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INMM Members Can Play a Central Role in the Extension of the NPT

At the Review and Extension Conference of Parties to the Treaty on the Nonproliferation of Nuclear Weapons (NPT) in May, the parties to the NPT agreed to its indefinite extension. This significant achievement represents a major victory for all Nuclear-Weapon States and serves to strengthen the nonproliferation regime through continued broad support for the NPT. In conjunction with the decision for indefinite extension, the parties also adopted a declaration on principles and objectives for nuclear nonproliferation and disarmament and a text on strengthening the NPT review process.

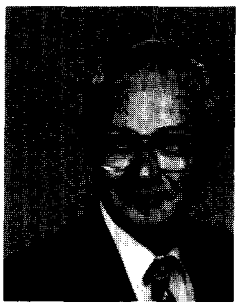
What do these important events mean for the nuclear materials management profession in general and the INMM in particular? Sound nuclear materials management practices are fundamental to preventing nuclear proliferation, and International Atomic Energy Agency (IAEA) safeguards provide the verification of commitments to use nuclear materials for peaceful purposes under the terms of the NPT. Thus, the strong reaffirmation of the NPT is also a reaffirmation of the nuclear materials management and safeguards procedures that have been developed by our community since the beginning of the nuclear era, and especially over the 25-year life of the NPT. However, the declaration on principles and objectives for nuclear nonproliferation and disarmament and the text on strengthening the NPT review process that were adopted at the conference make clear that we cannot rest on our laurels.

The NPT will continue to be reviewed every five years, with preparatory conferences to be held in each of the three years leading up to the five-year review conference. Clearly, the performance of the nuclear materials management systems employed around the world and of the international safeguards regime will be examined as a part of this process. Furthermore, the declaration calls for continued strengthening of IAEA safeguards and universal adherence to the NPT, as well as states that "nuclear fissile material transferred from military use to peaceful nuclear activities should, as soon as practicable, be placed under Agency safeguards in the framework of the voluntary safeguards agreements in place with the nuclear-weapon States. Safeguards should be universally applied once the complete elimination of nuclear weapons has been achieved." The declaration also calls for "the immediate commencement and early conclusion of negotiations on a nondiscriminatory and universally applicable convention banning the production of fissile material for nuclear weapons or other nuclear explosive devices, in accordance with the statement of the special coordinator of the Conference on Disarmament and the mandate contained herein."

It is clear we have our work cut out for us. The INMM can, of course, continue to play a central role in facilitating the advancement of nuclear materials management technologies and procedures in support of this ambitious agenda through information exchange and professional development. For the INMM to be successful, we need your help. The people who organize the technical meetings and workshops, edit the *Journal of Nuclear Materials Management* and serve on committees are all volunteers dedicated to furthering the nuclear materials management profession. Those of you who contribute through meeting attendance and writing and presenting papers are also volunteers. To meet the challenges of the future, we need more of you to volunteer and we need new blood. Get involved and bring a friend. These are exciting times for nuclear materials management professionals.

James W. Tape
Los Alamos National Laboratory
Los Alamos, New Mexico, U.S.A.

Materials Management, Safeguards Remain Vital to INMM, NPT



In 1963, President John F. Kennedy predicted a world in the 1970s having 15 to 25 nuclear-weapon States. Yet, although 40 or 50 States have the technical capabilities to develop nuclear weapons, the number that have done so can be counted on your fingers — five declared nuclear-weapon States and perhaps a similar number of States suspected to have undeclared weapons or the immediate capability of producing them.

Maybe the Treaty on the Nonproliferation of Nuclear Weapons (NPT) is part of the reason for this contrast. Based on the worldwide *a priori* assumption that proliferation is bad, and recently called "one of the pillars of a stable world order" by Egyptian President Hosni Mubarak, the NPT was negotiated in the mid-1960s and entered into force in 1970. Under the NPT, the nonnuclear-weapon States undertook not to transfer or receive any nuclear weapons and to submit all their nuclear facilities to IAEA safeguards. The nuclear-weapon States promised "the fullest possible exchange" of nuclear technology and good-faith negotiations on effective arms control and disarmament measures.

Since then, nearly 50 States have adhered to the provisions of the NPT. It is part of the international system for preventing the spread of nuclear weapons. It works!

But keeping the nuclear weapon materials out of the environment, and, more importantly, out of the hands of States and terrorist groups determined to acquire nuclear weapons, is still one of the most difficult challenges that we face.

And that is what we, the INMM, are all about. Nuclear materials management. Safeguards. Nonproliferation.

Two of the papers in this issue of the *Journal of Nuclear Materials Management* discuss state systems of accounting for and control of nuclear materials, designed to accommodate IAEA inspections. The first, by Wan Ki Yoon of the Technology Center of Nuclear Control in Korea, presents an overview of Korean safeguards implementation. It describes a vigorous nuclear power program and the extensive measures taken to manage the associated nuclear materials.

The second paper, by Hiromasa Nakano and Mitsunori Akiba of the Power Reactor and Nuclear Fuel Development Corp. in Japan, discusses the major facilities in a total nuclear fuel cycle and a novel approach to materials accounting therein.

The final paper in this issue is by Roger Johnston, Anthony Garcia and Kevin Grace. It describes an extensive study of tamper-indicating seals and the somewhat disturbing results of that study.

I end this note with my usual call for papers. We are always looking for papers for future issues of the *JNMM* — please help!

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

Alvin Weinberg's Two Books Skillfully Recount His Life, Development of Nuclear Energy

Alvin Weinberg, *The First Nuclear Era: The Life and Times of a Technological Fixer.* (American Institute of Physics, New York, 1994)

Alvin Weinberg, *Nuclear Reactions: Science and Trans-Science.* (American Institute of Physics, New York, 1992)

The personal histories of individuals who played a key role in the events of their days are especially valuable in that the histories not only depict the events themselves, but provide a glimpse into the ideas and perceptions of the participants during these events. To one who has witnessed the entire 50-year course of the development of nuclear technology in the United States, from its inception to its present state of near-dormancy, Alvin Weinberg's latest book, *The First Nuclear Era: The Life and Times of a Technological Fixer,* is particularly interesting, for it describes a professional life in this field that spanned the same course, from the early days of the Manhattan District to the present.

Weinberg relates his personal sagas, those of his colleagues and the technological accomplishments in which they all participated. These accomplishments are interesting enough in themselves, but, more importantly, the book as a whole clearly and thoughtfully articulates the concerns we have all shared about the role of nuclear energy in society and the broader, more fundamental questions of science, technology and public policy. *The First Nuclear Era* is so rich in both history and philosophy that a review can only attempt to treat a few topics that are of particular interest; readers will find many more to interest them.

Weinberg's professional life consisted of three phases:

- Wartime service in the Manhattan District where, working with Eugene Wigner, he played a key role in the early development of reactor theory and in the design of the pilot X-10 reactor at Oak Ridge and the Hanford production reactors;
- a long tenure at Oak Ridge National Laboratory, from 1948 to 1973, during which he was successively associate director, director of research and director, making major contributions to the development of nuclear energy as it is known today; and
- service to the U.S. government in various capacities dealing with numerous issues of science, technology and public policy, including membership on the President's Science Advisory Committee from 1959 to 1962, directorship of the Federal Office of Energy Development in 1974, foundation of the Institute for Energy Analysis at Oak Ridge in 1974 and directorship of the Institute for 11 years thereafter. Weinberg's accomplishments during these years brought him many honors and awards, among them the Ford Family's Atoms-For-Peace Award, AEC's prestigious E.O. Lawrence Memorial Award and the Enrico Fermi Prize.

Weinberg's scientific career began in 1939, when he completed his Ph.D. thesis at the University of Chicago under the direction of Nicholas Rashevsky, a gifted physicist who is credited with founding the discipline of mathematical biophysics. At the same time, Weinberg also worked with Carl Eckart, a prominent theoretical physicist who later became the world's foremost theoretical oceanographer.

Weinberg's career in nuclear energy began in late 1941, when Eckart, who was already working with Sam Allison, distinguished nuclear physicist and professor at University of Chicago, on the problem of obtaining a self-sustaining fission chain reaction, asked Weinberg to assist him in evaluating the use of beryllium as a moderator for this purpose. Shortly thereafter, in February 1942, all work in this area was concentrated at the Metallurgical Laboratory in Chicago. The team assembled there included Enrico Fermi, John Wheeler, Wigner and Walter Zinn. The principal task of this group was to attain a self-sustaining chain reaction, and *The First Nuclear Era* conveys the sense of wartime urgency permeating the effort. The first successful operation of the Chicago reactor was on Dec. 2, 1942.

Perhaps less well-known is the parallel effort carried out at the same time, by a team led by Wigner and including Weinberg, to design a 500-MW water-cooled plutonium production reactor. Remarkably, this work was completed in early January 1943, only one month after the Chicago reactor first achieved criticality. In the book, Weinberg gives much of the credit for this work to Wigner, who, in addition to his well-known accomplishments in physics, was competent in engineering. This reactor design, with some modifications, was adopted for the Hanford production reactors that were constructed and put into operation during 1943 and 1944, in itself an astonishing achievement.

In connection with the initial operation of these reactors, we learn an interesting bit of history: Shortly after startup, a large, unexpected drop in reactivity occurred, causing dismay among the developers. Within days after this occurrence, Wheeler and Fermi correctly interpreted the cause of this phenomenon: The now well-known poisoning of the reactor by the fission product ^{135}Xe. Apparently, Wheeler had anticipated that, among the many nuclides produced in fission, there might be one or more with thermal neutron absorption cross-sections large enough to reduce the reactivity substantially and was prepared for this eventuality.

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INMM Offers Many Ways for Professionals to Influence Its Direction

The message from INMM Chair James W. Tape (page 4) is timely from an international perspective and also with respect to the INMM. The INMM will continue to facilitate the advancement of nuclear materials management technologies and procedures through information exchange and professional development, but it needs the help of dedicated professionals who are willing to volunteer their time.

By getting personally involved, you have an opportunity to influence the direction and activities of your professional association. By participating, you help shape the future of nuclear materials management. In addition, your participation can provide many positive personal experiences, strengthen your ties with the association community, introduce you to many nuclear material professionals you not have had the opportunity to meet, allow you to share your expertise with others, and gain additional expertise.

There are many different ways to volunteer your support to the INMM, including serving as an INMM Executive Committee member, participating on one or more of the standing committees or technical divisions, contributing an article to the *Journal of Nuclear Materials Management*, and assisting with any of the INMM Annual Meeting activities. The degree of commitment and effort varies between activities, but each contribution is equal in value.

If you are interested in additional information, call me at (509) 372-4663, or find me during the Annual Meeting, July 9–12, at the Marriott Desert Springs Resort Hotel, Palm Desert, Calif. I welcome the opportunity to discuss these options with you, or I will ensure the appropriate individuals get in touch with you.

Obie Amacker, INMM Vice Chair
Pacific Northwest Laboratory
Richland, Washington, U.S.A.

Third International Uranium Hexafluoride Conference: Processing, Handling, Packaging and Transporting

The Third International Uranium Hexafluoride (UF_6) Conference is being organized to continue the dialogue and discussion of issues that were initiated at the two previous meetings and also to provide opportunities to discuss current issues of importance to the UF_6 industry.

The conference is Nov. 28-Dec. 1, 1995, at the J.R. Executive Inn in Paducah, Ky., U.S.A.

This year's conference is being organized by the Institute of Nuclear Materials Management. Participating organizations are Martin Marietta Energy Systems Inc., Martin Marietta Utility Services Inc., U.S. Department of Energy, U.S. Nuclear Regulatory Commission and U.S. Enrichment Corp.

In order to assure that the most important topics are included, your response is requested. **Please complete the form on the right and return to INMM, Third International UF_6 Conference, 60 Revere Dr., Suite 500, Northbrook, IL 60062. Or fax to INMM at 708/480-9282.**

Name ______________________

Company ______________________

Address ______________________

City ____________ State ______ Zip ______

Phone ____________ Fax ____________

Country ______________________

I **plan** / **do not plan** (circle one) to attend the Third International UF_6 Conference

I **wish** / **do not wish** (circle one) to present a **paper** / **poster exhibit** (circle one). My presentation will be on:

____

Presenters will receive submission information at a later date.

I would like to see the following issues or topics discussed:

____

____

Committees: Communications

Once upon a time, there was an organization called the Institute of Nuclear Materials Management, and the organization did a lot of communicating with its members. The members were primarily English-speaking, domestic professionals interested in furthering sound nuclear materials management practices. Communications for the INMM was fairly simple.

Gradually, the organization grew and gained international members, and new communications problems developed. It became more difficult to communicate with each other and with the professional community, and ensure the focus of the *Journal of Nuclear Materials Management* adequately reflected the INMM's membership. However, the field of nuclear materials management remained fairly stable, and eventually the efforts of dedicated individuals tackling these problems paid off. Communicating once again became fairly straightforward, and the INMM forgot about how difficult it was for a while.

We, the INMM, once again face major changes in the climate in which we communicate. This year we welcomed yet another new international chapter into the fold, the first Russian Federation Chapter of the INMM. We anticipate more chapters forming in the former Soviet Union, as the United States is presently involved in multiple programs of mutual nuclear materials management cooperation and assistance. The Treaty on the Nonproliferation of Nuclear Weapons was recently renegotiated, in a much-changed world from the mid-1960s when it was first negotiated. Nonproliferation and arms control activities will continue to expand our communications environment. Will communications ever be simple again?

My challenge as the INMM Communications Committee chair is to assist in trying to find ways to communicate more effectively, in a number of arenas. They include Executive Committee communications, the *JNMM*, public outreach, and member and chapter communications. Throughout the past year, the Communications Committee worked primarily in the area of Executive Committee communications and the *JNMM*. An Operations Handbook was developed to assist members of the Executive Committee and technical and standing committees. In addition, the committee sought imput from the membership on ways to improve the *JNMM*, and develop additional means of member communications.

During the coming year, we need to continue to concentrate on these activities and move into the public outreach area. There is a growing need for INMM's guidance and expertise in domestic and international arenas. We need to share on a broader scale our vision of what the INMM is about. Past INMM Chair Dennis Mangan is leading a very important strategic planning effort for the INMM. In his column in the last issue of the *JNMM*, he included a draft of the INMM vision statement: "Our vision is to be the leading professional society to develop, advocate and *communicate* responsible nuclear materials management principles and practices throughout the world." Please notice my emphasis on the word *communicate* — that's what the Communications Committee is all about.

INMM Vice Chair Obie Amacker wrote a timely article in this issue about volunteering your services to INMM (page 7). As we continue our strategic planning efforts, communications will continue to play a key role in creating successes. Please consider joining the Communications Committee. The items listed in this column are only a few ways to contribute. Each new member brings additional creativity to the committee, and I'd like to see that new member be you.

I'll be at the INMM 36th Annual Meeting in Palm Desert, Calif., and would be happy to discuss the committee activities with you. You can also reach me via e-mail at da_dickman@pnl.gov, or by telephone at (509) 372-4432.

Debbie Dickman, Chair
INMM Communications Committee
Pacific Northwest Laboratory
Richland, Washington, U.S.A.

Government Liaison

For the fourth consecutive year, the INMM Government Liaison Committee is organizing a special morning session July 13 at the INMM Annual Meeting. As last year, the session will feature invited speakers addressing "National and International Initiatives in Nuclear Materials Management." As of June 2, the following topics and speakers are confirmed:

- Arms Control and Disarmament Agency Nonproliferation Regimes, Dr. Michael Rosenthal, ACDA;
- On-Site Inspection Agency Nonproliferation Programs, Dr. Joerg Menzel, OSIA;
- Department of Energy Vision for United States-Russian Cooperative International Monitoring of Nuclear Materials; Dr. John Rooney, U.S. Department of Energy; and
- Changes in DOE Oversight: A Multidisciplined Approach, Barbara Stone, U.S. Department of Energy.

The committee is still seeking speakers for two additional topics: the Cooperative Threat Reduction Program and the black market for nuclear materials. Please plan to attend this timely, informal session. See the INMM Annual Meeting Final Program for information on location and time. For more information on the session, contact Committee Chair John Matter at (505) 845-8103, fax (505) 844-5321 or e-mail jcmatte@sandia.gov.

John Matter, Chair
INMM Government Liaison Committee
Sandia National Laboratories
Albuquerque, New Mexico, U.S.A.

N14 Standards

The INMM N14 Standards Committee will hold its annual meeting and sponsor a poster session at the PATRAM '95 Conference in Las Vegas, Dec. 3–8, 1995. The International Standards Organization and American National Standards Institute were asked to consider a similar effort.

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

N15 Standards

The scope of the American National Standards Institute (ANSI) N15 standards is closely aligned with the domestic and international nuclear material safeguards and security requirements. The N15 standards provide guidance to facilities and oversight organizations for the development of those critical procedures that are required if a facility is to have an effective safeguards and security system. The scope of the N15 standards is as follows:

"Standards for protection, control, accounting and environmental monitoring of nuclear and related materials in all phases of the nuclear fuel cycle, including analytical procedures where necessary and special to this purpose, except that physical protection of nuclear materials within a nuclear power plant is not included."

The N15 technical standards program currently maintains the following standards:

- N15.10–*Classification of*

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N15 Standards Committee

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Unirradiated Plutonium Scrap

- N15.18–*Mass Calibration Techniques for Nuclear Material Control*
- N15.19–*Volume Calibration Techniques for Nuclear Material Control*
- N15.20–*Guide to Calibrating Nondestructive Assay Systems*
- N15.22–*Calibration Techniques for Calorimetric Assay of Plutonium-Bearing Solids Applied to Nuclear Materials Control*
- N15.28–*Guide for Qualification and Certification of Nuclear Safeguards and Security Personnel*
- N15.36–*Nondestructive Assay Measurement Control and Assurance*
- N15.41–*Guide to Nuclear Facility Measurement Control*
- N15.50–*Measurement control Program – Nuclear Materials Analytical Chemistry Laboratory*
- N15.54–*Radiometric Calorimeters – Measurement Control Program*
- N15.55–*Guide to Measurement Control for Volumetric Measurements*

As can be seen, nine of the 11 standards pertain to calibration and measurement control. However, measurement control is only one aspect of an effective safeguards and security system. Technical standards specifying the requirement of the other components of a safeguards and security system were withdrawn because they became out-of-date and need to be redeveloped.

The goal of the voluntary consensus standards program administered by ANSI is to use the expertise of people involved with a technical issue to define those qualities of a procedure or item that will assure the greatest benefit to industry and government. The voluntary standards program requires contributions from personnel beyond the requirements of their routine job responsibilities. Few people, especially in the safeguards and security field, have funding to support standards development efforts.

Decreasing funding for implementation of safeguards and security at the nuclear facilities, as well as at the government regulators, has severely impacted the capability to maintain technical standards and regulatory guidance for nuclear material safeguards. Many of the N15 technical standards were withdrawn from active service because they were out of date. Many of the U.S. Nuclear Regulatory Commission's regulatory guides need to be updated. The U.S. Department of Energy has only a small number of guidance documents to support its orders.

A solution to the issue is to pool the resources of the N15 Committee (i.e., the membership of the INMM) and regulatory and oversight organizations to develop technical standards that define the procedures and systems that contribute to an effective safeguards system.

Guidance provided throughout the U.S. government already espouses preferential use of international and national voluntary standards over the development of guidance and regulations by government organizations. The use of international and national standards represents cost-savings to the government with respect to the resources that must be expended by a government organization to develop and maintain guidance and regulatory documents. Use of the same reference standards also promotes consistency among the requirements of the regulatory agencies and the implementation by the facilities. Voluntary technical standards supported by the government regulators provide commercial organizations the opportunity to participate in the development of best practices for safeguards and security systems that can be referenced by the regulatory or oversight agencies.

The following meetings to define the short- and long-range goals of the N15 technical standards program will be held during the INMM 36th Annual Meeting in Palm Desert, July 9–12:

- July 7, 8, 13 and 14: N15 Standards Development Committee Meetings. Meetings may be scheduled on these days to work on revising or reviewing existing standards and those under development.
- July 9, 11 a.m.–1 p.m.: N15 Management Committee Meeting. The mission of the N15 standards program and its objectives will be defined. The meeting will be a working luncheon open to all people on N15 committees or wishing to participate on a standards committee.
- July 9, 4 p.m.–5 p.m.: ANSI Technical Standards Information Meeting. This is an open meeting for all interested people and will review the INMM's role in the development of ANSI and International Standards Organization (ISO) standards. The activities of the N14 and N15 technical standards programs will be discussed.

I hope to see you at the INMM Annual Meeting so that we may set the N15 technical standards program on a course to meet the needs of the future.

Bruce Moran, Chair
INMM N15 Standards Committee
Martin Marietta Energy Systems
Oak Ridge, Tennessee, U.S.A.

Divisions: International Safeguards

On May 12, 1995, the INMM International Safeguards Division (ISD) met at the Eurogress in Aachen, Germany, the site of the 1995 ESARDA 17th Annual Symposium on Safeguards and Nuclear Material Management. Twenty members of the international safeguards community participated in the meeting, from EURATOM, EC/JRC-Ispra, ABACC, Australia, France, Germany, Japan, Netherlands and the United States.

Extensive discussions were held on the current environment surrounding international safeguards and the changes that are expected to occur in the coming years. There are a wide variety of new measures under consideration and related field trials, including expanded SSAC interactions, extended declarations, extended access, and environmental and remote monitoring. As in past meetings of the ISD, it was recognized that many technical and policy issues must be considered before the introduction of the measures currently under consideration.

The next ISD meeting will be held July 9, 1995, from 2 p.m. to 3 p.m., during the INMM 36th Annual Meeting in Palm Desert, Calif., July 9–12.

Cecil Sonnier, Chair
INMM International Safeguards Division
Sandia National Laboratories
Albuquerque, New Mexico, U.S.A.

Please note:
All INMM technical division meetings at the Annual Meeting will take place on Sunday, July 9, from 2 p.m. to 5 p.m.

Nonproliferation and Arms Control

Dr. Jim Fuller of Pacific Northwest Laboratory (PNL) agreed to serve as vice chair of the INMM Nonproliferation and Arms Control Division. Since 1990, Fuller has worked in several capacities at the U.S. Department of Energy (DOE) in Washington, D.C., including acting deputy director of the Office of Research and Development (DOE/NN-20) and DOE staff member supporting the Non/Counter Proliferation Programs Review (Deutsch) Committee. His current position is senior program manager in the Office of Arms Control and Nonproliferation in the National Security Division at PNL.

Andrew Bieniawski is the first secretary of the INMM Nonproliferation and Arms Control Division. He is the Fissile Materials Group leader in the Division of Negotiations and Technical Analysis at the DOE Office of the Arms Control and Nonproliferation. He recently returned to the DOE from a year at the Paul H. Nitze School of Advanced International Studies at Johns Hopkins University, where he did the bulk of his study toward a master of arts degree in international relations.

The INMM Nonproliferation and Arms Control Division made a few minor revisions to the division charter, including removal of references to "intelligence" as part of monitoring aspects of verification.

This year the INMM saw the highest number of abstracts submitted for inclusion in the division sessions at the 36th Annual Meeting, July 9–12. There will be seven full sessions, with parallel sessions occurring on the afternoon of July 11. In designing the program, the division attempted to minimize the overlap of papers that might have similar audiences.

A division meeting will be held at the Annual Meeting on July 9 and all are welcome. The division is always looking for active participants and Standing Committee members.

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

Physical Protection

The Physical Protection Division meeting scheduled for July 13 at the 36th INMM Annual Meeting and announced in the last issue of the *Journal of Nuclear Materials Management* was rescheduled for July 9 at 3 p.m. There are a few items of division business to conduct, and there will be a presentation or discussion on at least one physical protection topic. Please make a note of the schedule change.

The Annual Meeting is July 9–12 at the Marriott Desert Spring Resort Hotel, Palm Desert, Calif. As in years past, you will find at least one session of interest to physical protection personnel during each session period.

A workshop on a physical protection topic yet to be determined is being planned for this fall. The division is seeking input on a topic and location that will be of greatest interest to members of the division and the physical protection community in general.

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

Divisions: Waste Management

The Waste Management Division received 12 vendor submissions for the INMM spent fuel storage monograph and began the review and editing process. Submissions were received from, among others, AECL Technologies, ENSA of Spain, Foster-Wheeler, Holtec, NAC, Transnuclear, Siemens, Sierra Nuclear, Vectra and Westinghouse. Due to the size of some submissions, the editing process will probably take two to three months. A target date of mid-1995 has been set for a final version.

The division pulled together the final speakers for the INMM 36th Annual Meeting in July in Palm Desert, Calif. Seven sessions were developed, including a short waste-management plenary session, plus sessions on low-level radioactive waste management, high-level waste and spent fuel disposal, spent fuel storage, transportation and packaging, and environmental restoration.

Ed Johnson, Billy Cole and Bill Teer participated in the Technical Program Committee meeting on March 7, 1995, in Chicago, for the purpose of reviewing abstracts for inclusion in the Annual Meeting.

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

Chapters: Central Region

The Central Region Chapter participated in the WATTec Conference in Knoxville, Tenn., in February 1995. The INMM held a morning session at which several topics involving information technology were discussed.

The chapter held an Executive Committee meeting during the conference. Plans are being made to hold the Central Chapter Annual Meeting at the Oak Ridge Country Club, Oak Ridge, Tenn., Oct. 30–31. A call for papers will be sent by July 1.

The chapter is also planning to participate in the Third Annual Uranium Hexafluoride Conference in Paducah, Ky., in November. (See page 7 for more information.)

Dave Shisler, Chair
INMM Central Region Chapter
Martin Marietta Energy Systems
Piketon, Ohio, U.S.A.

Pacific Northwest

The Pacific Northwest Chapter has two events planned for the near future. First will be the Annual Summer Barbecue, Aug. 18, a purely social event that will feature an all-you-can-eat catered affair. There will be no guest speaker in order to allow time to get reacquainted with chapter members and their families.

The second event will be the Safeguards Symposium on Sept. 16. It will feature the presentations that local people gave at the INMM Annual Meeting in Palm Desert, July 9–12. By highlighting these speakers, those who were unable to attend the Annual Meeting will be able to hear the presentations and participate in discussion groups. During a period of tight budgets for everyone, this symposium is important to local professional society members and guest. An evening dinner with a featured speaker will follow.

Election planning is underway, and the Nominating Committee is beginning to identify interested and qualified candidates for chapter offices. The elections will be held Aug. 1 and the new officers will take over Oct. 1.

Gary Fetterolf, Secretary/Treasurer
INMM Pacific Northwest Chapter
Westinghouse Hanford Co.
Richland, Washington, U.S.A.

Weinberg

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During the intense activity of the war years, the early development of a number of concepts for reactors other than the natural uranium-graphite moderated-water cooled reactors intended for plutonium production stands as testimony to the creativity of the first generation of reactor physicists. Heavy-water moderated reactors had their origin with the P-9 reactor concept developed during this time, and the concept of breeder reactors was originated by Fermi and Leo Szilard in April 1944.

Prophetically, at this time Fermi already anticipated that these reactors would encounter major problems of public acceptance, stemming from their production of enormous quantities of radioactive fission products and the possibility of the diversion of plutonium for destructive purposes. The important concept of the pressurized water-moderated low-enriched uranium lattice, leading to the present generation of light-water reactors, was originated by Weinberg in 1944.

The second phase of Weinberg's professional life, from shortly after World War II into the 1970s, corresponds to what might be referred to as the golden age of nuclear technology. On a national scale, the prevailing mood during this era was one of unbounded confidence — the United States had emerged from a long and painful economic depression and won a devastating global war, acquiring along the way a faith that, thanks to technological progress, those in each generation would enjoy a better life than their predecessors. With respect to nuclear energy in particular, this confidence was inspired by the example of the scientists and engineers who, in less than six years, had turned a new discovery in nuclear physics into a powerful instrument of war, creating along the way a giant complex of new production facilities.

Weinberg's history of this era provides not only a view of the technology developed during these years, but also the personalities, politics and policies that led to the particular technological choices adopted. The number of potentially feasible reactor configurations, each involving a particular choice of fuel, moderator and coolant, is extremely large, and, so far, only a few of these possible paths have been exploited. The selection of a particular configuration for development was always a complex process, but often the decisive factor would be the fact that once resources were invested in a particular concept, alternate choices then became prohibitively expensive to pursue.

The development of pressurized light water reactors, for example, and their eventual adoption worldwide for central station power, came about because their compact size and other features made them suitable for submarine propulsion, leading to their adoption for Admiral Rickover's Nautilus (the first nuclear submarine), and subsequently, the Shippingport facility (first nuclear power station). Once the technology had been demonstrated successfully, its further utilization for civilian nuclear power was a foregone conclusion.

Prominent among projects that were pursued and eventually abandoned were the fast breeder project and the aircraft nuclear propulsion project, which was carried out over a decade from 1950 until it was canceled by President Kennedy in 1960. By today's standards, the decision to embark on the propulsion project, with the enormous risks to the public that it evidently presented, can only be viewed as an extreme example of technological hubris (in ancient Greece, an affront to the gods). At the time, this decision was driven both by the then-existing faith in technology and the perception in the defense community that, in an era before intercontinental ballistic missiles, nuclear powered aircraft were an absolute necessity.

In the last chapter devoted to this era, titled "Nuclear Reality: The Faustian Bargain," the history of the well-known problems that overtook nuclear technology, such as radioactive waste, reactor safety, nuclear proliferation and the economics of nuclear power, is addressed in the context of the prevailing attitudes of that day and from the present. Weinberg's famous pronouncement, made in 1972, is still valid:

"We nuclear people have made a Faustian bargain with society. On the one hand we offer, in the breeder, an inexhaustible source of energy ... But the price we demand of society for this magical source is both a vigilance and a longevity of our social institutions that we are quite unaccustomed to."

The remainder of *The First Nuclear Era* is devoted to Weinberg's career as director of the Institute for Energy Analysis and his other activities in policy analysis and development. In the final three chapters, he relates his personal philosophy in areas such as the administration of science, nuclear weapons and possible future options for nuclear technology.

Weinberg's second volume, *Nuclear Reactions, Science and Trans-Science*, is a wide-ranging collection of 22 essays written over the past two decades on various topics in the areas of science, technology and public policy and treats these ideas and others in considerable detail. Again, there is only space here to touch on a few of the most interesting highlights.

The 22 essays are grouped under five headings: "Science and Trans-Science," "Scientific Administration," "Strategic Defense and Arms Control,"

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"Time, Energy and Resources" and "Nuclear Energy."

"Science and Trans-Science" deals with the fundamental inability of science, in its interaction with society, to provide answers to many of the questions that arise in effort to, one, evaluate the risks that citizens are subjected to and, two, adopt the necessary measures to ameliorate those risks. In these instances, in the absence of hard scientific evidence, public policy will, in the end, be formulated via a political process, usually adversarial in nature.

Weinberg coins the terms "trans-science" to refer to those questions that science may be able to formulate but is unable to provide answers to, including, for example, the health effects of low-level radiation, the chance that an extremely improbable event will occur, or various phenomena in the social sciences.

In the best-known of these examples, that of the health effects of low-level radiation, the effects of high-level radiation doses have been studied exhaustively and are well-established, but it is impossible to discern any effects resulting from small doses, even in a very large subject population. Studies of human populations living in local areas with very high natural background radiation have not disclosed any corresponding adverse effects, and laboratory studies at the cellular level strongly suggest that repair mechanisms which reverse the effects of low-level insults (physical damage) probably exist, so that the health effects of low-level radiation may well be nonexistent or of negligible significance. This evidence notwithstanding, the most conservative approach is followed in the formulation of public policy in this area, that of extrapolating the known effects of high-level radiation doses to the case of small doses to a very large population.

The second essay under this heading, "The Regulator's Dilemma," explores these questions in more detail, considering examples such as radiation effects, reactor safety and chemical carcinogens, where only a tenuous connection may exist between a given agent and possible harmful effects, and any quantification of this possible harm is evidently impossible, and yet the regulating agency is obliged to promulgate standards and regulations. Those individuals who have followed events in this area during the past few years will find this section both thought-provoking and useful.

In the second section, "Scientific Administration," which could be termed a handbook for scientific administrators, Weinberg reflects on the experience he gleaned during several decades of service at Oak Ridge National Laboratory. The chapter is worthwhile reading for both managers and practitioners, as it covers topics such as what good science is; the goals of a scientific program, in terms of technical, social and scientific merit; and the allocation of resources to achieve these goals.

The third section, "Strategic Defense and Arms Control," contains two thoughtful, carefully drafted articles on the Strategic Defense Initiative and on nuclear deterrence, written in 1984 and 1988, respectively. While events have moved rapidly in this area, accompanied by a great deal of new analysis and comment, these articles retain their essential relevance.

In an era when short-term goals dominate both political policy and economic planning, it is rare to find anyone concerned with the long-term prospects of the U.S. industrial economy, and the individuals who express such concerns are usually members of the scientific community. In the fourth section, "Time, Energy and Resources," Weinberg draws on his experience as director of the Institute for Energy Analysis to map out society's options and strategies for assuring sufficient resources of energy and raw materials and dealing with the consequences of their use, most importantly, global warming. The quantitative, common-sense approach of the articles in this section provides a useful counterbalance to the often utopian and visionary approach found in other quarters.

In the fifth and final section, "Nuclear Energy," Weinberg returns to the area that has been his principal concern since the early days of the Manhattan Project. In a series of seven articles, all of the major topics relevant to future prospects for the utilization of nuclear energy are treated. This includes questions of reactor safety, nuclear waste and the associated areas of public perceptions and social institutions; the breeder reactor and the future availability of energy resources; and global warming. Upon reading these articles, it is difficult not to believe that, at some future time, but almost certainly not in this lifetime, a sane and orderly society will turn to nuclear fission as a safe, clean and essentially inexhaustible energy resource.

Through *The First Nuclear Era* and *Nuclear Reactions*, Weinberg performed a major service in documenting the history of the development of nuclear energy in the United States and relating his perceptive discussions of important questions of science and public policy. Such memoirs should be the rule, rather than the exception, for those who participate in society's major events.

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Korean Safeguards Experience and Its Perspective

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Abstract

This paper presents an overview of Korean safeguards implementation. The Korean safeguards program has been influenced by a wide range of international and national developments. The Joint Declaration for Denuclearization in the Korean peninsula and the recent establishment of the Technology Center for Nuclear Control are the most prominent factors to have a major impact on Korean safeguards. Their influences, as well as the general status of safeguards in Korea, are described.

Introduction

Nuclear energy has been a driving force in the development of Korea, which has few natural resources. Korea historically has a long connection with nuclear power as a developing country, dating back to 1959 with the establishment of the Office of Atomic Energy as a governmental body. This office demonstrates Korea's strong passion for atomic energy. The Korean nuclear power program has steadily increased and produces about half of the national electric power supply. From the beginning of the nuclear age through building research reactors in the 1960s and nuclear power plants in the 1970s, the Korean nuclear power program has played an important role in meeting national energy requirements caused by rapid industrialization and modernization. The Korean nuclear power program is estimated to be one of the most active programs in the world.

Korea became a member of the International Atomic Energy Agency (IAEA) in 1957. In 1968, a trilateral agreement was signed among Korea, the United States and the IAEA that included safeguards inspections of nuclear materials and facilities. A research reactor, TRIGA Mark II, was the first target for nuclear safeguards under INFCIRC/66. Korea signed the Nonproliferation Treaty (NPT) in 1975 and signed a full-scope safeguards agreement with the IAEA under INFCIRC/236[1]. Therefore, all nuclear materials and facilities are under the IAEA's comprehensive safeguards.

State System of Accounting for and Control of Nuclear Material

The objectives of the State System of Accounting for and Control of Nuclear Material (SSAC) are to account for and control nuclear material in Korea; contribute to the detection of possible losses, or unauthorized use or removal of nuclear material; and provide the essential basis for the application of international safeguards.[2] The philosophy of its implementation is based on the peaceful use of nuclear energy via nuclear transparency through active participation in the nonproliferation and IAEA safeguards regimes internationally, the Declaration for Denuclearization of the Korean Peninsula nationally, and the safe use of nuclear energy via national and international regulations.

The Ministry of Science and Technology (MOST) has the authority for the SSAC and governs all of its activities. MOST is an official contact point with IAEA and foreign countries. The Technology Center for Nuclear Control (TCNC) is a technical supporting organization to MOST on nuclear control matters. Facility operators are required to combine nuclear material accountancy and TCNC input for IAEA reporting. Every transaction is carried out based on the Korea–IAEA Safeguards Agreement and the IAEA guidelines for SSACs. There have been no national inspections; however this is expected to change because there have been changes in the international safeguards environment calling for more dependence on national systems of IAEA safeguards via Program 93+2[3] and a national environment of increased recognition of the significance of safeguards for nuclear materials,

Nuclear Activities in Korea

Tables 1 and 2 (page 16) show the list of nuclear facilities operating and under construction in Korea. There are nine operating nuclear power plants at three different locations that belong to the Korea Electric Power Cooperation (KEPCO). They consist of eight pressurized light water reactors

(PWR) and one pressurized heavy water reactor (CANDU). The total gross capacity of nuclear electric power is 7,615 MWe. Seven nuclear power plants are under construction. Two PWRs are being constructed, with completion scheduled for 1995 and 1996. Three CANDUs are planned for completion in 1997, 1998, and 1999. According to the long-term plan for nuclear reactors, 24 will be operational by 2004. Since the introduction of PWRs with turnkey operation supplied by the United States, Korea has made every effort to adapt the design technology and equipment at the Korea Atomic Energy Research Institute (KAERI). As a result of successful research and development, two PWRs (Ulchin #3 and #4) are under construction. They use Korean reactor design, which is based on ABB-CE technology.

There are two fuel fabrication plants: one, operated by the Korea Nuclear Fuel Company (KNFC), produces PWR fuel, and the other, operated by the Korea Atomic Energy Research Institute (KAERI), produces CANDU fuel. Both production technologies were developed at KAERI. In 1997, KNFC will have another fabrication facility to accommodate increasing demands of nuclear fuels. KAERI has two research reactors, TRIGA Mark II and III, and a Post Irradiated Examination Facility (PIEF). KAERI has had an Irradiated Material Examination Facility since 1994. A 30-MWe multipurpose research reactor at KAERI will be ready in 1995, while TRIGA Mark II and III, which are outdated for effective research and radioisotope production, will be decommissioned. Approximately 900 institutions are using radioisotopes for medical, industrial, and research purposes, and the demand for radioisotopes has increased about 10 percent annually. There is one additional research reactor for educational purposes at a university.

Table 1: Operating Nuclear Facilities in Korea

Facility	MBA	Capacity (MWe or Ton/year)
TRIGA Mark II & III	KO-A	—
Kori PWR # 1	KO-C	587
Research Reactor at Kyunghee University	KO-D	—
CANDU Fuel Fabrication Plant	KO-E	100
Wolsong CAN #1	KO-F	678
Kori PWR # 2	KO-G	650
Kori PWR # 3	KO-J	950
Kori PWR # 4	KO-K	950
Post-Irradiated Examination Facility	KO-L	—
Yonggwang PWR # 1	KO-M	950
Yonggwang PWR # 2	KO-N	950
Ulchin PWR # 1	KO-O	950
Ulchin PWR # 2	KO-P	950
PWR Fuel Fabrication Plant	KO-R	200
Total	14	

A central disposal facility for low-level radwastes and an interim away-from-reactor (AFR) storage facility for spent fuels have been planned to accommodate these materials from nuclear power plants. However, these facilities are pending issues because of site selection difficulties. The matter is expected to be solved in the near future through civil and governmental compromise resulting from serious electric power shortages and intensive promotion of public acceptance.

Korea is pursuing an extensive program to develop advanced nuclear technologies under the long-term (10-year) national nuclear research and development programs, which started 1992 with a budget of $2.5 billion. These programs include the next-generation reactor, a fast breeder reactor, direct use of spent PWR fuels in CANDU reactors, nuclear safety and radwaste management. They are being carried

Table 2: Nuclear Facilities Under Construction

Facility	Capacity (MWe or Ton/year)	Expected Completion Year
KMRR	—	95
Yonggwang PWR #3	1000	95
Yonggwang PWR #4	1000	96
Fuel Fabrication Plant		
PWR	200	97
CANDU	400	97
Wolsong CANDU #2	700	97
Wolsong CANDU #3	700	98
Ulchin PWR #3	1000	98
Ulchin PWR #4	1000	99
Wolsong CANDU #4	700	99

out in KEPCO, KAERI, Korea Institute of Nuclear Safety (KINS), and others.

Joint Declaration for Denuclearization

The Joint Declaration for Denuclearization of the Korean Peninsula on November 8, 1991, was an epoch-making development in Korean safeguards history.[4] It prohibits testing, manufacturing, producing, receiving, possessing, storing, deploying, or using nuclear weapons. It also does not allow possession of facilities for nuclear reprocessing or uranium enrichment. Furthermore, it prohibits any kind of research and development programs on enrichment and reprocessing to complete the nuclear fuel cycle. It is sometimes said, in scientific circles, that this was a premature decision to give up any research on the front- and back-end of the fuel cycle for peaceful uses because Korea has already joined the NPT and committed to the peaceful use of nuclear materials and no diversion to nuclear weapons. Even in politics, there have been many criticisms that the Declaration has crippled nuclear programs and sacrificed the long-cherished desire to have the independence of nuclear energy, which is regarded the only viable energy option. It might be sad news to many innocent but curious nuclear scientists. However, if it works properly, the decision provides an opportunity for double transparency of the Korean peninsula. This is important because it is the first international agreement in Asia in which the parties have undertaken not to produce fissionable material.[5]

The current situation in the North Korean nuclear program does not seem to give a hopeful prospect for implementation of the Joint Declaration for Denuclearization of the Korean Peninsula. North Korea appears to have broken the Declaration by processing irradiated fuel from the 5-MWe research reactor at the Radioactive Chemical Laboratory to produce a small quantity of plutonium, which IAEA Director General Dr. Hans Blix confirmed during his visit to North Korea. North Korea's nuclear activities have not been cleared and have received most suspicious attention from foreign countries. In Korea, the Joint Declaration plays a basic role in nonproliferation and safeguards policy making.

Table 3: Nuclear Material Accountancy Report to the IAEA

(Unit: Number of lines)	'90	'91	'92	'93
PIL (Physical Inventory Listing)	1860	2860	1791	2170
ICR (Inventory Change Report)	4815	4433	6162	7573
MBR (Material Balance Report)	211	174	222	237

Table 4: IAEA Inspection

Year	No. of MBAs	Person-Day Inspections
84	8	85
85	8	97
86	8	95
87	8	120
88	14	150
89	14	163
90	14	203
91	14	200
92	14	335
93	14	454

Status of Safeguards

Nuclear Material Accountancy Report to the IAEA

Korea has provided nuclear materials information on the design information questionnaire, international transfers and national nuclear material accountancy reports. Reporting of nuclear material accountancy started with the inventory change at TRIGA Mark II in March 1975. The number of reports has gradually increased as listed in Table 3 (left). Material accountancy reports were manually prepared until 1985, when KAERI developed a computerized accountancy program using a commercial database package on a personal computer. The computer program helps to minimize errors in the accountancy report to IAEA. Modifications and upgrades are under study.

Inspection

Since the beginning of IAEA inspection of TRIGA Mark II in 1975, the targets of IAEA inspections has steadily increased because of the expansion of the Korean nuclear program. Currently, there are 14 material balance areas (MBAs) at 15 facilities (nine power plants, three research reactors, two fuel fabrication plants, and one research facility). Table 4 (left) shows the annual IAEA person-day inspections (PDI) in recent years. IAEA inspection has intensified from 1993 both in number and frequency in bulk-handling facilities and CANDU reactors. The increase is a result of the startup of a MOX surveillance system and the transfer of spent fuels to a dry storage facility caused by the lack of storage space at the Wolsong power plant. The transfer takes place for several months annually and contributes to the increase of PDIs. Construction of an interim storage facility for spent fuels will cause heavy IAEA inspections. It will involve every movement of spent fuel, such as ship, transfer, loading and unloading, and may require resident inspectors to complete the tremendous tasks. Every inspection by the IAEA is accompanied by Korean representatives to facilitate the inspections. It is the governmental policy to help IAEA inspectors in every aspect of inspectors' activities, both technical and personal.

IAEA Cooperation

Korea has actively participated in the Standing Advisory Group on Safeguards Implementation (SAGSI) since 1992 and cooperated to realize SAGSI's recommendations on improving the implementation of safeguards through Program 93+2. Field trials of environmental monitoring to enhance the IAEA Secretariat's ability to detect undeclared nuclear activities were carried out June 20–24, 1994. The sample analysis by chemical methods provides important evidence of hidden activities that might be inconsistent with the declared nuclear program. Water, soil, sediment and vegetation were sampled in the vicinity of KAERI by an IAEA environmental monitoring team, and analyzed by both the IAEA and KAERI.

Research and Development Program

A computer code has been developed to reduce the complexity of the nuclear material accountancy report to IAEA. Its functions include a database of national and facility material accountancy and error checking by IAEA's Code 10. Nondestructive assay (NDA) measurements and chemical assay on fresh and spent fuels have been extensively studied. Direct use of PWR spent fuel in CANDU reactors (the DUPIC program) has been studied jointly with KAERI, the Atomic Energy Cooperation Limited of Canada, the Los Alamos National Laboratory in the United States, and the IAEA. The study involves various accountancy and measurement techniques. DUPIC is the first of this kind of approach that Korea, which has both PWR and CANDU reactors, can try.

Training Program

Korea has held safeguards training programs for domestic safeguards personnel from the government, research institutes, and facilities since 1984 to improve the capability of personnel and increase transparency.

About 180 safeguards personnel were trained at nine courses. Currently, discussions are under way between TCNC and the IAEA for a joint program that will train safeguards personnel in planning, implementation and evaluation of safeguards inspections with emphasis on applications in Korean nuclear facilities.

Technology Center for Nuclear Control (TCNC)

TCNC was created as a central hub for all nuclear control matters, as a positive step toward nuclear advanced countries and toward the strengthening of nuclear material administration as a result of the Joint Declaration for Denuclearization, to effectively cope with rapidly changing safeguards environment, and to prepare for the international undertaking of nuclear material administration with comprehensive programs. Before TCNC integrated nuclear control, KINS carried out tests with a small unit. Under the agreement among related ministries, a central hub for nuclear control and administration has been set up to exclusively promote nuclear transparency in Korea.

TCNC provides technical support for safeguards implementation of MOST. Its objective is to help MOST assure transparency, to enhance international credibility in national nuclear activities and to promote technical development for the peaceful use of nuclear energy. Its roles include policy development on nonproliferation and safeguards, support for IAEA safeguards, national nuclear material accountancy, MUF evaluation, NDA, environmental radiation monitoring and analysis, chemical analysis, radiological safety for inspectors, and health physics support. Besides safeguards, TCNC implements physical protection and export control, which are other major means of nuclear control, and their research and development. It has about 40 scientists and engineers. However, TCNC is not a governmental agency. Its responsibility is limited to the support of MOST, which has exclusive responsibility for safeguards. The current issue is the support of inter-Korean nuclear matters, which is very sensitive because of its characteristics of political dependence and secrecy.

Safeguards in the Future

Korea has nuclear neighbors such as Japan, China, Taiwan, and North Korea. China already has nuclear bombs, and the other countries are classified by the mass media as high-potential nations that are capable of building bombs and have the most intensive nuclear programs in the world. Regional cooperation with neighboring countries is very essential to promoting peace in this region. Ultimately among these neighboring countries, any kind of compromise should be made to ease tension and to build an international structure, such as a nuclear-free zone, ABACC or EURATOM in the near future. It looks very premature right now; however, it is essential for stability of the Far East in the long term.

Conclusion

Safeguards has been an important factor in Korean nuclear programs. Extensive nuclear programs under development will lead to closer cooperation with the IAEA and foreign countries and are expected to increase IAEA inspections in terms of both person-days of inspection and frequency. The recent development of the Declaration for Denuclearization and the creation of TCNC will provide momentum for nuclear transparency even in the coming 21st century, in which nuclear energy will still play a pivotal role.

Acknowledgment
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The Study of Material Accountancy Procedures for Uranium in a Whole Nuclear Fuel Cycle

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Abstract

Material accountancy procedures for uranium under a whole nuclear fuel cycle were studied by taking into consideration the material accountancy capability associated with realistic measurement uncertainties. The significant quantity used by the International Atomic Energy Agency (IAEA) for low-enriched uranium is "75 kg U-235 contained." A loss of U-235 contained in uranium can be detected by either of the following two procedures: one is a traditional U-235 isotope balance, and the other is a total uranium element balance. Facility types studied in this paper were UF6 conversion, gas centrifuge uranium enrichment, fuel fabrication, reprocessing, plutonium conversion, and MOX fuel production in Japan, where recycled uranium is processed in addition to natural uranium. It was found that the material accountancy capability of a total uranium element balance was almost always higher than that of a U-235 isotope balance under normal accuracy of weight, concentration, and enrichment measurements. Changing from the traditional U-235 isotope balance to the total uranium element balance for these facilities would lead to a gain of U-235 loss detection capability through material accountancy and to a reduction in the required resources of both the IAEA and operators.

1. Introduction

Concerning material accountancy in a gas centrifuge uranium enrichment facility at the Ningyo-toge works of the Power Reactor & Nuclear Fuel Development Corporation, the total uranium element balance was considered to be more cost effective than the conventional U-235 isotope balance as the approach to meet IAEA detection goals.[1,2]

In the low-enriched uranium conversion-fabrication facility, a significant gain in loss detection can be made by changing from the traditional emphasis of U-235 balance to the total uranium element balance.[3]

In Japan, recycling of uranium recovered from the Tokai Reprocessing Plant has started. Every batch of recycled uranium has a slightly different enrichment. Considering that the measurement accuracy for enrichment of final fuel product is 0.05 wt% absolute (about 1% relative), it is not likely that the uranium enrichment is always measured with the highest accuracy (around 0.1% relative) in all the UF6 conversion, uranium enrichment, fuel fabrication, reprocessing, plutonium conversion and MOX fuel production facilities. Under these conditions, the accountancy capability of the U-235 isotope balance is not very high, whereas the total uranium element balance keeps its high accountancy capability because it has nothing to do with enrichment measurement accuracy. This suggests that, as the material accountancy procedure in these facilities, the total uranium element balance is more cost-effective than the traditional isotope balance.[4]

One important aspect of Program 93+2, currently discussed in the IAEA, is to improve the cost-effectiveness of IAEA safeguards. IAEA effort spent for DU, NU, and LEU handling facilities is large, so the application of the uranium element balance in these facilities may lead to a reduction in effort without diminishing the effectiveness of the IAEA safeguards. We evaluated the advantages of the total uranium element balance relative to the U-235 isotope balance.

2. Design of the Safeguards Approach

The objective of safeguards, as stipulated in Article 1 of the INFCIRC/153 type Safeguards Agreement, is to verify that source or special fissionable material is not diverted to nuclear weapons or other nuclear explosive devices. A technical approach to attaining this objective is the use of material accountancy as a measure of fundamental importance, with containment and surveillance as important complementary measures. An essential part of material accountancy is to evaluate the closing nuclear material balance for a certain period for each individual material balance area.

The IAEA specifies significant quantities, detection time and detection probability as a set of quantitative parameters for material accountancy. Taking into consideration threshold amounts, significant quantities currently in use are:

Plutonium	8kg	Total element
Uranium (U-235 ≥ 20%)	25kg	U-235 contained
Uranium (U-235 < 20%)	75kg	U-235 contained

The significant quantity "75kg U-235 contained" is equivalent to 1,500 kg U for 5% enriched uranium. Therefore, for the material accountancy to detect the diversion of a significant quantity, either the U-235 isotope balance method or the total uranium element balance method can be applied.

3. Comparison of Material Accountancy Capability for Each Facility

The material accountancy capability relates to the measurement uncertainty, σ_{MUF}, in closing a material balance. The minimum loss of U-235 expected to be detected by the IAEA through the U-235 isotope balance and the total uranium element balance would be 3.29 $\sigma_{U235MUF}$ and 3.29 $\sigma_{UMUF}E$ respectively, where $\sigma_{U235MUF}$ and σ_{UMUF} represent the uncertainties of measurement expected in closing a material balance based on the U-235 isotope and total uranium element. E stands for the maximum enrichment of uranium present in the facility. To be on the conservative side, the total uranium element balance was evaluated on the assumption that uranium with the maximum enrichment in the facility was diverted. Accordingly, the material accountancy capability can be examined by comparing $\sigma_{U235MUF}$ for the U-235 isotope balance with $\sigma_{UMUF}E$ for the total uranium element balance. In closing material balances on DU, NU, and LEU, the factors to be determined are weight, concentration and enrichment of uranium. While all these data are necessary for the U-235 isotope balance, the total uranium element balance method does not require an accurate enrichment measurement for each batch. The enrichment generally varies from batch to batch of uranium. This makes taking representative samples hard and accurate enrichment measurement difficult. On the other hand, high accuracy can usually be achieved in weight and concentration measurements.

The flow and inventory of uranium, and accuracy of weight and concentration measurements were considerably simplified in our comparison of material accountancy capability between the U-235 isotope balance and the total uranium element balance reported here. These simplifications do not affect the conclusions.

3. UF6 Conversion Facility

3.1.1. Characteristics of the Facility

In this facility, refined natural uranium is converted into UF6, and material accountancy for the purpose of safeguards application starts from the final UF6 product. Therefore, the MUF evaluation is not so important.

On the other hand, in the treatment of recycled uranium, the MUF evaluation is essential because all nuclear material is subject to safeguards application and materials accountancy. Recycled uranium is converted into uranium trioxide in powder form in the reprocessing facility. It is placed in containers and fed to the conversion facility. The enrichment of uranium in each container ranges from about 0.8% to 1.5%. Accuracy of the enrichment measurement obtained by the facility operator is only about 1% relative or poorer. This is because uranium trioxide is a powder, and it is difficult to take representative sample for the enrichment measurement.

3.1.2. Material Accounting Capability

Recycled uranium is subject to material accountancy throughout the conversion process. Figure 1 (page 23) shows a comparison of material accountancy capabilities (case C) between the U-235 isotope balance and the total uranium element balance as a function of enrichment measurement accuracy when the total error in weight and concentration measurements are assumed to be 0.05% relative. In the figure, it can be noted that the material accountancy capability of the U-235 isotope balance is almost equal to that of the total uranium element balance, even with the highest accuracy of enrichment measurement (0.1% or higher). At a level of accuracy achievable under practical plant operating conditions, about 1% relative or higher, the total uranium element balance is definitely better. This suggests that the total uranium element balance is suitable for the UF6 conversion facility as the material accountancy procedure.

3.2. Gas Centrifuge Uranium Enrichment Facility

3.2.1 . Characteristics of the Facility

The gas centrifuge uranium enrichment facility is a plant in which natural uranium or recycled uranium is enriched to 3% to 5%. While the enrichment of feed uranium and enriched uranium are accurately measured, the facility operator does not pay much attention to the enrichment of depleted uranium tails. In fact, the enrichment plant is not designed to measure the enrichment of depleted uranium accurately. Furthermore, the safeguards agreement basically does not require the U-235 content of depleted uranium to be reported to the IAEA.

From the viewpoint of the implementation of safeguards, the Hexapartite Safeguards Project concluded that material production could be verified to be in the range of declared enrichment (5%) by limited-frequency unannounced access to the cascade area. Because the supply of recycled uranium is accompanied by increased fluctuations in enrichment, it is foreseen that difficulty will increase in the enrichment measurement of depleted uranium tails.

3.2.2. Material Accountancy Capability

Based on our experience at the Ningyo-toge Uranium Enrichment Plant of PNC, we set the total errors of weight and concentration measurements at values actually achievable (about 0.04% relative). With the error of the enrichment measurement as a variable, we compared the accountancy capabilities between the U-235 isotope balance and the total uranium element balance. The result is shown in Fig. 1, case B. It is noted that with enrichment measurements at a high level of accuracy, the accountancy capability of the U-235 isotope balance exceeds that of the total uranium element balance, but the latter is still quite high and allows detection of the diversion of 1 SQ for a plant having a capacity of up to about 1,000 tswu/y. This suggests that, with the cost-effectiveness taken into account, the total uranium element balance is preferable for plants having a capacity less than around 1,000 tswu/y.

3.3. Fuel Fabrication Facility

3.3.1. Characteristics of the Facility

The fuel fabrication facility is a plant in which nuclear fuel is manufactured by converting UF6 into uranium dioxide, making pellets and assembling fuel pins. The enrichment of uranium handled in this facility is around 3% to 5%. The enrichment accuracy guaranteed for final product is 0.05% absolute (approximately 1% relative).

3.3.2. Material Accountancy Capability

The material accountancy capabilities under the two methods with total error in weight and concentration measurements assumed to be 0.05% relative and the enrichment as a variable are shown as case C in Fig. 1. It is clear from this figure that the total uranium element balance is more favorable.

3.4. Reprocessing Facility

3.4.1. Characteristics of the Facility

In the reprocessing plant, the amount of uranium received is measured — after the spent fuel is chopped and dissolved — in the input accountability tank, and the amount of uranium shipped is measured in the output accountability tank.

3.4.2. Material Accountancy Capability

The material accountancy capabilities for the U-235 isotope balance and the total uranium element balance are those of case C in Fig. 1. Loss detection capability is obviously higher in the total uranium element balance for enrichment measurement accuracies in the actual range (0.5% to 1% relative).

3.5. Plutonium Conversion Facility and MOX Fuel Production Facility

3.5.1. Characteristics of the Facility

MOX fuel is fabricated by mixing uranium and plutonium, so DU, NU, LEU and recycled uranium are handled at the plutonium conversion and the plutonium fuel production facilities.

3.5.2. Material Accountancy Capability

The comparison of material accountancy capability in these facilities is similar to case C in Fig. 1.

4. Enrichment Verification Activities in the Total Uranium Element Balance

Because the total uranium element balance does not require accurate enrichment verification activities by the IAEA, use of this balance can be expected to reduce IAEA efforts, while assuring verification activities of the maximum enrichment level of uranium in the facility concerned. Such assurance will not require much effort for the following reasons:

1) In the gas centrifuge uranium enrichment facility, maximum enrichment can be verified mainly by limited-frequency unannounced access to the cascade area with activities such as visual observation of the cascade area, NDA on cascade header pipes, etc.

2) In the fuel fabrication facility, there is no possibility that the enrichment of uranium exceeds the maximum enrichment of uranium produced in the enrichment plant. Therefore, maximum enrichment verification should not be necessary.

3) In the reprocessing facility, NDA techniques should suffice for verifying the maximum enrichment.

4) In the UF6 conversion facility, the maximum enrichment of recycled uranium does cannot exceed that in the reprocessing plant. Therefore, maximum enrichment verification should not be necessary.

5) In the plutonium conversion facility and the MOX fuel production facility, NDA techniques should be sufficient for verifying the maximum enrichment.

The authors pointed out[3] that high-quality enrichment measurements must still be maintained after changing to a total uranium element balance in order to detect substitution scenarios. However, it is reasonable to consider that the detection of substitution scenarios could be achieved without state-of-the-art enrichment measurement, such as in case of plutonium, where the emphasis is placed on total plutonium element in material accountancy.

5. Total Weight Balance

Generally speaking, weight measurements are far more accurate than the measurement of chemical purity; therefore, a weight balance is considerably more sensitive to loss detection in an area or facility under the condition that no unmeasured flows or inventories of materials are included in the balance. The authors are now considering whether this approach is practical from operational viewpoints.

6. Conclusions

The material accounting capability of the total uranium element balance is higher than that of the U-235 isotope balance in the UF6 conversion, fuel fabrication, reprocessing, plutonium conversion and MOX fuel production facilities for enrichment measurement accuracies practically available.

In the gas centrifuge uranium enrichment plant, it is hardly conceivable at present that the enrichment of depleted uranium will be measured with a high accuracy by operators. Because recycled uranium does not have constant enrichment for each feed lot, high-accuracy enrichment measurement of depleted uranium will be more difficult than in case of natural uranium feed.

Changing to the total uranium element balance contributes to reducing the effort not only of the IAEA, but also of the facility operator.

Based on the above considerations, we consider that the total uranium element balance is appropriate for the material accountancy procedures in most DU, NU and LEU handling facilities.

On the other hand, the U-235 isotope balance is essential at a facility that handles uranium having a wide range of enrichment. An example of this type of facility is one in which high-enriched uranium recovered from dismantled nuclear weapons is blended with natural or depleted uranium to 3% to 5% low-enriched uranium. A comparison of loss detection capabilities in such a facility is represented by case A in Fig. 1.

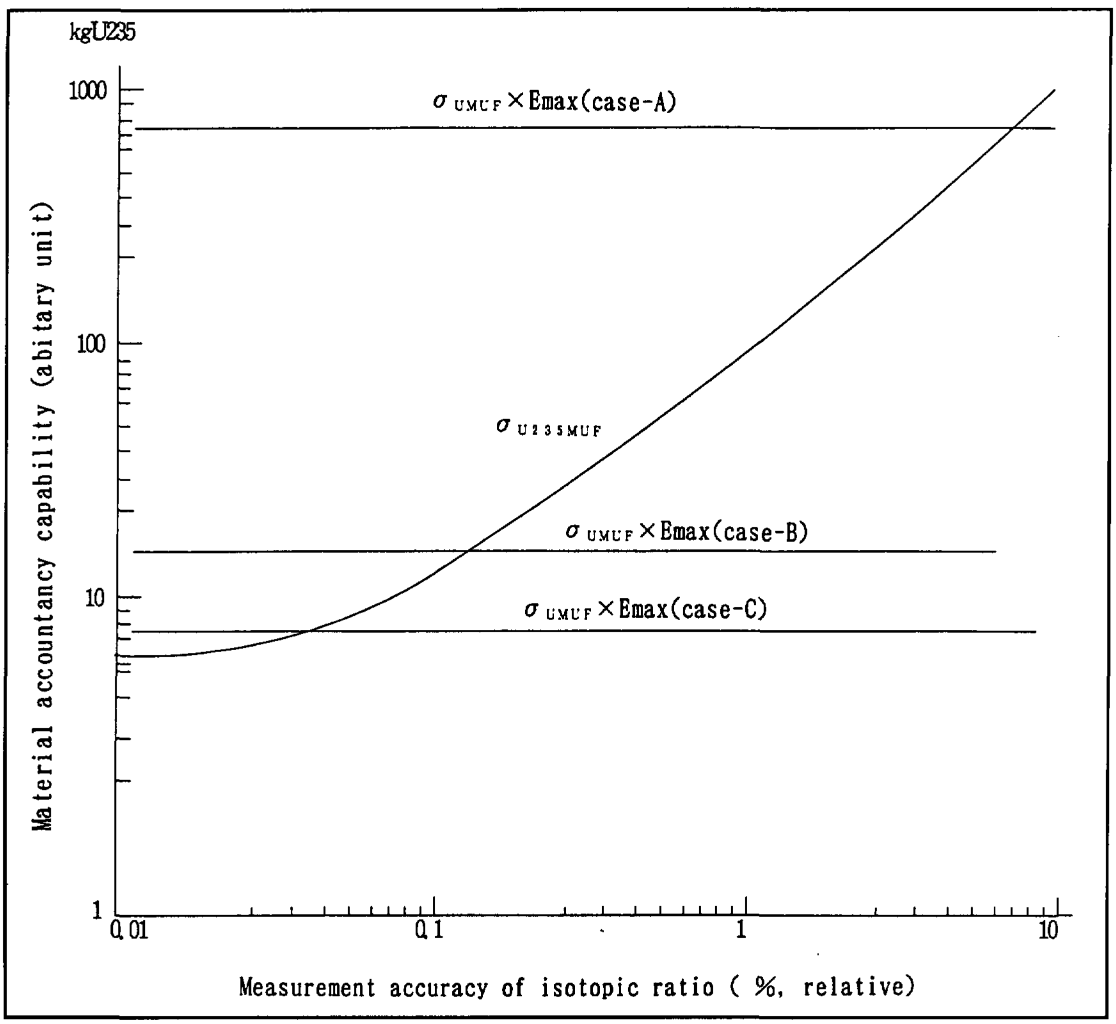
The authors hope the approach proposed here will be considered further in the application of safeguards.

Acknowledgment

The authors would like to express their sincere appreciation to T. Haginoya for helpful and informative suggestions.

Hiromasa Nakano is the executive director at the Power Reactor & Nuclear Fuel Development Corp. in Japan. Mitsunori Akiba is a senior staff member.

Figure 1: Comparison of material accountancy capabilities between the U-235 isotope balance and the total uranium element balance.
Case A: HEU, LEU and DU handling facility
Case B: Enrichment facility
Case C: UF_6 conversion, fuel fabrication, reprocessing, MOX facilities



Vulnerability Assessment of Passive Tamper-Indicating Seals

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Abstract

We examined 79 different passive, tamper-indicating seals. A number of these are in use, or under consideration, for nuclear security, nonproliferation and weapons control, radioactive waste management, and nuclear materials accountability. We learned how to spoof all the seals using rapid, low-tech methods. Cost was not a good predictor of seal security. It appears to us that many of the seals can be dramatically improved with minor, low-cost modifications. Seal users and manufacturers are encouraged to contact us to discuss specifics.

Introduction

Tamper-indicating seals are widely used in industry and government for a variety of applications, including access control, records integrity, inventory, shipping integrity, hazardous material accountability, customs control, theft prevention/detection, counterterrorism, counterespionage, protecting instrument calibration, testing for illegal drug use, and consumer protection.[1,2] For nuclear applications, seals are widely used for nonproliferation and weapons control, access control, nuclear materials accountability and radioactive waste management.[3-5]

Seals do not stop unauthorized access, but are intended to leave unambiguous, nonerasable evidence of entry or tampering. Passive seals require no external power. They are popular for nuclear applications because of their safety, low cost, small size, portability, ruggedness, disposability, simplicity and ease of use. Passive seals often utilize pressure sensitive adhesive tapes, brittle materials, fiber optics, crimped cables or other (supposedly) irreversible mechanical assemblies.

As part of a comprehensive project on vulnerability assessment, we studied 79 different passive seals. They are categorized in Table 1 to the right. All but four are commercially available. These seals are widely used by both industry and government. To our knowledge (which is probably incomplete), at least 20 are currently in use for nuclear applications, and at least seven others are under consideration.

We devised and demonstrated successful attacks on all 79 seals. A total of 91 different successful attacks were developed for the 79 seals (one, two or three per seal). All attacks were low-tech and can be successfully performed by anyone who has access to a hardware store and a standard machine shop, has sufficient practice, and is reasonably skilled with his/her hands, at the level of an average artist or artisan. For some attacks, none of these attributes are required.

The results of our vulnerability analysis are presented here solely in statistical form. We do not wish to single out specific commercial products for criticism, nor to freely disseminate information on how to defeat widely used seals. Rather, we emphasize the lessons and conclusions that this vulnerability assessment has to offer.

Definitions

A successful attack is defined as opening the seal, then resealing it or replacing it with a counterfeit such that the entry or tampering goes undetected. We classified successful attacks into three categories: type 1, 2 or 3. In all three types,

Table 1: Types of the 79 seals used in this study.

Type of seal	Number of seals
Plastic loop	15
Wire loop	4
Metal cable	13
Metal ribbon	10
Bolt type	7
Fiber optic	2
Adhesive tape	27
Other	1

the seal is broken, then repaired or counterfeited.

In a type-1 attack, the tampering will not be detected if the usual inspection process is followed. The usual process is either that recommended by the manufacturer of the seal, or the inspection process typically employed by end-users. The tampering will be detected, however, if unusual efforts are taken. For many seals, an example of an unusual inspection process would be to disassemble the seal and examined it in great detail to look for tampering.

In a type-2 attack, the tampering will not be detected even if unusual (but low-tech) inspection occurs, such as is disassembling the seal and examining it in detail by eye.

In a type-3 attack, the tampering cannot be detected even if the most advanced postmortem analysis is done. State-of-the-art techniques in forensics, material science or microscopy will not be able to tell that the seal was broken or counterfeited.

Results

Only demonstrated attacks are considered here. For most of the seals, we have devised, but not yet fully demonstrated, one or more alternative (usually low-tech) attacks. Out of our 91 demonstrated attacks, 37 were classified as type 1, 42 as type 2 and 12 as type 3 (the most thorough defeat). Most of the attacks can be completed using tools and materials that will fit inside a briefcase or, in some cases, a pocket or the palm of a hand.

Only four of the 91 attacks developed in this study involve counterfeiting, that is, removing the original seal, then replacing it with a counterfeited duplicate. The majority of the attacks involved opening the seal, then resealing it and repairing the damage (if any).

Counterfeiting, nevertheless, appears to be relatively simple for most of the seals. Manufacturers frequently make counterfeiting easier by providing free samples of the seals to anyone who asks; using readily available materials or components; using easily replicated colors, logos or numbering; and using embossing or stamping for logos or numbers that is so shallow it can be easily buffed off and replaced with an alternative embossing or impression.

With practice, the time to successfully complete the attacks varied from three seconds for three of the seals to 125 minutes for the most difficult. The mean time was 5.7 minutes, with a standard deviation of 14.5 minutes. Figure 1 (page 26) shows the histogram of defeat times for the 91 attacks. (Two attacks are off-scale at 45 and 125 minutes.) The defeat time is the total time required to open the seal, reseal it or counterfeit it, and then cover up any evidence of entry at the appropriate level of attack (type 1, 2 or 3).

Figure 2 (page 27) shows little correlation between the defeat time and the unit cost of the seal. The linear correlation coefficient is only $r = 0.25$. Figure 3 (page 27) shows that there is also little correlation ($r = 0.10$) between the defeat time and type of defeat (1, 2 or 3).

In Figure 4 (page 28), we see a histogram of the time required to initially develop the successful attacks. This is the time needed to devise the attack, gather up materials, make any specialized tools that were needed and demonstrate the attack for the first time. This first demonstration might not be fully successful; it sometimes took two to 20 times longer to become proficient at the attack. In all cases, however, the attacks could be developed relatively quickly. The mean time to develop an attack for the 91 attacks was 3.9 hours. There is little correlation between the time to develop an attack and other parameters, such as the cost of the seal (Figure 5 (page 28), $r = 0.61$), the defeat time (Figure 6 (page 29), $r = 0.37$), or the type of defeat (Figure 7 (page 29), $r= 0.01$).

Caveats

Ideally, vulnerability studies should evaluate seals in the specific, real-world context in which they are used. For about 11 percent of the seals we studied, we developed attacks in terms of an actual application. For most of the seals, however, we investigated the vulnerability in a generic sense, without one specific application in mind.

Another potential problem with this work is the classification of the attacks. Classifying an attack as successful and of what type (1, 2 or 3) is, for many of the seals, primarily our own estimation. Out of the 91 attacks we developed, only 43 were discussed with independent seal, security or nuclear experts, usually outside Los Alamos National Laboratory. An additional 13 were demonstrated to them. In each case, the experts agreed with our assessment that the attack was successful and our categorization (type 1, 2 or 3).

For only three of the 91 attacks did we do a rigorous double blind test. We had security personnel familiar with the seal try to determine which samples had been defeated. We did a blind test on three additional attacks. In these six cases, the security personnel were unable to detect which seals had been defeated, at the appropriate level of inspection (type 1, 2 or 3). (In a double blind test, the seals are independently coded so that neither the experimenter nor the test subjects are aware of which seals have been defeated until after the test is completed. In a blind test, only the experimenters are aware of the which seals have been defeated.)

The reasons for so few rigorous blind and double blind evaluations of our attacks include limitations on time and funds available for such tests, limited availability (and often a surprising lack of interest) of security personnel, and uncertainties about the context and real-world applications for the seals. Ideally, double blind tests of vulnerability should be conducted on security personnel unaware that a test is taking place. To ask security personnel which seal has been defeated is not a realistic way to evaluate real-world vulnerability. Adversaries do not usually announce to security personnel that they have defeated some of their seals. Tests on unaware security personnel, however, tend to be expensive, time-consuming and difficult to arrange.

In analyzing this work, it is also appropriate to bear in mind that classifying an attack as type 3 is problematic. It is difficult to prove a negative — that no technology can detect the tampering. We are unable to envision any method of detecting our type-3 attacks, but that does not guarantee that such a method does not or will not exist.

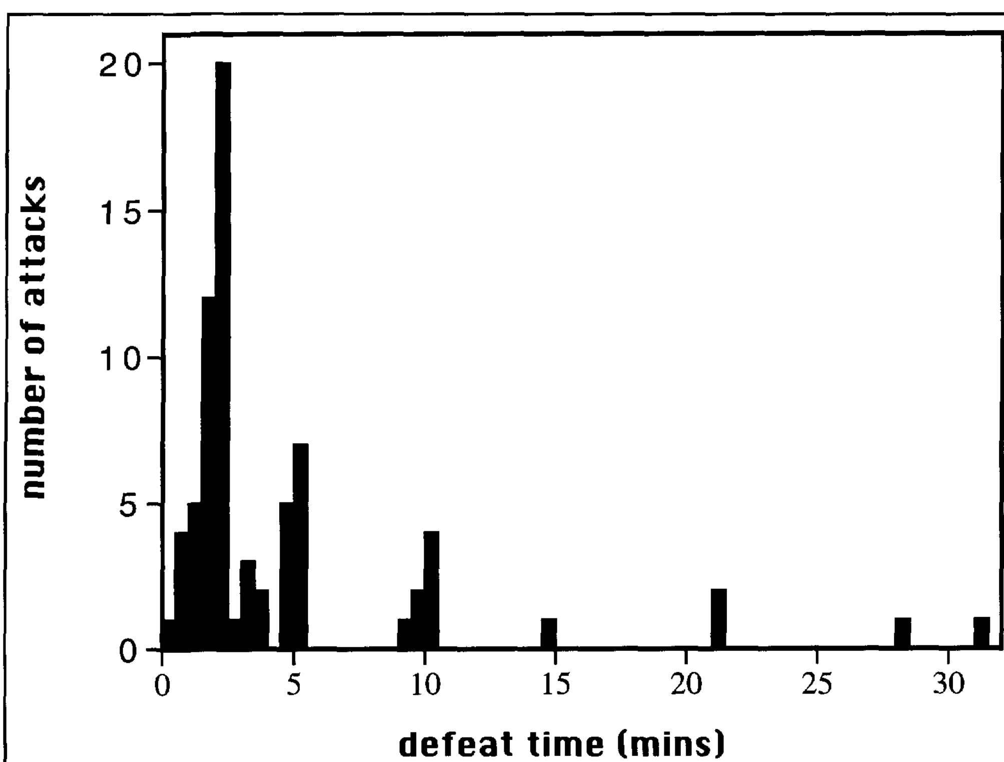
Concluding remarks

We believe this is the most comprehensive vulnerability assessment of passive seals ever undertaken. The major finding of this work is disturbing: All the tamper-indicating seals we examined can be defeated quickly, using low-tech methods available to almost anyone. Many of these seals are widely used for critical applications, including nuclear applications. The Department of Energy recognizes the vulnerability of seals and considers their safeguards effectiveness to be minimal unless they are combined with other containment/surveillance measures as part of an integrated system.[6]

For most of our attacks, minor modifications to the seal would substantially increase the difficulty of an attack. These modifications would usually add little to the cost. Most seals would also benefit significantly from changes in the manufacturer's suggested protocol for use and inspection. Most of the changes we would suggest are relatively minor. For many seals, we believe having security personnel aware of the most likely attack scenarios, and having them watch for these attacks, would dramatically improve tamper detection. Seal users and manufacturers with a legitimate interest in vulnerability issues are welcome to contact us to discuss specifics.

Finally, we were surprised to discover that neither the seal defeat time, nor time to develop an attack, are strong functions of unit cost (Figures 2 and 5) or the type of defeat (Figures 3 and 7). Prior to this study, we anticipated that the most costly seals would be the most effective, and that type-3 attacks would be most difficult.

Figure 1: Histogram for the demonstrated time to defeat a seal (with practice) for our 91 attacks. Two attacks are off the scale at 45 and 125 minutes.



Acknowledgments

This work was performed under the auspices of the U.S. Department of Energy. We benefited from the input of Chuck Mansfield, Padmini Sokkappa and James Jones.

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5. Gritton D. and Riley M., "Electronic Identification Devices," *Energy & Technology Review*, UCRL-52000-92, January 1992.

6. "Safeguards Seal Reference Manual," December 1986, DOE/DP-0035 (issued by the U.S. DOE, Assistant Secretary for Defense Program, Office of Safeguards and Security.)

Figure 2: Seal defeat times vs. unit cost in quantities of 1,000. Each point corresponds to one attack. Data are plotted on a log-log graph. Note the lack of correlation, i.e., defeat times are not a strong function of seal cost.

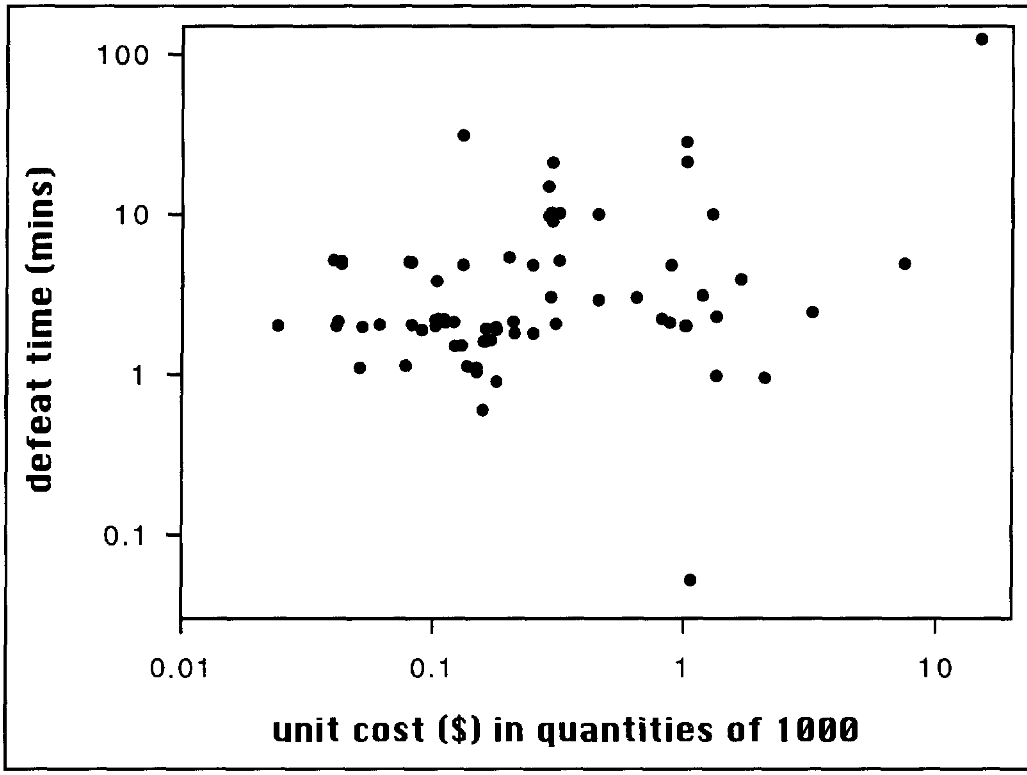


Figure 3: Defeat times vs. type of defeat (1, 2 or 3). One type-1 attack is off the scale at 125 minutes, and one type-2 attack is off the scale at 45 minutes. Note the lack of correlation.

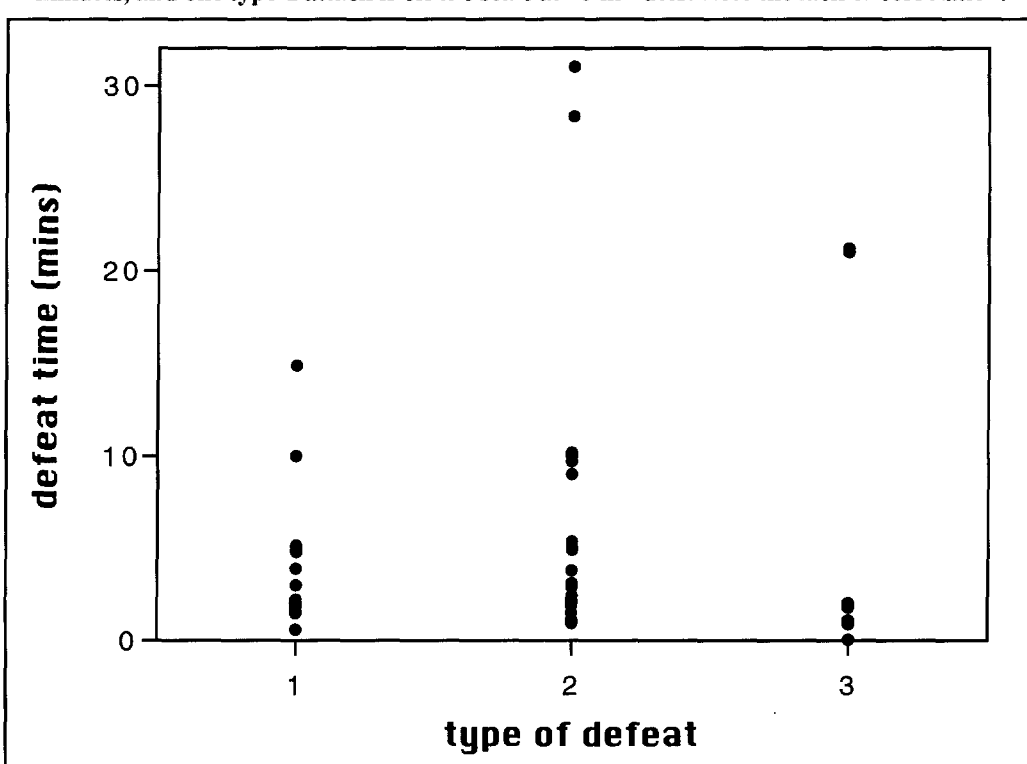


Figure 4: Histogram of the time to initially develop an attack. Two attacks are off the scale at 20.5 hours and 240 hours.

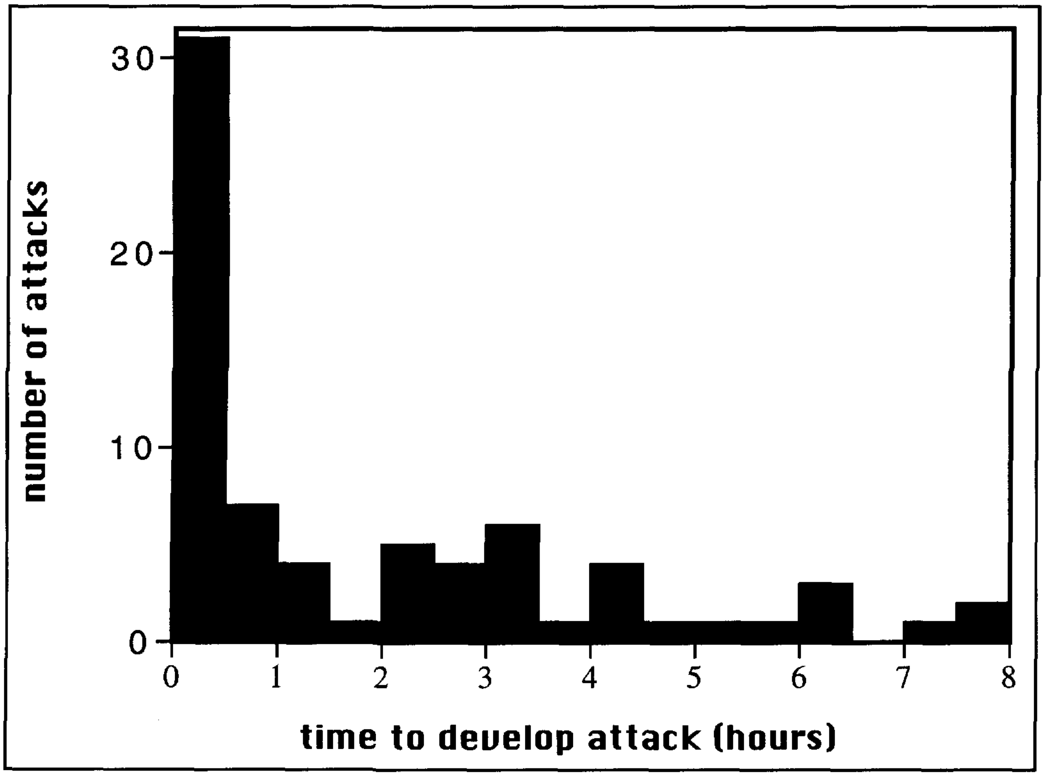


Figure 5: Time to initially develop an attack vs. unit cost in quantities of 1000. This is a log-log plot. Note the weak correlation. Unit cost is not a strong predictor of how long it takes to develop at attack.

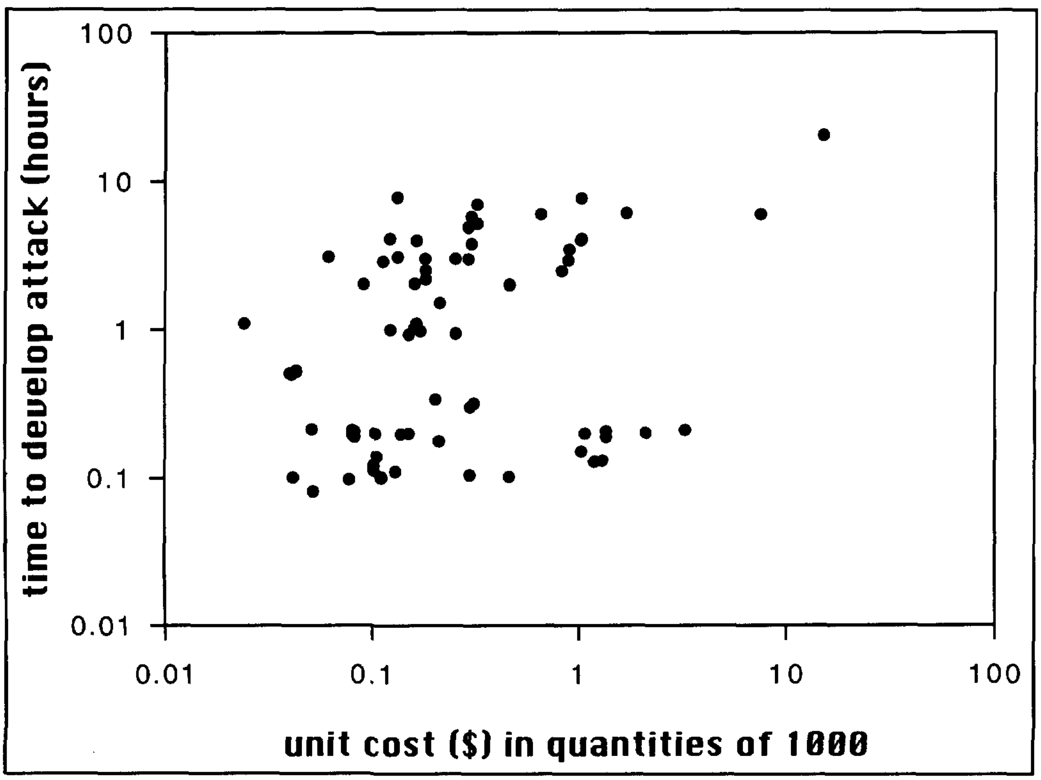


Figure 6: Time to initially develop at attack vs. the time to successfully complete the attack (with practice). This is a log-log plot. Note the relatively weak correlation.

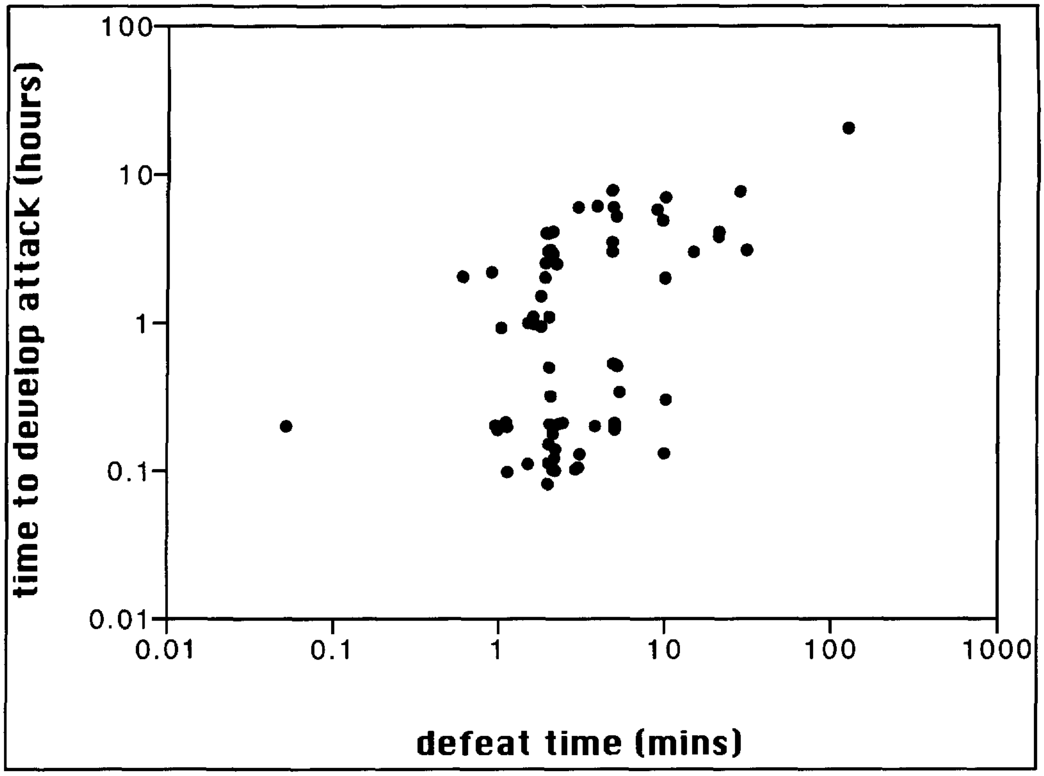
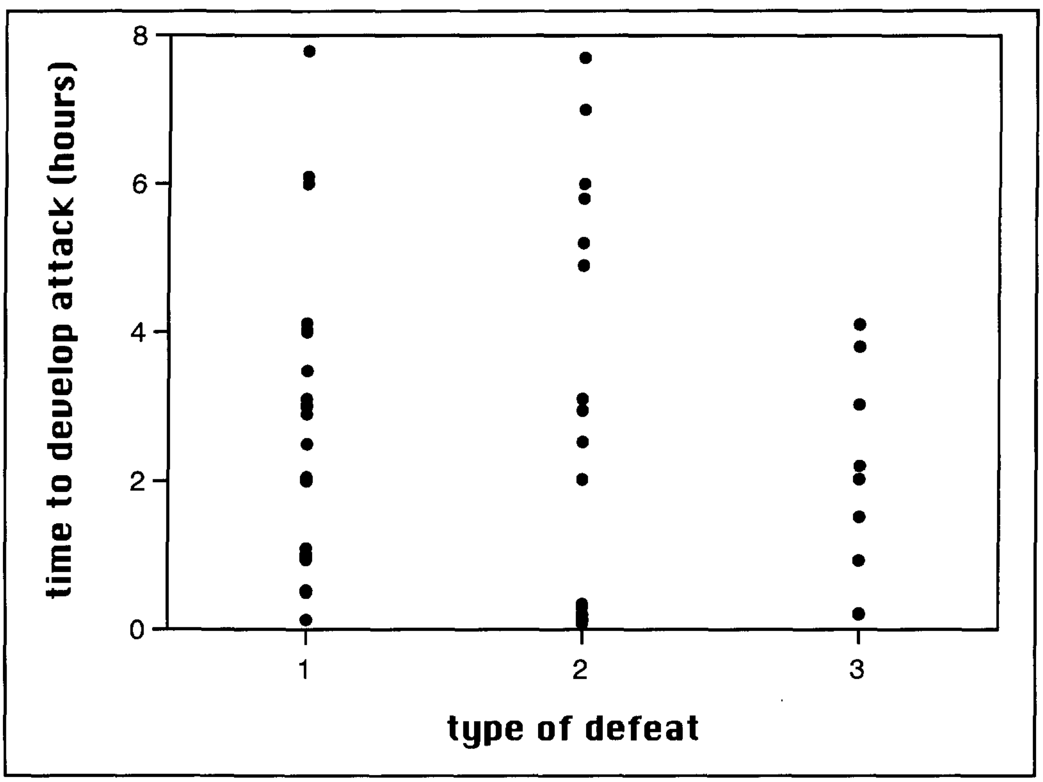


Figure 7: Time to initially develop an attack vs. the type of defeat (1, 2 or 3). Two attacks are off the scale at 20.5 hours and 240 hours. Note that there is little correlation between the development time and the type of defeat.



PCI expands protective clothing line

Performance Contracting Inc. (PCI) expanded its existing line of protective clothing. PCI Wear is designed to meet the needs of employees in the nuclear, cleanroom, petrochemical and process markets. For the nuclear area, The Dry-One is a waterproof, breathable, lightweight, launderable and incinerable garment made from 100 percent nylon carrier fabric. It offers the wearer protection from contamination while dramatically reducing the risks of heat stress-related illnesses. For more information, contact PCI at (800) 888-7241.

New database on nuclides

Nuclides is a database from Cole-Parmer Instrument Co. that contains the properties of 2,500 nuclides from data collected and maintained by the National Nuclear Data Bank. The data is managed in a relational database system, permitting a wide range of data searches. Nuclear ground and meta-stable state properties for any element can be displayed by selecting an element from the Periodic Table. For more information, contact Cole-Parmer at (800) 323-4340.

Hazardous materials risk management software available in Windows

Abkowitz & Associates Inc. (AAI) released HazTrans 3.0 for Windows, which provides comprehensive transportation networks, analysis tools and census populations. This version also incorporates modules to comply with federal regulations addressing worst-case scenarios, emergency preparedness and designated routing of hazardous materials. It also includes a proprietary database representing a complete inventory of the public hazmat response teams located throughout the United States. The software is updated every year. For more information, contact AAI, (615) 321-4848.

Canberra signs agreement with Los Alamos to develop software

Canberra Industries and Los Alamos National Laboratory signed a cooperative research and development agreement to develop the software for the Combined thermal/Epithermal Neutron (CTEN) System. Los Alamos researchers conceived the idea of the CTEN method for nondestructive assay of transuranic waste in 55- and 85-gallon drums to provide more accurate active neutron assays. Canberra will participate in the development of the first CTEN unit by providing specialized, quality-assured software to analyze data from CTEN assays. It will also develop the software requirement specification and software design description, write accompanying software manuals, install and test the software, and write the software validation and verification plan and report. Los Alamos will supply CTEN analysis algorithms and basic functional specifications and will test the software.

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