing the priority for residue recycle, the residues with large plutonium content, and therefore most easily recovered, were selected for recycle first. The lower-concentration residues were stored for future recovery. This approach was referred to as "High-Grading." The decisions were based on available budget and not limited based on whether appropriate technology was available for processing. Clearly this approach was flawed in that it is the lower-concentration residues that contain undesirable characteristics and constituents that are today causing storage difficulties. These difficulties include container failures, corrosion, pressurization, and general loss of containment.[17]

Of special interest is the fact that the basis for discard of nuclear materials was based on an economic evaluation and did not take into account the cost of waste management nor did it take into account the cost of future safeguards. This means that the basis for Material Accountability and Safeguards and the basis for discarding the material as waste were not coordinated. Therefore, some materials having a realtively high attractiveness were not deemed recyclable and were discarded.

The New Goals: Taking Into Account The New Requirements

Clearly today, the goals for plutonium handling have changed dramatically. The focus of the past was on the use of plutonium in nuclear weapons and advanced fuels, while the emerging needs revolve more around the elimination of the current packaging hazards, as well as around the safe isolation and stabilization of material. With regard to the excess residues, waste, facilities, and equipment, Table 3 illustrates this change in paradigm and, therefore, states the basis for the new goals.

In recognition of this new paradigm, DOE has abandoned the concept of "Economic Discard Limits"[18] and is in the process of preparing an approach referred to as the "Plutonium Discard Methodology" (PDM), which takes into account a number of criteria including technology availability; waste minimization; diversion risk; health and safety of processing; and cost.[19] In addition, the DOE has prepared an approach for defining when safeguards provisions are to be terminated on discardable nuclear materials.[20] It is a concentration based criteria and provides for an absolute concentration calculation for safeguards termination. To evaluate the impact of this new paradigm, and both the PDM and termination criteria, it is essential

Table 3. The Paradigm Shift in the Management of Plutonium

Old Paradigm	New Paradigm
• Pu had great value.	• Pu is a liability.
• Pu was purified.	• Bulk residue is purified.
• Pu is the product.	• Bulk residue is the product.
• "Economic Discard Limit" . economy is practiced.	• "Zero" hazard discharge economy is practiced
• TRU waste was accepted.	• Benign discharge is most desired.
• Exceptions were granted to rules.	• Full compliance with rules is expected.

to evaluate the status of plutonium inventories and then to evaluate the status of technology needed to address isolation and stabilization requirements properly.

Status Of The Residues

The First Problem Area

Many plutonium residues and reprocessing wastes are complicated mixtures of different compounds. This means that maintaining accurate accountability records and proper safeguards are difficult. In many residues, there is little fissile content in large-bulk inventories of material. Therefore, handling and packaging strategies are not obvious. Although the problems associated with plutonium residues were recognized by the sites, there is now a heightened awareness within the DOE, and a basis for action, addressing the problems associated with the legacy plutonium residues within U.S. Defense Complex, has been prepared.[21,22] The significance of the residue problem is illustrated by the recently completed plutonium ES&H vulnerability study,[12] which revealed that there are more than 50,000 at risk packages of plutonium stored in various configurations throughout the DOE Complex. Of the 26 metric tons (MT) of plutonium identified as potentially at-risk during this assessment, most exist in a variety of unstable and reactive solid matrices with varying degrees of ES&H vulnerabilities. For example, at three major locations within the DOE Complex, there are large quantities (more than 100,000 gal. total) of solutions containing plutonium and other transuranics having high likelihood for causing environmental contamination and worker safety problems. Table 4 indicates the distribution of residues around the DOE Complex.

Table 4. The Number Of Residue Items Located At Various DOE Facilities[12]

Facility	Total Number of Items
Rocky Flats Environmental Test Site	27,679
Hanford Reservation	8,404*
Los Alamos National Laboratory	9,470
Savannah River Plant	3,794
Argonne National Laboratory (West)	2,360
Lawrence Livermore National Laboratory	2,299
Mound Facility	236
Argonne National Laboratory East/New Brunswick	9,898
Oak Ridge National Laboratory	622
Sandia National Laboratories	117
Lawrence Berkeley National Labortory	473
Total	65,352

* Does not include equipment holdup and in-process soltion.

Declaring these items as waste and directly disposing of them is being considered.[23] None of the current fissile material is in a form that could be packaged directly for waste disposal, and the United States has not yet opened a TRU or HLW repository, despite decades of effort. Recent studies[1] conclude that direct disposal does not adequately address the theft and diversion problems. These constraints suggest that it could be prudent and economically attractive to separate the radioactive material from the bulk materials and thereby provide a robust long-term storage form. To meet the standards that will be required for long-term storage, current technologies[24,25] will need to be adapted and, in some cases, new technologies will need to be developed to isolate plutonium. In addition, these technologies must be in total compliance with the 1992 Federal Facilities Compliance Act and the 1993 Executive Order mandating major waste reductions at all federal facilities,[26,27] particularly with regard to TRU and mixed waste generation. To ensure success, a technology base has to be maintained and new technologies have to be developed and demonstrated to manage the inventories of fissile materials. Consequently, actinide processing and handling technology, in conjunction with enhanced waste treatment technology, is essential to the successful development of a national strategy for fissile material disposal. In particular, developing criteria for suitable material storage forms and processes to manufacture these forms will enable the proper decisions to be made.

1. Status of Technologies for Addressing the Residue Problem
   There are demonstrated technologies that can be immediately applied to reduce the short-term safety concerns resulting from inadequately stored residues. Approaches must be con sidered for ultimate disposal of excess fissile material. Fabricatiion into reactor fuel or immobilization in glass are two possibilities. No schedule for implementation of fissile material disposition has been set by either Congress or by the Clinton Administration. Because a national policy has yet to be formulated, long-term retrievable storage is required. Since much of the material is in solution form and in dilute degradable matrices, processing/stabilization is required to prepare it for safe storage.
2. TRU Residue Processing
   On the basis of our current knowledge of residues, only properly prepared oxide and metal are considered suitable for long-term storage. Because oxide and metal are a relatively small portion of the residue holdings in terms of net weight, we completed an assessement of the entire residue inventory to identify vulnerabilities. The overall priorities for stabilization were assigned as follows:
   - Items that present an unusual radiation or release hazard;
   - Items that are corrosive and can breach their current con tainers;
   - Items that are combustible or can easily form com bustible mixtures;
   - Reactive/unstable mixtures such as organics in contact with radioactive material, calcium metal, or solutions in interim containers.

The ultimate goal is to isolate radioactive materials and other hazards from the bulk matrix; produce only a LLW (or better) during processing; and to store the radioactive material in a safe, acceptable form pending final disposition. To accomplish this goal, we must be able to treat effectively the spectrum of radioactive residues and to continue to develop and demonstrate enhanced recovery, stabilization, and assay capabilities. As examples of the type of capability improvement, we continue to lower detection limits for assay instruments and to develop residue processing operations for the improvement of the actinide recovery efficiencies, using better separation and waste treatment technologies.

To eliminate these immediate corrosive and reactive hazards, several existing technologies have been identified and can be implemented to reduce the risk involved with these residues. In order to reduce the life-cycle cost of radioactive material management and the long-term liability of handling and storing energetic materials, the final state of material must meet the storage criteria. The only proven method to achieve this stability is to separate the plutonium or other radioactive material from the bulk matrix, discard the bulk material as a certified waste form, and store the radioactive material as a metal or oxide. In essentially all cases, methods exist for remediating residues. However, these methods were developed and optimized to purify plutonium, rather than to produce a safe storage form with minimium waste. Consequently, in order to meet the new goals, it will be desirable to adapt proven technologies for plutonium separation and advanced waste treatment. These modified and new methods should be implemented to ensure that the processing of plutonium residues has the least impact on the environment and worker safety as is technically and economically possible. At Los Alamos, a multistaged sampling program for vault holdings, was designed in an effort to assess the status of packaging against the above criteria. Every container was visually inspected and handled in order to evaluate container integrity. Suspect packages were removed from the vault shelves and repackaged. In a second phase, 160 items were selected at random and totally unpackaged in order to evaluate package integrity. In phase three, 220 old packages were selected in an effort specifically to evaluate the effect of age on package integrity. Finally, every item that is brought up for processing undergoes an evaluation for package integrity simultaneously with the actual residue stabilization effort.

All vault items are categorized, based on hazard reduction, for processing as shown in Table 5. Therefore, the risk-reduction approach will be to process and stabilize these items so that they can be properly converted to stable oxides for long-term storage.

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Table 5. Processing Approach By General Category

Residue Category	Identified Hazards	Remediation Approach
Solutions	Containment, radiolysis, criticality, control of solution chemistry	Ion extraction, solvent extraction, precipitation, direct calcination
Salts		
Pyrochemical	Reactive metals, corrosion, gas generation	Oxidation, reduction, distillation
Sand, Slag, and Crucible	Reactive metals, corrosion	Size reduction, Pu separation
Ash	Radiolysis, gas generation	Calcination, Pu separation
Metals	Oxidation, radiolysis	Repackaging
Oxides	Radiolysis, pyrophoricity, dispersibility	Calcination, repackaging
Combustibles	Radiolysis, gas generation, flammability	Volume reduction, matrix destruction, Pu separation
Noncombustibles	Radiolysis of packaging materials, gas generation	Volume reduction, Pu separation

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3. *Separation Techniques*

- Salts — Pyrochemical salts and sand, slag, and crucible represent a signficant fraction of the residue inventory in the DOE Complex. Potential hazards associated with these salts include corrosion of the container, gas generation from radiolysis of moisture with the salt or the packaging materials, and the presence of reactive metals.

  Processing techniques have been developed that use carbonate to oxidize the reactive metals in pyrochemical salts. Tests for water decomposition by reactive metals have been conducted to document the efficiency of this process. In all cases using this chemical oxidation procedure, no hydrogen evolution above the baseline was observed. Chemical oxidation alone would meet the sta bilization requirements, but plutonium separation is required to facilitate the safe disposal of these salts as waste. A distillation process is under development that will extensively reduce the need to use aqueous processing flowsheets to remove plutonium from this matrix. A recent trade study commissioned by the Department of Energy's Nuclear Material Stabilization Task Group,[28] taking into account waste minimization, radiation expo sure, disposal costs, and schedule, found that salt distillation would be the most efficient process to facilitate the disposal of the majority of the pyrochemical salt inventory.

- Solutions — Plutonium nitrate and chloride solutions are currently being stored in configurations that were not designed for extended storage. The solutions are stored in plastic bottles, stainless steel and plastic-lined tanks, and process piping. These solutions, which range from 0.25 to 300 g Pu/L, represent some of the most significant vulnerabilities to the worker. Control of the solution chemistry to prevent unanticipated concentration or precipitation of neutron absorbers, such as boron, is required. There is no question that solutions are not suit able for safe interim storage and must, therefore, be solidified as expeditiously as possible. Several processing techniques have been or are under development with in the DOE Complex to meet specific site requirements for the stabilization of these solutions. Well-demonstrated precipitation techniques may be the most efficient. A flowsheet involving the Pu (III) oxalate precipitation followed by magnesium hydroxide precipitation of the filtrate has been demonstrated for the stabilization of Rocky Flats nitrate solutions containing high levels of plutonium (less than 6 g Pu/L). This technology effectively stabilizes the solution, while minimizing processing exposure and waste generation.

A vertical calciner is being developed by Hanford personnel for the direct conversion of plutonium nitrate solutions to a stable, storable solid. In this process, small amounts of plutonium-bearing solutions are metered into a continuously heated and stirred bed of solids. Calcination proceeds through rapid evaporation of liquid, slowly drying to solids, denitration, and initial heat treatment of stable plutonium dioxide. This process is known to work on solution concentrations ranging from 15 to 500 gm/l.

- Combustibles and Noncombustibles — Currently, pyrolysis, electrochemical oxidation, and hydrothermal processing are being tested as advanced methods of processing combustible wastes. As an example, a pilot-scale pyrolysis experimental setup was designed and constructed to test the viability of this approach. Materials commonly used in glovebox applications were pyrolyzed. All of the materials were reduced significantly in mass to dry, solid, black materials. Introducing a few conventional technologies (e.g., a cold trap and an activated carbon filter to capture the organics, and a catalytic converter to oxidize carbon monoxide to carbon dioxide), will allow pyrolysis to be readily deployed in a manner compliant with environmental regulations.

In addition, it is possible, with a select variety of combustible and noncombustible items to remove the plutonium by first freezing the material and then crushing it to increase surface area. The plutonium on the surface can then be removed by simple washing. Therefore, safety concerns about potential fire or explosion hazards caused by radiolytic-hydrogen generation or high flammability can be reduced. Bench scale tests on polypropylene filters, which were used as pre-filters in the rich-residue - ion-exchange process line at the Los Alamos Plutonium Facility were performed using ultrasonics and advanced dissolution agents as a method for dislodging particulates. Batch experiments were run on crushed filter material in order to determine the amount of Pu removed by stirring, stirring and sonication, and stirring and sonication with the introduction of Pu-chelating watersolu able polymers or surfactants. Significantly more Pu is removed using sonication and sonication with chelators than is removed with mechanical stirring alone.

As leaner residues are scheduled for processing, improved solid treatment methods will be required to reduce the volume of TRU (less than 100 nCi/g) waste. This is important because of the large cost difference between TRU and LLW. Also, physical solid-solid separation methods, such as magnetic separation, are being implemented to reduce the initial volumes of the low-level residues, such as ash and graphite.

Waste Treatment

The Second Problem Area

Waste exists in solid, liquid, and gaseous forms. For the most part, gaseous forms are treated by scrubbing and filtering, and are therefore not considered a problem in waste management. The principal issues include treating liquid and solid wastes as well as certifying waste products.

- Liquid Waste — This treatment effort must meet all applicable state and federal regulations for radioactive and hazardous waste. Generally, the most pressing issues involve characteristics other than radioactive materials, such as nitrate content or heavy metal content. In addition, there are considerable cost savings incurred by minimizing waste wherever possible. At Los Alamos, for example, it is planned to implement acid recycle in order to lower the volume of solid waste produced at the TA-50 Low-Level Waste Treatment Plant. Also, chelating extractants will be deployed to reduce the radioactivity discharges from the liquid waste stream in order to comply with the proposed 0.5 (Ci/L discard limits being considered for the Liquid Waste Treatment Facility.
- Solid Waste — Improved methods, such as advanced soaps, plasma-based, and electrochemical decontamination techniques will be tested and implemented to remove plutonium from the solid residues, such as plastic filters, dirt and blacktop, and other items that do not meet the current waste acceptance criteria. These technologies can also be used to reduce the volume of secondary radioactive solutions that are inevitable during processing operations.

Nondestructive Assay (NDA) Methods

Because of the nonhomogeneous and dilute nature of the residues, better assay methods are required to ensure good accountability of fissile material. Improved NDA techniques will also ensure that the waste forms can be properly certified for final disposal. NDA methods are attractive because they can be done in-line and do not require chemical sampling of the matrix. Furthermore, they can be computerized to ensure repeatability and reduce operator exposure.

Conclusions

With the end of the cold war, the goals for plutonium management have changed dramatically. The focus seems to be on the immobilization of plutonium caused by vitrification, mixing into ceramic based materials, or mixing with high level waste. In addition, direct packaging and disposal at Waste Isolation Pilot Plant, of Rocky Flats residues, is being planned.[23] It is imperative that plutonium be safeguarded against theft and diversion. Recent studies have asserted that materials, such as SNF, may represent an unacceptable diversion risk if disposed of in its present form. By using the DOE Order on Nuclear Material Safeguards, it is clear that plutonium bearing residues, and many waste materials (TRU and LLW) are at least as attractive as SNF, and therefore, must be safeguarded in as rigorous a fashion. This implies that d irect discharge of residues and some waste items into repositories is likely unacceptable.

With regard to the storage of plutonium materials, experts know most about the long-term stability of relatively pure plutonium oxide and metal. The storage of plutonium in all other forms, such as residues, has resulted in the loss of containment within relatively short periods of time, by corrosion and pressurization mechanisms. In addition, the country has been unable to open and operate a long-term repository for storage of waste and excess materials, presumably a result of the inability to assure containment of radioactive materials.

Therefore, it is prudent to consider a fourth approach for plutonium management, that of separation. Separation of plutonium from the bulk matrices, discarding the bulk as certified waste, and storing plutonium as a storable oxide, provides the option to manage plutonium safely until such time as disposition approaches can be evaluated and ultimate disposition can be selected. The oxide would not be highly purified as in the "Cold War" past. The necessary separations technology base exists to handle essentially all forms of plutonium residues and can be quickly deployed. Some research and development is appropriate to properly tailor process flowsheets to meet this new challenge. Separating and storing the plutonium meets safeguards needs, protects against escape of plutonium into the environment, eliminates identified vulnerabilities, and preserves all options currently being considered for ultimate disposition, whether they be vitrification, cementation, deep bore hole discharge, spent fuel standard, or transmutation.

Disclaimer

The views expressed in this paper are solely those of the authors. The views are based on the evaluation of numerous references concerning the management of plutonium, most of which are DOE citations. Despite this, the views do not necessarily reflect the views of the U.S. government or of any of its agencies.

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DOE Finances Research for New Nuclear Waste Container

The U.S. Department of Energy recently awarded University of Missouri-Rolla (UMR) a $628,834 three-year grant to continue research on a unique iron phosphate glass that could be used to dispose of excess plutonium from nuclear weapons being dismantled after the end of the Cold War.

The research, which is being conducted in conjunction with Westinghouse Savannah River Co. and Battelle Pacific Northwest National Laboratories, consists of using a special iron phosphate glass to chemically dissolve the nuclear waste, says Delbert E. Day, a UMR curators' professor of ceramic engineering and director of the research. Day says it will take several years and billions of dollars to dispose of all the radioactive waste that was created from the production of nuclear weapons and electricity in the United States.

"We prepare simulated nuclear waste and determine how much of that waste can be dissolved in the iron phosphate glasses," Day says. Through vitrification, Day and his colleagues melt a mixture of simulated radioactive waste with nonradioactive base material to form a glass that immobilizes the waste.

"The glass container can then be stored in a repository deep in the Earth for thousands of years, with little or no chance of radioactive materials escaping into the environment," Day says.

Directory Lists Nuclear and Biological Weapons

Terrorism is likely to move into a terrifying new realm as the tools of biological warfare become increasingly available, says Terry J. Gander, editor of Jane's Nuclear, Biological and Chemical Protection Equipment.

This annual directory which lists nuclear and chemical weapons and provides inventories of all three types of weapons for nearly every country. Bacteria that cause such diseases as typhoid fever, "black death," Rocky Mountain spotted fever, dysentery, cholera, and diphtheria, among others are also listed.

Each entry contains a description of the equipment, specifications, manufacturer information, and "status" section listing those countries using the product. Entries are listed by country of manufacture. Indexes list both manufacturers and products.

For more information, contact Jane's Information Group Ltd. at 800/243-3852 (in Virginia call 703/683-3700) or visit Jane's on the Internet at http://www.janes.com.

New Gamma-Ray Spectrometer Connects to Ethernet

EG&G Ortec announces its new 92X-II Gamma-Ray Spectrometer that can connect directly to an Ethernet for convenient use of high-performance gamma-ray spectroscopy. According to EG&G, its Maestro MCA emulation software will provide PC control across the ethernet for all Windows environments.

For more information, contact EG&G Ortec at 800/251-9750 for a free, four-color brochure describing the gamma-ray spectrometer.

ADVERTISER INDEX

December 16–20, 1996
Preventing the Proliferation of Weapons of Mass Destruction; Steyning, UK; Wilton Park Conferences. *Contact*: Elizabeth Harris, tel.: (UK) +44 01903 815020; fax: +44 01903 81593

January 29-31, 1997
Spent Fuel Management Seminar XIV, Washington, D.C. *Sponsor:* INMM. *Contact:* Barbara Scott or Melanie Epel, tel.: 847/480-9573.

April 1997
(date and location to be announced)
International Symposium on Applications of Isotope Techniques in Studying Past and Current Environmental Changes in the Hydrosphere and the Atmosphere, Vienna, Austria. *Sponsor*: International Atomic Energy Agency.

April 1–3, 1997
Software Quality Forum, Albuquerque, New Mexico. *Sponsors*: Software Quality Assurance Subcommittee of DOE's Quality Managers, the Quality Managers of the Nuclear Weapons Complex and the Albuquerque Office's Weapons Quality Division. *Contact*: Wayne Jones, tel.: 201/903-4655.

The International Inspection of Excess Fissile Materials Seminar,

which was to be held November 13–14, 1996, at the Sheraton Centre, Washington, D.C., has been posponed until further notice.

If you have any questions, please call INMM headquarters at 847/480-9573.

May 1997
(date and location to be announced)
1997 ESARDA Symposium
19th Annual Symposium on "Safeguards and Nuclear Materials Management." *Contact:* Ms. F. Genoni; tel.: +39-332-789421; fax: +39-332-789509.

Author Submission Guidelines

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  2. Jones F.T., *Title of Book*, New York: McMillan Publishing, 1976, pp.112-118;
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