JNMM

Journal of Nuclear Materials Management

Published by the Institute of Nuclear Materials Management ▪ Volume XXIII, Number I ▪ October 1994

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

SUBSCRIPTION RATES: Annual (U.S., Canada and Mexico) $100.00; annual (other countries) $135.00 (shipped via air mail printed matter); single copy regular issues (U.S. and other countries) $25.00; single copy of the proceedings of the annual meeting (U.S. and other countries) $65.00. Mail subscription requests to *JNMM*, 60 Revere Drive, Suite 500, Northbrook, Illinois 60062 U.S.A. Make checks payable to INMM.

ADVERTISING, distribution and delivery inquiries should be directed to *JNMM*, 60 Revere Drive, Suite 500, Northbrook, Illinois 60062 U.S.A. or contact Mary Dulabaum at (708) 480-9573, fax (708) 480-9282. Allow eight weeks for a change of address to be implemented.

ISSN 0893-6188

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How Can The INMM Contribute In This Changing World?

Every two years the INMM membership elects a new chair and vice chair who, along with the secretary and treasurer, constitute the officers of the Institute. The officers, the Executive Committee members-at-large and the past chair are responsible to you, the members, for conducting the business of the INMM. I am honored to serve as the chair and hope that I can meet the high standards set by my predecessors.

Fortunately, the entire team of officers and Executive Committee members, as well as the committee chairs and technical division heads, are experienced and capable. In particular, I take considerable comfort in having the continuing counsel of Secretary Vince DeVito and Treasurer Bob Curl to keep the INMM out of serious trouble in the next few years as they have for the past many years. For your reference, and so you can contact us regarding any aspect of INMM business, our phone and fax numbers and e-mail addresses (where available) are listed at the end of this column (page 11).

The world appears to be in a period of continual change, and our nuclear materials management community is no exception. In fact, in many ways, world events are impacting us more than other professions. The end of the Cold War, the breakup of the Soviet Union with the accompanying significant downsizing of nuclear weapons arsenals, the election of a new administration in the United States with an agenda that includes new initiatives for enhanced management and control of nuclear materials, and this summer's media attention on the discovery of plutonium smuggling in Germany all drew attention to nuclear materials management. It is a credit to the Institute that we have been able to keep up with the change and provide an international forum for the exchange of technical information in nuclear materials management.

During the Clinton campaign, there was a sign in his campaign headquarters that read, "It's the economy, stupid." It was designed to keep the campaign staff focused on the main issue for the democrats. For most of the international nonproliferation and arms control agenda, there could now be a similar sign: "It's nuclear materials, stupid." But we have always known this. On the one hand, it's nice to be appreciated; on the other hand, we've been worried about the responsible management of nuclear materials for a long time.

The question for the INMM is, how can we contribute in this changed world? We have always been able to accommodate change in the past, whether it was the growth and subsequent decline of the commercial nuclear industry in the United States, the development of international safeguards, the push to add security measures to the U.S. Department of Energy nuclear facilities, or the increasingly restrictive regulatory climate surrounding the transportation of radioactive materials or the management of nuclear waste.

As Ed Johnson, chair of the INMM Waste Management Division, often notes, our strength as a profession and a professional society is our systems approach to solving problems; we integrate the knowledge of many disciplines to improve the management of nuclear materials. Our ability in systems integration is also the key to meeting the changing demands of the future and is the fundamental reason we continue to be out in front in dealing with the new challenges for nuclear materials management.

Over the past few years, the Institute worked to broaden the membership and encourage international participation in what is truly an international professional society. The establishment of the technical divisions resulted in a significant strengthening of the INMM in each of the six areas represented and an overall improvement of the Institute. The divisions are instrumental in conducting workshops and seminars and developing the technical program for the annual meeting. But the question remains, what should we do next to serve our membership and the broader nuclear materials management community?

One answer is to do more planning so we are better prepared for change. As you may know, long-range planning is one of the responsibilities of the INMM Fellows. When Past Chair Dennis Mangan was chair, he asked *his* past chair, Darryl Smith, to lead the Fellows in their planning duties in order to provide more leadership for the INMM's planning activities. This assignment recognizes the past chair's unique knowledge of the current and impending issues facing the Institute. I intend to continue this assignment by asking Mangan to take over from Smith in leading the planning activities of the Institute. There is a rich agenda ranging from what we should do over the next year to thinking about the long term. We need their wisdom along with yours. Call or fax us with your ideas and comments.

Finally, on behalf of the membership, I want to thank Mangan for his outstanding service as chair the last two years, Smith for his continued support as past chair, and Tom Williams and Debbie Dickman for their service as members-at-large. I look forward to working with new Vice Chair Obie

Continued on page 11

The *Journal* Is Still An Important And Valuable Forum For Ideas And Discussion

On behalf of the editors of the *Journal of Nuclear Materials Management*, I apologize to P.M. Rinard, K.L. Coop, N.J. Nicholas and H.O. Menlove for not listing them on the cover of the July issue as the authors of their article, "Comparison of Shuffler and Differential Die-Away Technique Instruments for the Assay of Fissile Materials in 55-Gallon Waste Drums." Unfortunately, the authors who appeared on the cover of the previous issue reappeared where the Los Alamos authors should have been.

As Dennis Mangan, now the INMM past chair, noted in his message in the July issue, I have some physical disabilities that severely restrict my ability to travel. However, I am able to continue my consulting and editorial activities. I am looking for an understudy as technical editor of the *Journal*, but expect to continue in this role for several years. I would be bored stiff if I did not have these challenging assignments.

What I miss most is attending the annual meetings and chatting informally with so many of you. Now I rely more on the phone and the mail to keep in touch. I have never been able to hear and digest all of the papers that interest me at an annual meeting. As in years past, the Proceedings will be bedtime reading for me this winter.

In this issue, we have the second paper by Pierre Saverot on low-level radioactive wastes. They have to be accounted for, of course, and disposed of safely. In the United States, they are beginning to pile up at the facilities where they are generated because almost no one wants the wastes to be buried anywhere near them.

The other paper, by Fred Tingey, has something new to contribute for safeguards statisticians. I have great respect for Tingey as he understands national nuclear material control and accounting, as well as statistics, and because he is now a professor at the University of Idaho in Idaho Falls.

The issue also contains transcriptions of interviews with Bruno Pellaud, International Atomic Energy Agency deputy director general and head of the department of safeguards, and Ivan Selin, chair of the U.S. Nuclear Regulatory Commission. Both officials presented papers on the morning of the first day of the annual meeting. The interviews are an important means to ask the questions that arise after hearing them talk.

From time to time, I complain because so few of you take the time to contribute papers for the *Journal* to publish. I realize that many of you save your papers for presentation at the annual meeting, and this is good. It increases attendance at the meeting. However, to have any value, the *Journal* also needs articles. While the *Journal* cannot offer the inducement of a meeting, it does offer visibility. A *Journal* paper is one of a select few, not one of more than 200 in a single, large volume.

Furthermore, as many of the Institute's traditional areas of interest mature, the *Journal* should become the home for technical articles that are too long to print in the Proceedings, and for the review articles that are so very important to a mature technology. Finally, as we become even more excited about addressing worldwide proliferation concerns, the *Journal* provides a forum for new and interesting ideas and discussion.

Dear reader, please help us out.

William Higinbotham, Ph.D.
Brookhaven National Laboratory
Upton, New York, U.S.A.

Recent Research Paper Is Misleading

In the April 1994 issue of the *Journal of Nuclear Materials Management*, the research paper titled "Analysis of Active Well Coincidence Counter Measurement" is interesting but misleading.

The curves showing measured values plotted against declared values are actually the calibration points used to determine the function that is proposed for calibration. No actual measurements were made on "unknowns" that were not included in the calibration function. This data just shows that the residuals are small because the counting statistics were small, there was good control over extraneous variables other than mass, and that the mathematical model fits the data. Any function that fits the data could have been used for this purpose. Insufficient data are given to determine the measurement error because counting time and number of replicates are not given (three or four times is mentioned as a footnote).

The Demming curve fitting program will fit Howard's function to the declared mass and real coincidence count rate with results that are almost as good. The authors do not explain how the conventional curve shown in Figure 6 was obtained. If one plots the ratio of Measured/Declared U235 mass derived from data given in the Consolidated AWCC Data table and the calculated values from the Demming fit to Howard's function, it shows that the improvement is in the low-mass end of the curve where multiplication is less important. The advantage of the authors' approach may be that a linear function forced through zero gives a better fit than a nonlinear function using the same number of points (13 degrees of freedom compared to 12 degrees) because there is only one parameter to determine.

The practical problem for implementation of NDA methods is to reduce the number of calibration curves necessary to assay a variety of material types, container types, matrix types, enrichments, etc. The fact that the residuals are smaller when the function suggested in the paper is used indicates that some unidentified variable may be compensated for using their approach. Whether this will allow the calibration to apply to a wider range of samples, such as metal samples with varying enrichment or alloys of various composition, remains to be seen. At this point, it is not clear that the authors' empirical formula will give better results.

Ronald B. Perry
Argonne National Laboratory
Argonne, Illinois, U.S.A.

Correction

On the cover of the July 1994 issue of *JNMM*, "Comparison of Shuffler and Differential Die-Away Technique Instruments for the Assay of Fissile Materials in 55-Gallon Waste Drums" was attributed to the wrong authors. The correct authors are P.M. Rinard, K.L. Coop, N.J. Nicholas and H.O. Menlove from Los Alamos National Laboratory, Los Alamos, New Mexico.

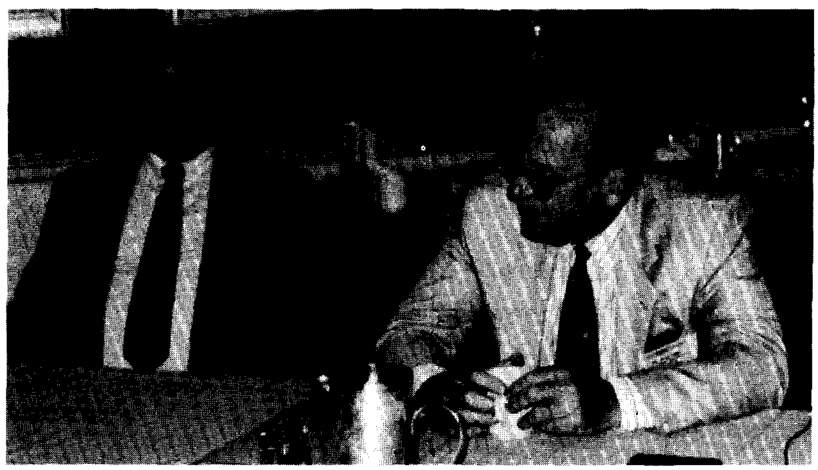
35th Annual Meeting Draws Outstanding Reviews

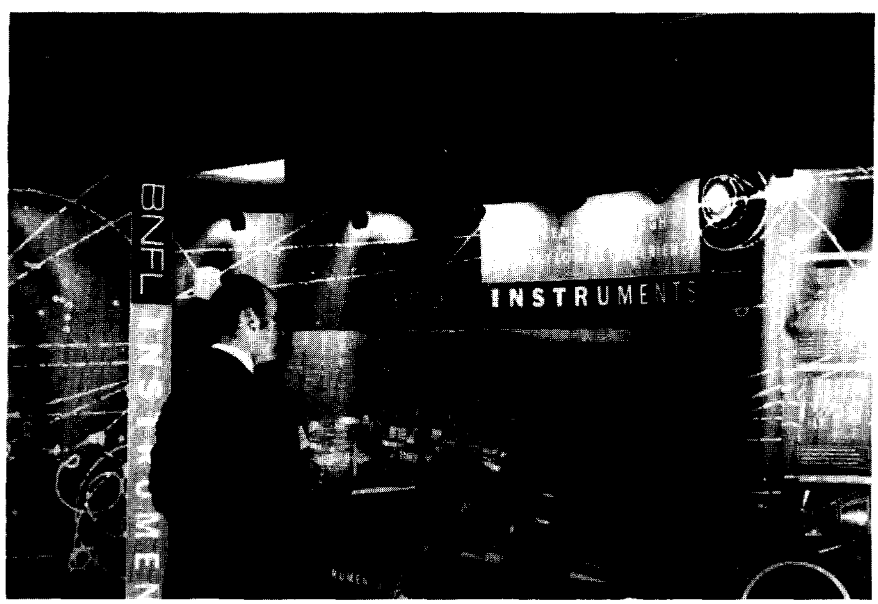
Suspected diversion of nuclear materials from the former Soviet Union for potential military or terrorist purposes, extension of the Nonproliferation Treaty, impact of Iraq and North Korea, and a new policy initiative on the storage of spent nuclear fuels sparked the opening of the 35th Annual Meeting of the Institute of Nuclear Materials Management at the Registry Resort Hotel in Naples, Fla., July 18–20.

Two plenary speakers, Bruno Pellaud, International Atomic Energy Agency deputy director general and head of the department of safeguards, and Ivan Selin, chair of the U.S. Nuclear Regulatory Commission, provided frank, authoritative and stimulating thoughts on these matters. Private interviews with both speakers revealed even more interesting and provocative comments. (See pages 29 and 38.)

If we measure the success of our Annual Meeting by the number of papers, sessions and attendees and the lack of complaints by attendees, we were successful. If we take into consideration the many compliments to INMM, we were superb. And the credit goes to all the participants and speakers, as well as the INMM committees. There were 32 sessions this year and 221 papers, making it the seventh consecutive year we had more than 200 papers. There were 571 registrants, 79 of whom were from outside the United States. Twenty-seven posters were presented and 14 exhibitors displayed booths.

Attendance at some sessions surprised us — the overflow crowd (more than 140 attendees) at one of the nonproliferation and arms control sessions prompted us to move to a larger room. The waste management





Top right: Bruno Pellaud, IAEA deputy director general and head of the department of safeguards, talks with members of the INMM executive committee.

Middle right: Ivan Selin, chair, U.S. Nuclear Regulatory Commission, joins INMM board members before his keynote address.

Bottom right: BNFL Instruments was one of 14 exhibitors at the three-day Annual Meeting.

sessions still need greater participation, although the waste measurements sessions were well-attended and the reprocessing and recycling panel discussion was a knockout.

Our Annual Meeting customer survey was interesting. The overall quality of the papers, meeting arrangements, exhibits and posters ranged from acceptable to outstanding. We received kudos for session content, program planning and smooth operation.

About 5 percent of the respondants gave us bad marks. Some complaints were that meeting rooms were cramped at times, a few of the papers were poor and the hotel drink prices were too high. The poster session was considered too long by some, while others thought it to be too short.

The Technical Program Committee will take these comments into consideration to make next year's meeting even better. The number of no-show speakers is still a concern. We do not plan to accept papers from these contributors in the future if an adequate reason for their absence is not provided to the INMM.

Several years ago the INMM introduced the practice of supplying contributors' abstracts on computer disks. Today, nearly 90 percent of our abstracts are received in this format and the number is increasing. To further reduce costs and simplify preparation of papers, we are evaluating a similar process for the Annual Meeting Proceedings. Our survey, although it received only about a 10 percent response, revealed that most authors produce their paper on computer and 72 percent would prefer to provide their final paper on disk. Those wanting the Proceedings on disk rather than hard copy were evenly divided. We will keep you informed on the progress of this evaluation.

We congratulate the speakers, session chairs, Annual Meeting Committee, Technical Program Committee and INMM headquarters staff for another outstanding Annual Meeting. Plans for next year's meeting are already under way, so start making plans to participate by either attending or presenting. Remember, papers are due by Feb. 1, 1995.

Charles Pietri, chair
INMM Technical Program Committee
U.S. Department of Energy
Argonne, Illinois, U.S.A.

Left: Outgoing INMM Chair Dennis Mangan passes the gavel to incoming Chair James Tape at the Awards Banquet, July 19.

Bottom: INMM sustaining members were honored at the banquet.

Second Annual INMM Golf Tournament

The Second Annual INMM Golf Tournament was held July 17 at the Pelican's Nest Golf Course in Naples, Fla., as a prelude to the Annual Meeting. The international field was composed of more than 50 golfers playing in teams of four. The event was well-coordinated by the INMM Tournament Committee and the Pelican's Nest staff.

The results of the tournament are detailed below, but the tournament contributes more than just golf and prizes. The opportunity to meet new people within the nuclear materials community was sited as a major benefit for the participants. If the interest in the tournament continues, it will become an annual event.

First place team: Rosemary Monson, Paul Monson, Ron Kapaun and Mike Catalano.
Second place team: Barry Crain, Jerry Hickman, John Cole and Pat Rood.
Longest drives: Barry Crain, John Smalling and Ruth Kempf.
Closest to the pin: Hastings Smith and Paul Monson.

Committees: Communications

As I sat down to write my first article as the Communications Committee chair, I thought I would look through previous issues to see what my predecessors wrote about in their columns. I looked through several years of the *Journal of Nuclear Materials Management* without locating any Communications Committee reports. To me, that says a couple of things. First, the activities of the committee need to be expanded and become more visible. Second, the members need to be kept up-to-date with what the committee is doing. Both of these items are on my agenda for the coming year.

One of the first issues to address is how we communicate with each other. The *Journal* has been that vehicle for many years. Yet as Technical Editor William Higinbotham says in his article on page 4, we get fewer and fewer papers for publication, and the *Journals* get slimmer and slimmer. Unfortunately, the publication costs for the *Journal* remain fairly constant, regardless of size.

We currently publish four issues a year, plus the Annual Meeting Proceedings. The Executive Committee discussed going to fewer issues of *JNMM* per year and instituting a newsletter for more frequent communications. In that event, the *Journal* would likely contain more papers, providing more "bang for the buck." The newsletters would be less expensive to publish and be more informal, containing such items as INMM news, announcements and calendar items.

Before such a move is made, I ask you to provide feedback on this suggestion. Please let me know what you think of this idea or if you have other proposals that would enhance member communications and be more cost-effective. My phone and fax numbers and e-mail address are listed at the end of this column. I welcome all ideas.

In addition, let me know if you have an interest in working with the Communications Committee. It could be a great way to become more involved in the activities of the INMM.

Debbie Dickman, chair
INMM Communications Committee
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Richland, Washington, U.S.A.
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Bylaws

According to Article III, Section 6, of the INMM bylaws, "the Secretary shall notify each member in good standing of the results of the election before Oct. 1 of each year." This notice in the *Journal of Nuclear Materials Management* is construed as having met that obligation.

The officers and members-at-large forming the Executive Committee effective Oct. 1, 1994, are as follows:

Chair: James Tape
Vice Chair: Obie Amacker
Secretary: Vince DeVito
Treasurer: Robert Curl
Members-at-Large: Gary Carnival (term expires Sept. 30, 1995), Philip Ting (Sept. 30, 1995), Jill Cooley (Sept. 30, 1996) and David Crawford (Sept. 30, 1996).

Write-in votes:

Members-at-Large: Carl Ahlberg, Ron Augustson, Debbie Dickman, Ed Johnson and Garland Longhouser.

Fax us your thoughts and comments about the *Journal* and INMM communications

The INMM Executive Committee is discussing the Journal *and its value to INMM members. One idea to increase value and communication among members is to publish the* Journal *fewer times per year and institute a smaller, more frequent newsletter to enhance communication.*

What do you think? Is the Journal *valuable to you in its current format? How could it be improved? Do you have a better way to enhance communication and be more cost-effective? Let us know in the space below, or attach another page if necessary.*

Fax to INMM headquarters at 708/480-9282.

Divisions: International Safeguards

On July 17, 1994, the INMM International Safeguards Division (ISD) met at the Registry Resort Hotel in Naples, Fla., the site of the 1994 INMM Annual Meeting. Thirty-eight members of the international safeguards community participated from the IAEA, CEC/JRC–Ispra, Australia, Canada, France, Germany, Japan, Russia, Sweden, United Kingdom and United States.

ISD Chair Cecil Sonnier opened the meeting with reference to the discussions on transparency and openness from the previous ISD meeting in March. He also made a suggestion to consider the feasibility of defining measures for reaching various levels of transparency and openness and the resulting potential effect on the inspection regime.

As in past meetings of the ISD, the participants recognized that many factors must be considered before the introduction of the variety of changes currently under consideration, as well as the vast array of new technology which may support these changes.

The next ISD meeting will be May 12, 1995, from 9 a.m. to 12:30 p.m., during the ESARDA meeting in Aachen, Germany. The topic of discussion will be the expected IAEA 93+2 Program report, which will be completed in early 1995. This report will contain IAEA information on a variety of new measures under consideration and related field trial results, including expanded SSAC interactions, extended declarations and access, and environmental and remote monitoring.

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

Chair's message, continued from page 3

Amacker and with Jill Cooley and David Crawford who join Philip Ting and Gary Carnival on the executive committee.

James Tape
Los Alamos National Laboratory
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Chapters: Pacific Northwest

The INMM Pacific Northwest Chapter held its annual barbecue on Sept. 21 at the Richland Yacht Club, Richland, Wash. The meeting did not have a technical program, but provided an opportunity to conduct chapter planning for the coming year.

Chapter Chair Dean Scott focused the business meeting on identifying ways to expand the active membership, generating topics for future meetings and planning the fall dinner meetings. In addition, the chapter discussed sponsoring joint meetings with other local technical societies.

The fall dinner meeting will be Nov. 10, and Dr. Steve Schlegel will be the guest speaker. He will speak on the bilateral meeting at the Russian Myak facility that he attended in late October. The Myak meeting was a reciprocal visit following a Russian visit to Hanford and other U.S. sites earlier this year.

Recent chapter Executive Committee meetings involved long-range planning for the chapter, including revival of the annual safeguards seminar, a mini-conference on safeguards and security program initiatives and technology applications, communications, and the expansion of the technical base of the membership.

Dean Scott, chair
INMM Pacific Northwest Chapter
Pacific Northwest Laboratory
Richland, Washington, U.S.A.

Business news: EET To Assist in Waste Managment

EET Corp. recently won a Martin Marietta Energy Systems Inc. subcontract extension to continue to provide waste management technical support services at five U.S. Department of Energy (DOE) facilities: Oak Ridge National Laboratory, Y-12 Plant, K-25 Site, Paducah Gaseous Diffusion Plant and the Portsmouth Gaseous Diffusion Plant.

EET will assist Martin Marietta — an INMM sustaining corporation — in fulfilling the requirements of the Federal Facilities Compliance Agreement, signed by the DOE and the U.S. Environmental Protection Agency in June 1992, and the Federal Facilities Compliance Act, signed by Congress in October 1992. EET's subcontract technical support areas include waste characterization methods and equipment development; sampling and analysis planning and execution; waste certification programs development and implementation; waste database management; quality assurance program/project planning and surveillance; waste treatment technology and planning; technical and economic evaluations; process engineering; operational readiness review planning and technical support; waste data validation; regulatory compliance analysis; transportation analysis and support; and project/program management planning.

EET is a privately held environmental, health and safety corporation that performs environmental technology development and commercialization activities at its Knoxville, Tenn., facility.

Boundary Conditions for Pathways, Safety Analyses and Basic Criteria for Low-Level Radioactive Waste Site Selection

Pierre Saverot
NUSYS
Paris, France

Editor's Note: This is part two of a two-part series of papers discussing various aspects of low-level radioactive waste (LLW) disposal, written by Pierre Saverot, chair of the Low-Level Waste Disposal Committee of the INMM Waste Management Division. Saverot is associated with the French consulting firm NUSYS, which is involved in technical and management consulting on the back-end of the fuel cycle matters, and has been active in nuclear engineering activities for more than 15 years.

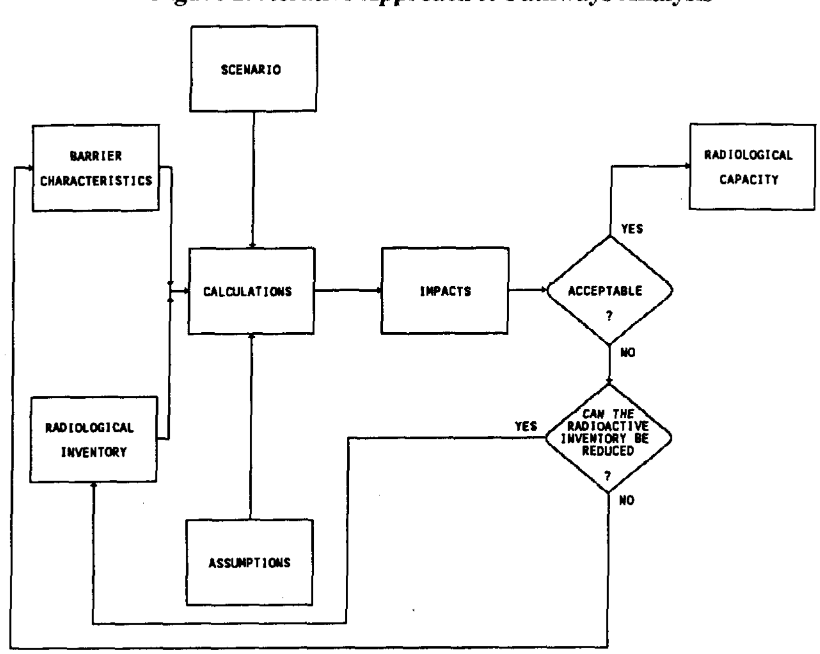
Introduction

There are three successive periods in the life of a disposal facility: the operating period, the institutional control period and the unrestricted site access period. The operating period spans the construction of the engineered structures designed to receive the waste, placement of the waste inside the structures, backfilling of the disposal structures, closure of the filled structures and installation of the final cover. The institutional control period covers the time necessary (300 to 500 years) for radioactive decay of the radionuclides disposed at the site: in France, the actual duration of this period is decided on the basis of a safety assessment of the potential impacts of the final radiological inventory of the site at the end of the operating period. The unrestricted site access period follows the end of the institutional control period, at which time the radioactivity of the site has decayed to a low enough level so that the site can be released for unrestricted use without undue risk to public health and the environment.

The purpose of safety analysis of the disposal facility is to ensure that the radiological impacts for each period in the life of the facility are acceptable under all circumstances. Founded on a deterministic approach, this analysis leads to a determination of the maximum quantity of each radionuclide present in the facility at the beginning of the institutional control period in order for the impacts to be considered acceptable. Safety analysis involves the calculation of the radiological impacts of a given radiological inventory under a selected scenario, from all plausible scenarios of radionuclide migration to the environment in both normal and accidental conditions, and taking into account other specified variables. The calculation itself involves an assessment of the quantities of radionuclides that could be released to the environment under the specific scenario selected and following identified pathways, and a determination of the resultant exposure, both internal and external, to the public.

An iterative approach is used in the performance of pathways analyses, as shown in Figure 1. If the pathways

Figure 1: Iterative Approach to Pathways Analysis



analyses result in unacceptable radiological impacts, either the radiological inventory of the site is reduced or barrier characteristics not previously factored into the analysis are taken into account. New pathways analyses are then performed until the results are within the acceptable range. Once accepted by the safety authorities, the radiological inventory becomes the radiological capacity, which is the approved quantities of specific radionuclides that may be disposed of at the site.

The following elaborates on the boundary conditions used in safety analyses and describes the types of pathways analyses performed for a LLW disposal facility.

Definition of Normal and Accidental Conditions

For each period in the life of the disposal facility, *normal conditions* are identified that are the most probable and that correspond to the expected performance of the different barriers over time. In normal conditions, only radionuclide migration by water is feasible because radioactivity transfer by air would mean that there has been an accidental failure of the primary and secondary barriers in the containment system.

- During the *operating period*, radionuclide migration by water is not feasible because the disposal structures are always sheltered from rainwater.
- During the *institutional control period*, it is assumed that water filters through the final disposal cap at a constant rate and that all of this water leaches the waste and is collected at the bottom of the disposal structures. Because the integrity of the concrete pad cannot be guaranteed for the duration of the institutional control period, the radiological impacts of extreme cases are assessed as follows:

(1) The pad's integrity is 100 percent intact, i.e, infiltrated water collected in the leachate collection system is discharged to the site outlet.

(2) The pad's integrity is lost, i.e., contaminated water percolates through the pads and the underlying subsoils before reaching the water table and a visible outlet.

- During the *unrestricted site access period*, the radiological impacts are modeled according to very conservative assumptions such as

(1) the final disposal cap returns to the conditions of the original soil at the beginning of the unrestricted site access period;

(2) the leachate collection system no longer functions and the waste packages and disposal structures have completely failed; or

(3) the existence of the facility is completely forgotten with permanent residences constructed on or near the site.

Or under more realistic assumptions such as

(4) the disposal cap, although eroded, maintains a high level of impermeability for several centuries, thus protecting the waste packages;

(5) the permeability of the disposal cap during the first thousand years of the unrestricted site access period is assumed to be x times greater than during the institutional control period;

(6) any infiltrated water is assumed to return to the soil; and

(7) the waste isolation system has completely disintegrated after 1,000 years.

Accidental conditions are conditions that alter the quality of the disposal facility's containment system so that one or more of the barriers fail to meet all or part of their performance objectives. The cause of the accident may be human or natural (landslide, tectonic shift, earthquake, etc.). Table 1 (below) shows these events for each phase in the life of the facility. Not all of the events are factored into the safety analysis, especially if they are improbable (fall of a meteorite), considered implausible (destruction of the disposal cap before 300 years since it is inspected and repaired as necessary during the institutional control period), not foreseeable (flood-

Table 1: Events Affecting the Quality of the Disposal Facility

ORIGIN	OPERATING PERIOD	INSTITUTIONAL CONTROL PERIOD	UNRESTRICTED SITE ACCESS PERIOD
HUMAN	handling incident fire concrete pad failure airplane crash	 concrete pad failure airplane crash	intrusion road construction residence agriculture water well airplane crash
NATURAL	earthquake disposal cap failure flooding animal intrusion bad weather meteorite	earthquake disposal cap failure flooding animal/plant intrusion bad weather meteorite	earthquake flooding animal/plant intrusion bad weather meteorite

Table 2: Normal and Accidental Conditions Used for Safety Analysis

OPERATING PERIOD	INSTITUTIONAL CONTROL PERIOD	UNRESTRICTED SITE ACCESS PERIOD
Normal conditions	Normal conditions	Normal conditions
Handling accident		Road construction
Fire in trailer truck		Residence area
Design basis accident	Design basis accident	Playground
		Water well

ing, given the location of the site) or not applicable. Based on evaluations of each of these events, accident scenarios, considered both plausible and conservative, are selected. (See Table 2 at left.)

• During the *operating period*, three accident scenarios are considered plausible: the handling accident, fire and the design basis accident.

(1) The worst-case handling accident studied is the fall of a heavy load on top of 55-gallon metal drums, each of which contains 70 kg of waste with the maximum allowable concentrations of alpha emitters (0.074 GBq or 0.02 Ci), with the most exposed worker at a few meters from the scene. The most exposed member of the public at 200 m from the scene of the accident, and the most unfavorable weather conditions (low diffusion, wind velocity, etc.).

(2) The fire accident scenario involves fire in a 40-foot trailer truck with combustion of 10 55-gallon drums containing bituminized waste with maximum allowable concentrations of alpha emitters, i.e., 3.7 MBq/kg.

(3) The design basis accident is considered to be the worst-case accident. In France, it consists of the collapse of the disposal cap which lets in rainwater over a period of one month, together with total failure of the infiltration water collection system resulting in total release of water into the subsoil.

• During the *institutional control period*, the only accident scenario considered is the design basis accident with two more assumptions: the final disposal cap is not repaired for one year, and the accident occurs when the activity at the disposal facility is at its peak.

• During the *unrestricted site access period*, the accident scenarios are established by the regulators. In France, it is conservatively assumed that the permeability of the disposal cap is similar to the original soil of the site, that the leachate collection system no longer functions, and that the existence of the site has been completely forgotten.

(1) The accident scenarios taken into account for these conditions include the construction of a highway, residences, a playground and a water well. In the road scenario, a highway is constructed across the entire length of the disposal site, *x* hours are spent on top of the waste disposal areas and inhalable dust is released from the radioactive waste, the cap, the backfill and the structural concrete.

(2) In the residential area scenario, the assumptions used in the safety assessment are very conservative: permanent presence of the resident on the site (all day, every day for life), inhalation of dust only from the soil of the site, highest dose factor resulting from alpha emitters, low protection of the residence and no radioactive entrainment by rainwater.

(3) The playground scenario evaluates the additional dose received by a child playing in dirt containing materials from the disposal facility.

(4) In the water well scenario, an individual digs a well on the disposal facility and uses up to 50 m^3 of water for domestic purposes.

Table 3: Examples of FALs Obtained Experimentally (Year^{-1})

RADIONUCLIDES	IMMOBILIZED WASTE
Co-60	$2. 10^{-3}$
Sr-90	$2. 10^{-4}$
Cs-137	$1. 10^{-2}$
Long-lived alpha emitters: Np-237, Pu-239, Am-241	$2. 10^{-6}$

Pathways Analysis

Pathways analysis involves modelling the migration of radionuclides from the site of the disposal facility to its surrounding environment, either by water or air, and then calculating the transfer of radioactivity to man, through the food chain or water supply for example. The basis of the pathways analysis is an assumption concerning water infiltration into the disposal units and subsequent leaching of the radionuclides contained in the waste packages. The leaching of the waste packages occurs at a certain rate called the *fraction of activity leached annually* (FAL). FAL values, defined as the ratio of the activity leached annually, a_i, for the radionuclide i, to the residual activity of the waste package at the time of leaching, A_0, are determined through long-term leach tests and also by extrapolation to the conditions prevailing at the disposal facility. Real and simulated full-scale immobilized waste forms and representative samples are completely immersed in water under standard procedures for leach tests: examples of FALs obtained by experimental means for radionuclides important for safety are shown in Table 3 (left). In addition, other FAL values are derived by correlation (5.10^{-2} for tritium, to take into account its high diffusion capability, long-lived beta-gamma emitters correlated with Co and Np, C-14 studied separately because of its more complex transfer mechanisms, etc.). For purposes of safety analysis, the FALs of the disposed waste packages are varied over time as a function of the quantity of water that may infiltrate the facility and come into contact with the waste.

Figure 2 (next page) illustrates the methodology used for pathways analysis relating to radionuclide migration due to water infiltration, which is the predominant pathway during the operating and institutional control periods.

Analysis of radionuclide migration by water

To perform pathways analysis for a particular site, information on the convection, diffusion and retention modes of radionuclide migration are needed. To calculate the migration mode by convection, the hydrodynamic parameters of the site (position and hydraulic potential of the aquifer, location of the outlets to assess the distances of the pathways, effective permeability and porosity of the site) must be identified to characterize the direction and the velocity of the water flow. The assessment of radionuclide migration by diffusion requires knowledge of the dispersion coefficients for the geologic formations along the water pathway. Characterization of the retention factor, which dominates the results of the pathways analysis, requires data on the physicochemical conditions of the site soils (pH, Eh, ionic force) and an assessment of the interactions between the radionuclides and the site.

During the operating and institutional control periods, an accidental situation could result in the partial or total failure of the disposal cap, exposing the waste packages to infiltration water that could leach the waste and entrain a certain amount of radionuclides. If the leachate collection system is affected by the accident, then there could be direct transfer to the site, the environment and the public. Figure 3 (below) illustrates the sequence of events leading to radionuclide migration by water. Radionuclide migration to the site is generally conservatively analyzed with the following assumptions: the radioactivity released is instantaneously deposited in the saturated zone, which means that the retention capability of the site in the upper layer of the unsaturated zone is not given credit in the analysis; and radionuclide migration occurs in a porous and homogeneous medium.

Although the waste containers and the disposal structures are designed to be water-resistant, their properties are altered by mechanical and physicochemical phenomena whose overall effect is one of aging. The quantity of activity leached annually by infiltrated water is defined, for a given radionuclide, as the product of the following factors: the cumulative proportion of failed waste packages (which is a function of the aging characteristics of the package), the fraction of activity leached annually (which depends on the quantity of water that has filtered through the disposal cap; different values are used for the different periods in the disposal facility's life), and the residual activity in the facility for the year considered taking into account both leaching rates (FALs) and radioactive decay.

Modelling of radionuclide migration to the site

The method used to model radionuclide migration to the site consists of characterizing the flow of water in the ground by a velocity field, V_p, followed by analysis of radionuclide migration in the ground taking into account the retention and dispersion phenomena of the latter.

The water flow in the ground is continuous, bidimensional and characterized at all points by the permeability of the aquifer, K, and by the hydraulic load of the water table, h. Since the water only flows in the accessible porosity, w_c, its actual velocity is linked to Darcy's velocity as follows: $V_p = K.\text{gradh}/w_c$.

Figure 2: Methodology for Pathways Analysis

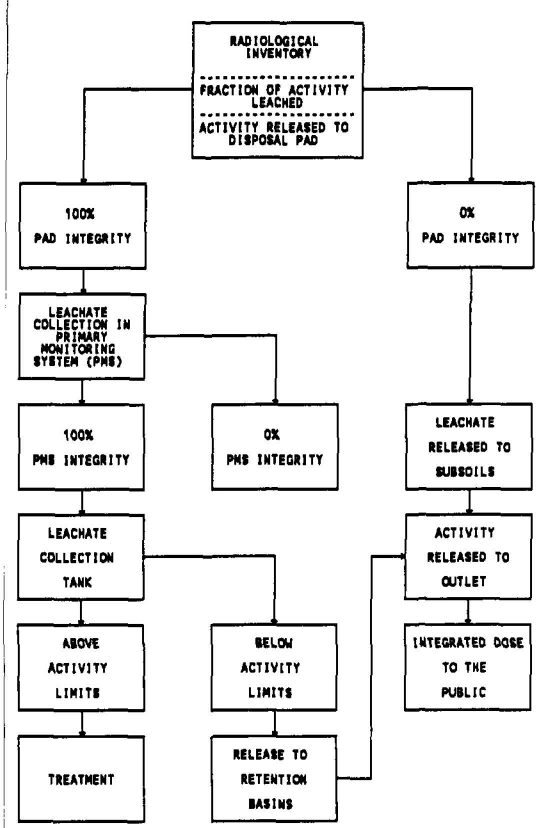
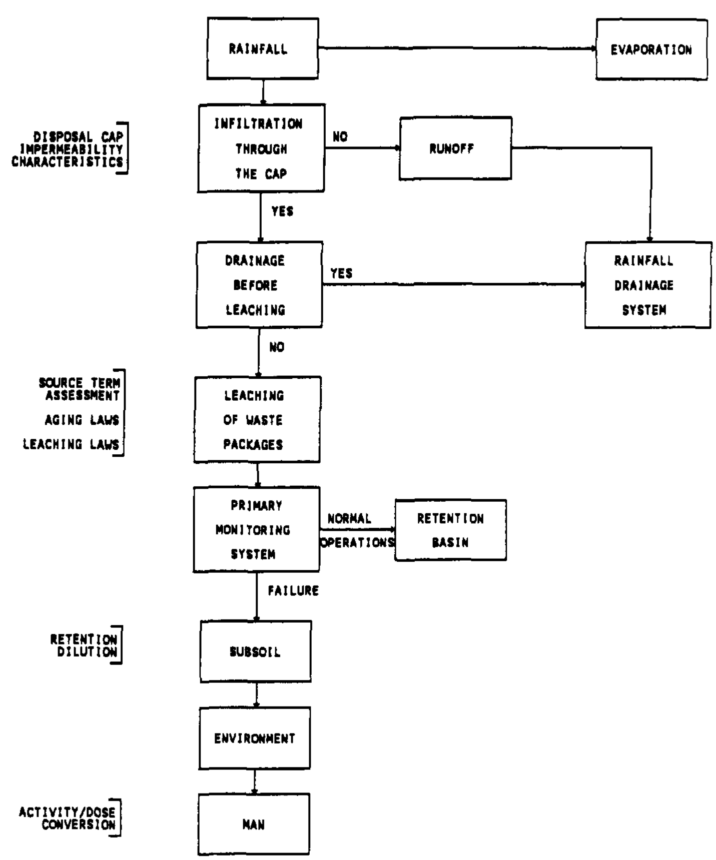


Figure 3: Radionuclide Migration by Water



Because of dispersion of local velocities of radionuclides, a portion of the radioactivity arrives at the outlet later than the water but with a greater velocity than the average velocity of the radionuclides. This phenomenon is taken into account in the model by establishing average dispersion values which result in modulation over time of the activity at the outlet.

Because of physicochemical interactions between the natural medium and the radionuclides, the average velocity V_i of a radionuclide i is determined by dividing the velocity of water V_p by a retarding coefficient R_i with $R_i = 1 + [(1-w).p_s/w_c].k_d$ where k_d is the distribution ratio between the water and the ground for a radionuclide i, p_s is the mass of solid particles, w is the porosity of the ground and w_c is the kinetic porosity of the ground.

Modeling of radionuclide migration to the environment

The evaluation of various pathways for radionuclide migration to the environment, and especially to ingested food products or to inhaled dust, is specific to the radionuclide considered and to the characteristics of the environment. To simulate the variety of pathways and mechanisms that could play a role in radionuclide migration to the environment, the following pathways are used:

- Release through the leachate collection system of the disposal facility, followed by release through the site outlet after migrating through the site soils,
- Radionuclide migration through the ground due to irrigation or flooding, through the environment to nonaquatic plants, to grazing stock and their products, and
- Ingestion or inhalation by humans of products likely to contain radioactivity.

The pathways analyses performed by Andra, in France, relative to radionuclide migration via water pathways and the modeling of the radiological impacts of such migration are summarized in Figure 4 (below). The radioactivity transfer mechanisms to man are also assessed and shown in Figure 5 (next page), using assumptions relative to the lifestyles of the local population, the K_d coefficient for each radionuclide which cover the ratios of water/soil and water/suspended matter, plus the transfer functions for soil/plant, water/milk, plant/milk, water/meat, water/fish, etc. These assumptions are entered into a computer code which models the resulting exposure to humans, identifies the key radionuclides and the food products acting as vectors, compares the ingested activity to the annual limits for incorporation and calculates factors of attenuation for ingestion and inhalation of radioactivity for the specific site being studied.

Activity–dose conversion

The activity–dose conversion factors, expressed in Sieverts per Becquerel and recommended by the ICRP, enable determination of the effective equivalent integrated dose received.

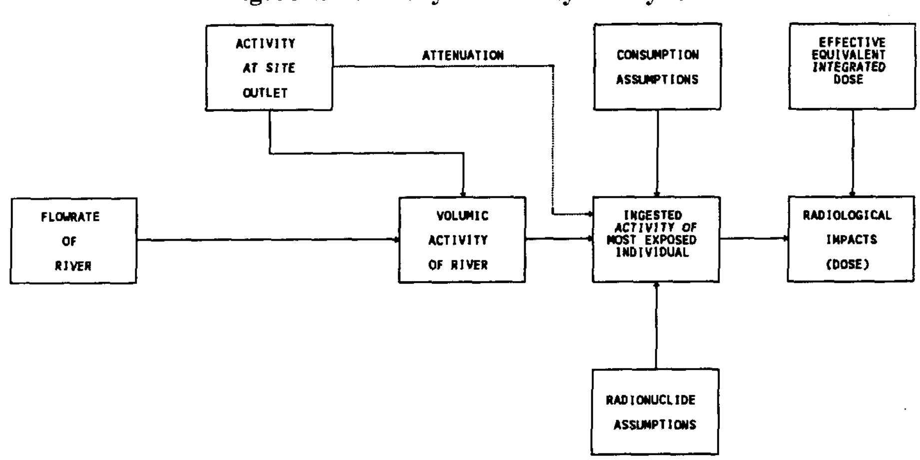
Analysis of radioactivity transfers in air

The waste dispersion scenario used to calculate the transfer of radioactivity in the air is the full breach of a metallic drum containing unimmobilized waste with the maximum allowed concentrations of alpha-emitting radionuclides by dropping or burning of the container, either of which would result in the greatest risk of inhalation given the activity–dose conversion factors.

The intrusion scenarios are calculated at the end of the maximum duration of the institutional control period (300 to 500 years), when there is unrestricted access to the site and construction projects may be conducted, and assume that the radionuclides initially present in the waste will not yet have migrated in the ground. Radioactive decay is taken into account in the calculations. Given the particular scenarios considered (construction of a highway or of residences), it is assumed that the composition of the radioactive dusts inhaled is similar to the average composition of the waste.

In summary, two stages are distinguished in pathways analyses. The first stage involves the migration of radionuclides, either by water or by air, from the site of the disposal facility to the surrounding environment. A computer code calculates the amount of radioactivity that will reach the site outlet as a function of the radiological inventory, the FALs and the K_d coefficients. The second stage involves transfer of the radionuclides from the site outlet to the environment and ultimately to humans. A computer code is also used to model the transfer of radioactivity. The final result of pathways analysis is the determination of the dose received by the most exposed member of the public under the various scenarios considered and for the different periods in the life of the facility.

Figure 4: Summary of Pathways Analysis



Summary Results of the Safety Analysis of the LLW Disposal Facility in France

The principal conclusions that may be drawn from the results of the radiological assessment of the LLW disposal facility in France are summarized below:

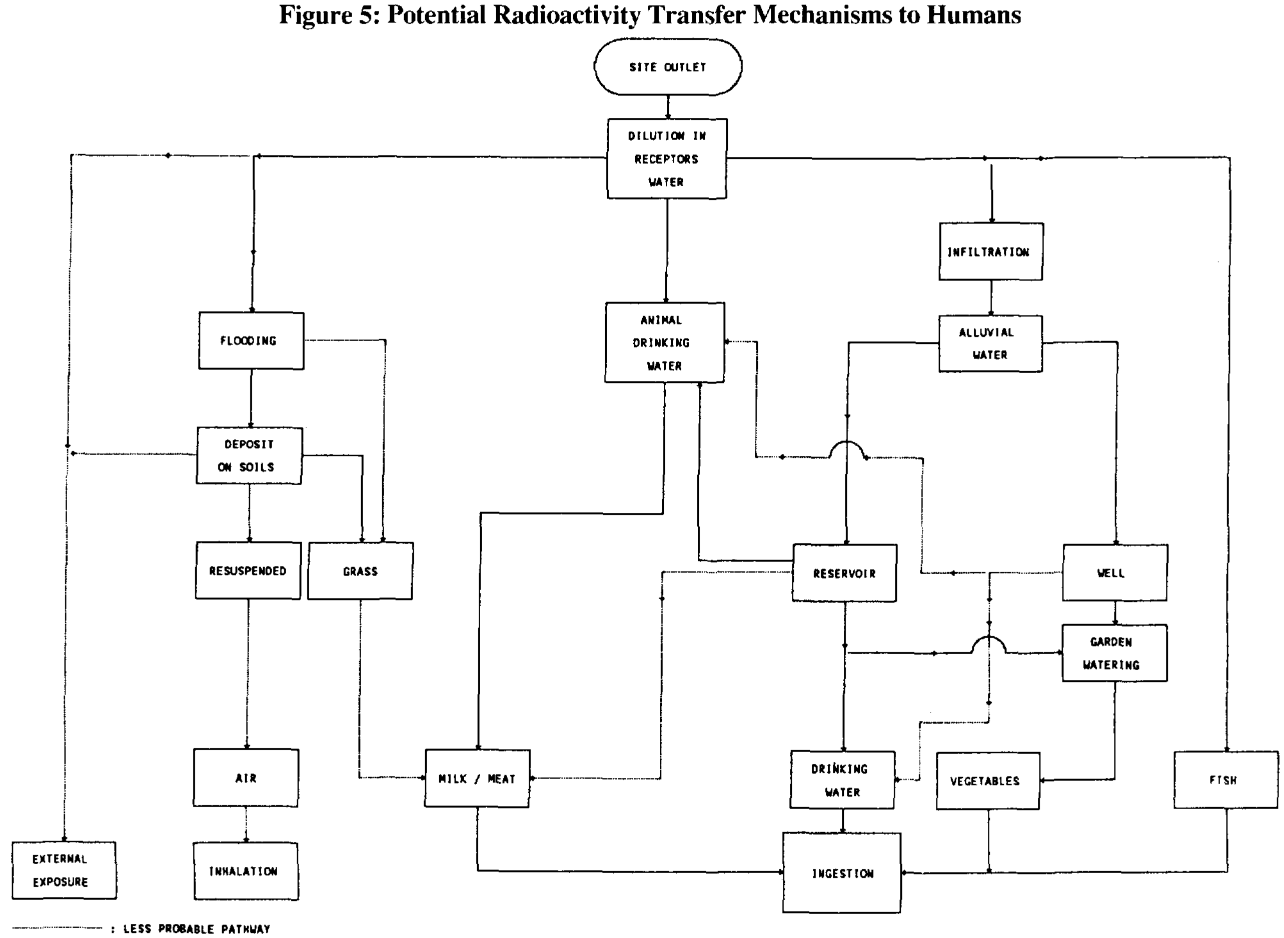
- During the operating period, site-specific potential radiological risks are very low (less than 1 microSv/year in normal operations and less than 20 microSv/year in accidental conditions). The corresponding occupational exposure would be, under all circumstances, less than 2 percent of the French average natural irradiation.
- During the institutional control period, the risk of exposure is very low in normal conditions, with a maximum radiological impact of 5 microSv/year. In accidental conditions, the worst case scenarios result in a radiological impact of 100 microSv/year, which is less than 10 percent of the natural irradiation.
- During the unrestricted site access period and based on the scenarios described above, the impacts are between 2 mSv for the road construction scenario and 3.2 mSv/year for the residence area scenario. However, these figures are based on site intrusion at the beginning of the institutional control period and therefore should be balanced against the very low probability of their occurrence.

This shows that the maximum potential exposures amount, under all circumstances, to levels comparable to the variations of natural radiation among the regions of France. Taking into account the conservative nature of the assumptions, the safety assessments are considered to be overstated by one or two orders of magnitude when compared to an approach with more realistic assumptions.

Basic Criteria for Site Selection

The site is required to provide an additional guarantee of the adequate isolation of waste from water, which is the only foreseeable mechanism for radioactivity transfer during the institutional control period. To accomplish this objective, the site must be safe from natural events (i.e., located in a tectonically stable area with low seismicity) that may adversely affect the waste isolation system. The site must be located above the highest level of the water table and possess certain hydrogeologic and geochemical properties to mitigate a potential failure of one of the barriers of the waste isolation system by "controlling" the release of the radionuclides into the soil of the site. The site must also feature simple hydrogeological characteristics capable of being modeled

Figure 5: Potential Radioactivity Transfer Mechanisms to Humans



for safety analysis purposes.

Seismic stability is a major criterion that applies to the site itself and to the surrounding structures likely to impair it, such as dams. Seismicity may affect the slope and the proper operation of the disposal facility water drainage and collection systems, as well as the water table and the water outlets. The major factors with respect to geotechnic stability are the topography of the site and the characteristics of the receiving stratum, which must complement each other. Sufficient information on the subsurface flows in the receiving stratum must be obtained to provide reliable and effective safety demonstrations. Furthermore, the receiving stratum should have a good retention capacity to retard radionuclide migration. It should be noted that materials with prevailing clayey content have this sorption and retention capacity.

The objective of the surface water studies is to describe surface water features and their flow characteristics and to determine the potential impact of surface processes, such as infiltration, flooding and erosion on the ability of the site to meet the performance objectives. The drainage areas and the stormwater runoff patterns within the site are described, and the frequency of flooding or ponding within the site is evaluated. The infiltration capacity of soils identified within the site is estimated by direct field measurements and corroborated by computer codes that evaluate infiltration rates through multilayer covers by considering precipitation, surface storage, runoff, evapotranspiration and lateral drainage. Soil erosion potential within the site is assessed to evaluate the long-term stability of the disposal site in its natural state; the soil types within the vicinity of the site, identified by soil survey and other data (including land use, ground cover, land slopes, slopes lengths and rainfall information) are used to qualitatively describe the erosion potential within the site. Infiltration and stream discharge data are used with precipitation and evaporation data from the meteorological investigation to develop a water balance for the site, and assess how precipitation falling within the site boundary may be transported within and from the site. A hydrologic model of the site is developed with a computer code to predict the magnitude of stormwater runoff and probable maximum rainfall event.

A Sequential Test for Contiguously Correlated Inventory Differences

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Abstract

The nature of statistical significance testing of a sequence of inventory differences (IDs) is that single test criteria are often used in the implementation of a test even though the IDs and hence the tests are correlated. As a consequence, the experienced false alarm rate for the sequence can be considerably larger than that presumably designed into the single test. Thus one is led to a consideration of test criteria that better address the false alarm rate problem. This paper is intended to do this. An application of Wald's sequential probability ratio test[1] to sequences of IDs under the assumption that only contiguous IDs are correlated results in one such test.

Introduction

Let X_i denote the ith ID in a time sequence of such differences. Wald's sequential probability ratio test (SPRT) for testing a hypothesis H_0 against an alternative H_1 requires the joint distribution of the realized sequence $\{X_i\}$ be determined under H_0 as well as H_1 and the ratios of the distribution functions be utilized in performing the test.

For a sequence of length *m*, the joint distribution of the realized sequence under H_0 or H_1 is multivariate of dimension *m*. If one could assume the X_is of the sequence were independently distributed, then the multivariate distributions are simply the product of m univariate distributions; however, if the X_is are not independent, a transformation[2] must be made in the usual case to facilitate sequential testing. Certainly sequences of IDs are not independently distributed for possibly several reasons:

(1) the ending inventory of one period is the beginning inventory of the next,

(2) measurements obtained by a common method may be correlated through systematic errors, and

(3) nonmeasured inventory held up in process in one period tends to "flush" in the next.

For this study it is assumed, therefore, that for any successive (in time) pairs of X_is, the joint distribution of, say, X_i, and X_{i+1} is bivariate normal with parameters: μ_i, μ_{i+1}, σ_i, σ_{i+1} and $\rho_{i,i+1}$. It is further assumed that for nonsuccessive pairs X_i, X_j, $j > i + 1$, the correlation coefficient, $\rho_{i,j}$, of the joint distribution is zero. (Correlations may exist but they are assumed to be minor compared to those between successive pairs).

Notation

Let $f(X_i, X_{i+1})$ denote the bivariate normal probability distribution function defined by

$$f(X_i, X_{i+1}) = \frac{1}{2\pi\sigma_i\sigma_{i+1}\sqrt{1-\rho_{i,\,i+1}^2}}\, e^{\frac{-1}{2\left(1-\rho_{i,\,i+1}^2\right)}A} \tag{1}$$

where

$$A = \left[\frac{(X_i-\mu_i)^2}{\sigma_i^2} + 2\rho_{i,\,i+1}\frac{(X_i-\mu_i)}{\sigma_i}\frac{(X_{i+1}-\mu_{i+1})}{\sigma_{i+1}} + \frac{(X_{i+1}-\mu_{i+1})^2}{\sigma_{i+1}^2}\right]$$

and $\phi(U_i, U_{i+1})$ the standardized bivariate normal distribution defined by

$$\phi(U_i, U_{i+1}) = \frac{1}{2\pi\sqrt{1-\rho_{i,\,i+1}^2}}\, e^{\frac{-1}{2\left(1-\rho_{i,\,i+1}^2\right)}\left[U_i^2 + 2\rho_{i,\,i+1}U_iU_{i+1} + U_{i+1}^2\right]} \tag{2}$$

It follows that the relationship between $f(X_i, X_{i+1})$ and $\phi(U_i, U_{i+1})$ is

$$f(X_i, X_{i+1}) = \frac{1}{\sigma_i \cdot \sigma_{i+1}}\phi(U_i, U_{i+1})$$
$$\text{for } U_i = \frac{X_i-\mu_i}{\sigma_i} \tag{3}$$

Similarly for the univariate normal distribution we have

$$f(X_i) = \frac{1}{\sqrt{2\pi}\sigma_i} e^{-\frac{1}{2}\left(\frac{X_i - \mu_i}{\sigma_i}\right)^2} \tag{4}$$

and

$$\phi(U_i) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}U_i^2} \tag{5}$$

so that

$$f(X_i) = \frac{1}{\sigma_i}\phi(U_i) \text{ where } U_i = \frac{X_i - \mu_i}{\sigma_i} \tag{6}$$

In what follows, the generalized notation $f(X_1, X_2, \ldots X_n)$ will be used to denote the joint probability distribution function of the sequence $\{X_n\}$. The usual notation for factoring joint distributions as products of marginal and conditional distributions will be used.

Derivation of Distribution Functions

For the sequence $\{X_1, X_2\}$, the joint distribution of the realized values is given by equations (1) or (3).

For the sequence $\{X_1, X_2, X_3\}$ the joint distribution of the sequence is

$$f(X_1, X_2, X_3) = f(X_1, X_2) f(X_3 \mid X_1, X_2) \tag{7}$$

Because X_3 and X_1 are independently distributed, this results in

$$f(X_1, X_2, X_3) = f(X_1, X_2) f(X_3 \mid X_2) = \frac{f(X_1, X_2) f(X_2, X_3)}{f(X_2)} \tag{8}$$

Similarly we have

$$f(X_1, X_2, X_3, X_4) = \frac{f(X_1, X_2) f(X_2, X_3) f(X_3, X_4)}{f(X_2) f(X_3)} \tag{9}$$

and in general

$$f(X_1, X_2 \ldots X_m) = \frac{\prod_{i=1}^{m-1} f(X_i, X_{i+1})}{\prod_{i=2}^{m-1} f(X_i)} \tag{10}$$

or recursively

$$f(X_1, X_2 \ldots X_m) = f(X_1, X_2 \ldots X_{m-1}) \frac{f(X_{m-1}, X_m)}{f(X_{m-1})} \tag{11}$$

for $m > 2$.

Sequential Probability Ratio Test

The Wald SPRT for testing H_0 against alternative H_i is defined as follows:

Two positive constants A and B ($B < A$) are chosen. At each stage of the sequence the probability ratio

$$\frac{P_{1m}}{P_{om}} = \frac{f(X_1, X_2 \ldots X_m \mid H_1)}{f(X_1, X_2 \ldots X_m \mid H_o)} \tag{12}$$

is computed. If at the mth stage

$$B < \frac{P_{1m}}{P_{om}} < A, \tag{13}$$

then no decision is made. If

$$\frac{P_{1m}}{P_{om}} \geq A \tag{14}$$

then the decision is made to reject H_0. If

$$\frac{P_{1m}}{P_{om}} \leq B, \tag{15}$$

then the decision is made to accept H_0.

The usual hypothesis, H_0, for a sequence of IDs $\{X_i\}$ is that there is no loss, which for the distribution function translates to $\mu_i = 0$ for all i. An alternate hypothesis is that $\mu_i = \delta$ for all i. Practical considerations relative to the choice of δ are given in *Considerations Relative to Choosing* δ (page 14).

From equations (1), (2), (3), (4), (5), (6), (10) and (11)

$$P_{o1} = \frac{1}{\sigma_1}\phi(U_1)$$

$$P_{o2} = \frac{1}{\sigma_1\sigma_2}\phi(U_1, U_2)$$

$$P_{om} = \frac{\prod_{i=1}^{m-1} \frac{1}{\sigma_1\sigma_{i+1}}\phi(U_i, U_{i+1})}{\prod_{i=2}^{m-1} \frac{1}{\sigma_i}\phi(U_i)} \tag{16}$$

$m > 2$

where

$$U_i = \frac{X_i}{\sigma_i}$$

Similarly,

$$P_{11} = \frac{1}{\sigma_1}\phi(W_1)$$
$$P_{12} = \frac{1}{\sigma_1\sigma_2}\phi(W_1, W_2)$$
$$P_{1m} = \frac{\prod_{i=1}^{m-1} \frac{1}{\sigma_i\sigma_{i+1}}\phi(W_i, W_{i+1})}{\prod_{i=2}^{m-1} \frac{1}{\sigma_i}\phi(W_i)} \tag{17}$$

where

$$W_i = \frac{X_i - \delta}{\sigma_i}$$

The probability ratio then is

$$\frac{P_{11}}{P_{o1}} = \frac{\phi(W_1)}{\phi(U_1)}, \frac{P_{12}}{P_{o2}} = \frac{\phi(W_1, W_2)}{\phi(U_1, U_2)}$$

and in general

$$\frac{P_{1m}}{P_{om}} = \frac{\left[\prod_{i=1}^{m-1}\phi(W_i, W_{i+1})\right]\left[\prod_{i=2}^{m-1}\phi(U_i)\right]}{\left[\prod_{i=1}^{m-1}\phi(U_i, U_{i+1})\right]\left[\prod_{i=2}^{m-1}\phi(W_i)\right]} \tag{18}$$

for $m > 2$

On substituting the actual distribution functions for $\phi(W_i, W_{i+1})$, $\phi(U_i, U_{i+1})$, $\phi(U_i)$ and $\phi(W_i)$ and taking the logarithm (for convenience) we have

$$\ln\frac{P_{11}}{P_{o1}} = \frac{1}{2}\left[U_1^2 - W_1^2\right]$$
$$\ln\frac{P_{12}}{P_{o2}} = \frac{1}{2\left(1-\rho_{1,2}^2\right)}\left[U_1^2 - W_1^2 + 2\rho_{12}\left(W_1W_2 - U_1U_2\right) + U_2^2 - W_2^2\right]$$

and in general for $m > 2$

$$\ln\frac{P_{1m}}{P_{om}} = \sum_{i=1}^{m-1}\frac{1}{2\left(1-\rho_{i,i+1}^2\right)}$$
$$\left[U_i^2 - W_i^2 + 2\rho_{i,i+1}\left(W_iW_{i+1} - U_iU_{i+1}\right) + U_{i+1}^2 - W_{i+1}^2\right]$$
$$+\frac{1}{2}\sum_{i=2}^{m-1}\left(W_i^2 - U_i^2\right) \tag{19}$$

which in recursive form is equivalent to

$$\ln\frac{P_{1m}}{P_{om}} = \ln\frac{P_{1,m-1}}{P_{o,m-1}} + \frac{1}{2\left(1-\rho_{m-1,m}^2\right)}$$
$$\left[U_{m-1}^2 - W_{m-1}^2 + 2\rho_{m-1,m}\left(W_{m-1}W_m - U_{m-1}U_m\right) + U_m^2 - W_m^2\right]$$
$$+\frac{1}{2}\left(W_{m-1}^2 - U_{m-1}^2\right) \tag{20}$$

The equivalent test to (13), (14) and (15) is obtained by replacing

(a) $\frac{P_{1m}}{P_{om}}$ by $\ln\frac{P_{1m}}{P_{om}}$

(b) A by $\ln A$ and B by $\ln B$.

Implementation of the Test

To implement the test, the constants A and B are chosen so that the test will have the desired type I and type II errors, i.e., α and β. Wald shows that for most practical purposes the approximate formulas:

$$A = \frac{1-\beta}{\alpha} \text{ and } B \approx \frac{\beta}{1-\alpha} \tag{21}$$

may be used.

From equation (20) it is apparent that one must have estimates of the parameters σ_i^2, $i = 1, 2 \ldots m$ and $\rho_{i,i+1}$, $i = 1, 2 \ldots m - 1$ to apply the test.

The σ_i^2 are the variances of the individual IDs (X_is) as obtained by error propagation or alternate procedures. The correlation parameter, is defined by

$$\rho_{i,\,i+1} = \frac{cov\left(X_i, X_{i+1}\right)}{\sigma_{X_i}\sigma_{X_{i+1}}}$$

As an approximation to the covariance between X_i and X_{i+1} one could use the propagated variance of the common components of the ending inventory in X_i and the beginning inventory in X_{i+1}. If one desires to consider contributions to the covariance other than common measurements, procedures exist[3,4] for providing that estimate also.

The actual test is implemented by computing (20) in sequence for each m, where σ_i and $\rho_{i,i+1}$ are defined as above, $\{X_i\}$ is the realized sequence of length m of IDs, and U_i and W_i are defined by

$$U_i = \frac{X_i}{\sigma_i},\ W_i = \frac{X_i - \delta}{\sigma_i}$$

The decision rules of (13), (14) and (15) as modified by using the logarithms are then applied.

Truncated Sequential Probability Ratio Test

Although Wald shows that the probability is 1 that the sequential test procedure will eventually terminate, it is sometimes desirable to truncate the SPRT at a predetermined upper limit, say m_0, for the number of observations. This is accomplished in practice by giving a new rule for the acceptance or rejection of H_0 at the m_0th trial if the sequential process did not lead to a decision for $m \le m_0$. Wald suggests the following simple and reasonable rule for truncation at the m_0th trial.

If the SPRT does not lead to a final decision for $m \le m_0$, accept H_0 at the m_0th trial when

$$\ln B \le \ln \frac{p_{1mo}}{p_{omo}} \le O \text{ and reject } H_o \text{ when } O < \ln \frac{p_{1mo}}{p_{omo}} < \ln A$$

By truncating the process at the m_0 trial, the probabilities of errors of the first and second kind are changed. The effect of truncation on these errors depends on the value of m_0. The larger the m_0, the smaller the effect of truncation on α and β will be. Wald derives upper bounds on the errors resulting from truncation.

Considerations Relative to Choosing δ

In the SPRT described above, δ corresponds to the minimum average loss one desires to detect with probability 1 - β. In this context, δ might correspond to the normal operating loss experienced per inventory period. In the context of performance testing where one desires that the sequence of tests has the capability to detect the loss of a goal quantity, say G, with probability 1 - β, then for each sequence of length m, one would define

$$\delta = \frac{G}{m} \text{ so that } W_i = \frac{X_i - \frac{G}{m}}{\sigma_i} \text{ for the given } m.$$

It is to be noted that the assumption $\mu_i = \delta$ for all i implies the actual loss each period is constant. In actuality, the loss may vary from period to period. The SPRT, as developed above, could be modified to accommodate certain distribution assumptions on the μ_is and thus facilitate a study on the sensitivity of the SPRT, as developed, to these assumptions. From an academic point of view this would be useful. As a practical matter, the loss distribution is never known *a priori*. By using the constant loss model, where δ is presumed to be the average of the μ_is as contrasted with a variable loss model, it is my impression that one would error in favor of increasing the false alarm rate which from a safeguard's point of view is the right direction for an approximate test.

Considerations Relative to Estimating σ_i, σ_{i+1}

As suggested in the abstract, both measurement errors and nonmeasured process inventory can contribute to the ID variance and the covariance between contiguous IDs. It seems reasonable to assume that process variability is independent of measurement errors thus, if variance estimates exist for each they can be added to obtain the σ_i necessary for implementation of the test. Similarly, if an estimate of the process covariance exists, this can be added to the propagated measurement covariance to estimate $\sigma_{i,i+1}$ also needed to estimate $\rho_{i,i+1}$ as required by the SPRT.

Summary and Conclusions

The SPRT as derived for testing sequences of IDs is a straightforward adaptation of Wald's original theory. Though certain parameters of the test need to be estimated, procedures currently exist to provide these estimates. The test will accommodate both a measurement error only or measurement and process errors model. It also accommodates contiguous ID measurement correlations as well as process correlations if desired. The computational routine is relatively simple and avoids complexities usually associated with tests involving correlated variables in a multivariate distribution format.

References

1. Wald, A. *Sequential Analysis,* New York; John Wiley & Sons. 1947, pp. 37–65.
2. Beedgen, R. "Statistical Near-Real Time Accountancy Procedures Applied to AGNS Minirun Data Using PROSA," LA-11196-MS, UC-15, March 1988, pp. 8–11.
3. Tingey, F. H. "Some Observations on the Construction of LEIDs," P*roceedings of the 27th Annual Meeting of the Institute of Nuclear Material Management,* Vol XIV, 1986.
4. *IAEA Safeguards Statistical Concepts and Techniques Vol. II,* fourth ed., International Atomic Energy Agency, Vienna, 1989.

New Dimensions in Nonproliferation — An International Atomic Energy Agency View

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INMM Annual Meeting Plenary Session
July 19, 1994
Naples, Florida, U.S.A.

Four years ago, Saddam Hussein invaded Kuwait with the intention of annexing it as Iraq's 19th state. The disclosure of the Iraqi nuclear weapons program in the aftermath of the Gulf War — through the IAEA inspections — signaled the end of one proliferation era and the start of the next. In my remarks today, I have found it useful to identify four distinct proliferation eras, each with different features, each calling for different emphasis in international nonproliferation efforts. They provide a convenient way to look at the history of nonproliferation, and to look into the future and to the new dimensions in nonproliferation that are slowly emerging.

Since the Gulf War, the nuclear world experienced a series of events of fundamental significance that changed the nature of nonproliferation, forcing changes in the mission of the IAEA and its methods. Certainly some of these events came in the form of unpleasant surprises, such as in Iraq, but very positive progress was also made on other fronts. I would like to share with you some perceptions of the events creating the present situation, and some views anticipating the requirements most likely to emerge in the coming years.

The first era: 1942-1954

America has been at center stage in the evolution of nuclear energy from the first chain reaction in Fermi's reactor at the University of Chicago in 1942, a reactor which was, incidentally, not very different from the 5 MWe reactor at Nyongbyong in North Korea. The destructive potential of this new energy form was exploited first by the United States in 1945, then by the Soviet Union in 1949 and by the United Kingdom in 1952. During this initial proliferation era, nuclear weapons were used to force the end of World War II and later to hold the rivalry between communism and capitalism in check during the Cold War. This era also saw the emergence of peaceful applications of nuclear energy and of naval propulsion reactors. Ideas for nonproliferation were not lacking even in this first era, but with the competition between vying political ideologies, progress could not be attained. The most notable ideas were the Baluch Plan in 1948 and early notions regarding a nuclear test ban and a cut-off on the production of fissile material for nuclear weapons.

The second era: 1954-1970

The second era began with the 1954 "Atoms for Peace" initiative of President Eisenhower, offering peaceful nuclear technology in return for restraints on the military use of nuclear energy. However, proliferation continued as France (in 1960) and China (in 1964) tested their first weapons. Nevertheless, this second era was above all marked by grand ideas and great progress in stopping further spread of nuclear arms. In this period, the Treaty of Rome established the EURATOM control authority in 1955 and the Tlatelolco Treaty signed in 1967 started the creation of a nuclear weapon-free Latin America.

The crowning accomplishment of this second era was the signing of the Nonproliferation Treaty [NPT] in 1968. The NPT is a remarkable creation. It established a nearly universal framework for managing international nuclear commerce and nonproliferation in a balanced manner. As part of the NPT, the IAEA was given the task of applying a uniform system of comprehensive, rigorous and demanding verification measures. IAEA safeguards, together with such complementary measures as quiet diplomacy, supplier guidelines and national intelligence, have served to restrain any lingering interests in nuclear weapons in almost all countries. Today, 26 years later, the NPT remains the cornerstone of the international nonproliferation regime.

The third era: 1970-1991

The third proliferation era began with the entry into force of the NPT in 1970 and ran through the 1970s, '80s and into the early '90s. During the third era, proliferation concerns concentrated on checking the spread of nuclear weapons first in large industrialized countries such as Germany and

Japan, and later in other countries that might see nuclear weapons as a way to gain prestige and regional influence. Some countries, like my own (Switzerland), kept the nuclear weapon option open until the NPT in 1968. In the 1970s and '80s, South Africa went the full distance, establishing an arsenal of six completed bombs before concluding that the possession of nuclear weapons would not enhance its future domestic or regional security. South Africa then destroyed its nuclear weapons, dismantled its nuclear weapons program and finally signed the NPT in 1991 as a nonnuclear weapon State. More recently, Argentina and Brazil similarly concluded, each on their own, that there were no security threats that required possession of nuclear weapons. They then formed a bilateral nuclear control system and took steps allowing the Tlatelolco Treaty to enter into force. The prospects for accession to the NPT are indeed very promising in that region.

Not all of the developments were positive during this third proliferation era. India, Pakistan and Israel established nuclear programs free of international inspection. India detonated a "peaceful nuclear explosive" in 1974, and all three are believed to have crossed the nuclear threshold. And, as mentioned, our 25 inspections in Iraq revealed a very comprehensive, sophisticated and well-funded nuclear weapons program. Even after 25 inspections visiting all suspected sites, we cannot issue a clean bill of health in Iraq, but we are confident that no major elements of that program remain.

The fourth era: beyond 1991

Our dispute with North Korea is one of initial events of the fourth proliferation era. The information declared officially by the Democratic Peoples Republic of Korea [DPRK] as a part of their obligations as an NPT State was found to be incomplete. For example, we concluded that the Radiochemical Laboratory reprocessed more fuel than declared, but with the inspection activities permitted thus far, we are unable to determine how much more. Samples taken from key locations within the plant enabled us to put together an operational history which suggests that several additional reprocessing campaigns were carried out. From our inspections, however, we cannot support or dismiss the speculations reported in the media that the DPRK may have acquired enough plutonium to produce a few nuclear weapons. Nevertheless, we remain hopeful that the DPRK will contribute to the resolution of the inconsistencies observed by our inspectors, sooner or later, in one form or another.

Setting aside the DPRK until further evidence, the fourth proliferation era begins with a preponderant community of nations which, according to their policies and preferences, employ nuclear energy solely for peaceful purposes. This is certainly a first positive note. We at the IAEA are also optimistic about the prospects for a nuclear-weapons-free Africa, and even for progress toward a nuclear-weapons-free Middle East. We expect those countries that are engaged in the peaceful use of plutonium to follow prudent guidelines in its management, and we hope that all production of highly enriched uranium might one day be banned.

We keep this optimism, but we are not naive. Too many countries choose to remain outside the mainstream of international life, and the rulers may still be very interested to acquire nuclear weapons. And economic opportunism and civil discord may threaten the secure storage of existing weapons or fissile material stocks in the former Soviet Union.

Where do we go from now on in this last nonproliferation era that started with Iraq and the DPRK? The nonproliferation regime will continue to evolve, incorporating a variety of elements intended to avoid problems before they arise or nip them in the bud if they can't be avoided. The key to success in this forthcoming era is the increasing social and economic integration of the international community, which binds its parties in a web of trade and social entanglement, making isolation unattractive.

As we look ahead, we can already see the first glimpses of the new horizon. Its features may well depend on progress in three aspects of nuclear arms reduction and control.

First, the climate achieved in relations between the United States and Russia, as manifested, in part, in the reductions of their nuclear arsenals through the INF and START I and II treaties, brought about an end to the nuclear arms race that dominated our lives. We may hope for further reductions in the Russian and U.S. arsenals, continuing to decrease the ceilings established in START II perhaps by another order of magnitude; we may hope for Britain, China and France to join the process in an appropriate manner.

Second, a comprehensive ban on the testing of nuclear explosives would be a good omen. It would complicate the development of new nuclear weapons, especially for countries that might be tempted to cross the nuclear threshold. The nuclear test ban treaty may be most important in the sense of turning nuclear weapon States away from their reliance on their weapons and toward establishing a universal ethic that rejects all weapons of mass destruction.

Third, a ban on the production of fissile material for use in nuclear weapons would provide a cap on the basic ingredients required for nuclear weapons. Such a cap may provide a first step on the road towards engaging the "threshold countries" (India, Pakistan, Israel) in a meaningful arms control process. For the five NPT nuclear weapon states, a cut-off treaty will, at the outset, formalize the end of the nuclear arms race and impose ceilings on the maximum number of nuclear weapons that can be produced. A cut-off treaty in and of itself is important and provides one avenue through which NPT nuclear weapon States can meet some of their Article VI obligations. The cut-off will become increasingly important as more of these NPT nuclear weapon States and the threshold countries follow the U.S. initiative in submitting surplus fissile materials to IAEA safeguards on an irreversible basis. Ultimately, we may even hope that the military inventories may become subject to internationally accepted limits, and that a mechanism will be found through which the unsafeguarded fissile material inventories of the NPT nuclear weapon States and the threshold countries may be reduced in the coming decades according to a common formula.

The nonproliferation regime is based on a nearly universal recognition of the calamity that could arise if nuclear weapons were to proliferate. This nearly universal concern will continue to be manifested in quiet diplomacy, existing and new treaties, responsible access to nuclear technology and through the application of IAEA safeguards.

Strengthening of safeguards: undeclared activities

In the aftermath of the Iraqi situation, the international community agreed, nearly unanimously, that Agency safeguards need to be strengthened in their ability to detect *undeclared inventories of nuclear materials and undeclared nuclear installations.* A variety of measures are under consideration in the IAEA to accomplish this goal.

This enhanced safeguards system will include systematic analyses of all information available on the nuclear program of each country, such as information gleaned through safeguards implementation and the systematic review of open literature and information provided to the Agency from various sources, including information from national intelligence organizations.

A considerable part of the effort to strengthen the Agency's ability to detect undeclared operations in declared nuclear facilities will be through the analysis of:

- smear samples from within declared nuclear facilities and
- environmental samples taken from locations nearby declared facilities.

Efforts to detect *undeclared or clandestine facilities* will involve the analysis of:

- environmental samples from locations where such activities are suspected, and
- wide-area environmental monitoring for the purpose of detecting undeclared reprocessing and enrichment operations.

The ability to analyze particulate samples as small as 10^{-15} g for chemical composition and isotopic abundances could dramatically enhanced the Agency's ability to seriously investigate undeclared activities.

In the United States, there is a saying that there are three things that are important in real estate pricing: *location, location and location.* Similarly, there are three key requirements for strengthening IAEA safeguard: *access, access and access.* Several of our Member States are ready to offer essentially unrestricted access to their territories. In fact, so many countries have offered to facilitate trials of these provisions that we are hard-pressed to keep up. The results of our tests are still coming in, but we can already conclude that the detection capability for undeclared reprocessing will be quite substantial, but that the detection of clandestine uranium enrichment is more difficult.

Implementing these capabilities within the IAEA will require some internal changes. We began training our inspectors to be sensitive to the types of operations or activities that might signal a country's interests in clandestine nuclear objectives. Our past inspection culture was rather too much directed toward confirming the declarations made by national authorities and that mind-set must now be updated for the coming proliferation era.

Our investigations relating to strengthening the Agency's safeguards system also address an enhanced role for design information verification and new verification alternatives that might be at least as effective as the current schemes, but less costly to implement. One particularly promising avenue for some types of facilities would be based on expanded declarations of flows and inventories and unannounced or short-notice inspections.

How fast can this strengthening become reality? The IAEA safeguards system is bounded by the legal instruments through which it is implemented. Yet, the Safeguards Agreements based upon the NPT and other treaties or arrangements for full-scope safeguards are remarkably prescient and provide substantial flexibility in their interpretation. Some of the measures currently under investigation can and will be adopted within the existing legal arrangements as the measures are proven and as we acquire the capabilities required for their use. However, some of the measures under consideration may go beyond the current limitations, and for these, we need to establish the foundations for their use through additional legal arrangements. The question of access rights will likely be the most complex of the many knotty issues that lay before us.

Strengthening of safeguards: declared activities

In addition to the new and somewhat exotic measures that will seek to uncover what is undeclared, the safeguards system will nevertheless remain focused on *the detection of diversion of declared inventories of nuclear materials from declared nuclear facilities.*

The first topic I would like to mention in this regard arises when countries first come under a comprehensive safeguards agreement. Under Article 1 of all such agreements, the country is obligated to accept safeguards on all sources of special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere. One of the first steps in the implementation of such an agreement is for the country to submit an official initial inventory. Correspondingly, one of the first steps in the application of Agency safeguards under such an agreement is to verify that the initial declaration is complete and accurate. (Incidentally, it is under this provision that our dispute with the DPRK arose.) The measures used include careful examinations of corroborating information, extensive consultations with specialists within the country who have intimate and recent information on the country's nuclear program, and verification activities at declared sites and at other locations. Collectively, these measures might be thought of as a forensic science of nuclear archeology. Recently, they were or are being applied in South Africa, Argentina and Brazil, and also in the DPRK. It is not possible to reach an absolute standard of certainty through these efforts, but with time, access and the cooperation of the national authorities and facility operators, a picture can eventually emerge that substantiates the initial declaration or provides a satisfactory explanation for any significant discrepancies.

Next is the subject of design information and the verification of that information over the life of nuclear facilities submitted to Agency safeguards. When safeguards agreements were first concluded, facilities submitted to safeguards were rather simple. They processed or used relatively small amounts of nuclear material. Over the years, however, it became evident that the period between the time required for the submission of design information and the initial operation of a facility was too short to permit the Agency, national authorities and facility operators to agree on the provisions necessary for the Agency to implement its inspections in an effective and efficient manner.

Remember the task at hand. For large-scale facilities, particularly for those processing plutonium or highly enriched uranium, design information verification activities carried out over the life of each facility should enable the Agency to conclude:

• First, that a facility is built for its declared peaceful purpose;

• Second, that the facility is properly used and that the nuclear materials are properly accounted for;

• Third, that the Agency can establish in due time a safeguards approach that will meet its objectives effectively and efficiently; and

• Fourth, that when anomalies are detected, the Agency will have sufficient understanding of the facility and of its operations to be able to determine whether the anomalies are due to innocent cause or whether suspicion is warranted.

To establish these capabilities, design information examination and verification must begin during the design and construction of facilities and continue through commissioning and over the life of the plant during periods of routine operations, plant maintenance and upgrades, and finally, even into the decommissioning of the facility.

Measures directed toward the detection of diversion from declared facilities will indeed remain an essential part of the safeguards system. Efforts are continuing to develop new methods to enhance our current capabilities. In this regard, I would like to mention a few examples of particular interest:

• Applications of process monitoring and near-real-time accountancy are underway on a limited scale, but such capabilities will become increasingly standard in plants that process plutonium and highly enriched uranium. For very large plants, such as the Rokkasho reprocessing plant, the measures adopted will include an integrated network of safeguards sensors providing information in real time to an on-site inspection center, where Agency inspectors will be able to track the flows and compute balances over selected portions of the process, as frequently as daily, but when and as they wish.

• Unattended verification technology, already applied successfully in plutonium processing plants and in certain nuclear power reactors (Candu, LMFBR) enable the Agency to expand its verification capabilities without the need for inspectors to be physically present at the facility. Remote monitoring applications will extend this capability further, as international telecommunications capabilities are adopted increasingly for this purpose.

Digital video technology is developing at a phenomenal pace. We can anticipate a future when surveillance becomes almost human in its ability to determine the nature of the activities it "sees" and to take appropriate steps.

Returning now to the broader proliferation issues, I already noted that the characteristics of the coming proliferation era, or non-proliferation era, will first of all depend on progress in the field of nuclear arms control. In his speech to the 1993 General Assembly of the United Nations, President Clinton put three items on the political agenda. I would like to share with you our understanding of some further essential aspects. The IAEA has not yet been given a formal mandate in these directions, but that is likely to change soon.

First item: Released materials from defense stockpiles

The first item involves the irreversible application of IAEA safeguards on plutonium and highly enriched uranium rendered surplus from defense requirements in the United States, possibly later in Russia, and hopefully later still in Britain, China and France. At present, we are establishing arrangements to begin verification activities in two U.S. facilities: Oak Ridge and Hanford. We may begin inspections this year, assuming that the necessary legal and financial requirements can be met. Other facilities will be added later on. We were informed that the plutonium and perhaps some highly enriched uranium may be submitted to IAEA safeguards in nuclear weapon components *bulkwise*. The verification arrangements adopted for those materials must not, of course, divulge sensitive information on the contents or configurations of those items.

Second item: Cut-off treaty

A cut-off treaty would alter the nonproliferation landscape in fundamental ways. The negotiation of this treaty was requested in late 1993 in a United Nations General Assembly Resolution, jointly sponsored by a number of countries, including the United States and India. The IAEA was asked through that resolution to provide assistance in establishing verification requirements for the cut-off treaty, and it is widely expected that the IAEA would be assigned the responsibility for verifying such a treaty. At present, we are carrying out preliminary analyses of the scope and cost of such verification in the NPT nuclear weapon States and in the threshold countries. We have thereby given some thought to verification alternatives and to their relationship with the conventional NPT verification requirements.

We expect that the cut-off verification activities would begin with the highest priority fissile materials and nuclear facilities. After the verification of these highest priority materials and facilities is in place, the verification activities could be expanded in steps to encompass the full range of nuclear facilities. Beyond that, provisions for verification activities addressing undeclared production could even be introduced, if so stipulated in the treaty.

Here there is a tough choice to be made by the negotiating parties of such a treaty A production cut-off treaty could have a *comprehensive* technical objective, addressing all plausible means through which a country could acquire additional plutonium or highly enriched uranium after the cut-off treaty enters into force. Or, it could have a technical objective of a very *limited* nature, providing, for example, assurances that known military reprocessing plants and enrichment facilities are permanently shut down. The final choice will depend on the willingness of the five nuclear weapon states and the three threshold states to sign such a treaty and on the costs of its verification. Most of us in the Agency would prefer a treaty in which the verification requirements for the cut-off treaty and for the NPT converge over time. This convergence could occur through the phased expansion of cut-off verification measures as available resources permit or, perhaps by the phased reduction of some nonproliferation verification measures that may no longer be considered essential in the next proliferation era.

At any rate, to be affordable, the verification arrangements under a comprehensive cut-off treaty would have to make full use of emerging technologies, and inspector deployment would have to be decentralized to improve productivity through expanded use of regional offices and resident inspector basing at large nuclear installations.

Certainly the production cut-off verification is very complex politically and even technically due to the age and status of the facilities involved. We anticipate that a considerable period will be required before a treaty is agreed on, signed and entered into force.

Third item: Test ban treaty

Such a treaty is now being discussed and negotiated with great intensity in Geneva, in the framework of the Conference on Disarmament. The IAEA may have a role in the verification of a nuclear test ban treaty. One of the reasons to assign the IAEA a role in this activity is the realization that a global radionuclide monitoring system, which will most probably be one of the measures adopted, could also provide indications of undeclared reprocessing. On the other hand, wide area environmental sampling foreseen for strengthened safeguards could as well provide information about the detonation of a nuclear explosive. There is broad recognition of this complementarity. The provisions of the verification systems could, therefore, meet both needs. We believe that substantial savings could be accrued by making use of the existing IAEA infrastructure and expertise.

A final word about costs and benefits. The costs estimated for these various nuclear verification systems and those for the Chemical Warfare Convention and those for the Biological Warfare Convention could easily exceed half a billion U.S. dollars annually. Countries are clearly concerned about such escalating obligations and practical constraints may have to be accepted. Yet, this kind of money is still a bargain for the world community, since all these confidence-building measures can indeed have a positive impact on many defense budgets.

Next April, the parties to the Treaty for the Nonproliferation of Nuclear Weapons will convene in New York to review the performance of the NPT over its first 25 years and extend it, either indefinitely or for a specified period. The NPT has been described as the cornerstone of the international nonproliferation system; its continuation is vital to world peace. While crystal ball gazing is prone to biases and misperceptions, I cannot foresee a world that would be better without this treaty, or with conditions that hold it hostage to frequent periodic political challenge. I believe that all of you, individually, and collectively as the Institute of Nuclear Materials Management, could hold no more worthwhile goal than to help to realize these specific aims next April in New York.

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Ninth Annual INMM Safeguards Roundtable Part I

July 19, 1994
Naples, Florida, U.S.A.

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Each year, INMM leaders interview the Annual Meeting plenary session speaker or speakers in a relaxed setting immediately following the plenary session. The purpose of the interview is to explore in more detail the issues presented during the plenary session and to provide Journal *readers with additional understanding regarding the issues as they affect the nuclear safeguards community.*

This year, the plenary session speakers were Bruno Pellaud, International Atomic Energy Agency deputy director general and head of the department of safeguards, and Ivan Selin, chair of the U.S. Nuclear Regulatory Commission. The roundtable session with Pellaud provided insight on the Nonproliferation Treaty Review and Extension Conference next year and on the IAEA itself. The roundtable session with Selin is on page 38.

JIM TAPE: You covered a very broad range of topics this morning. You touched on the history of nonproliferation and the growth of safeguards, and then got into some of the more recent activities, mentioning Iraq, North Korea and the current initiatives in inspections of excess weapons materials and cutoff, as well as the strengthening of safeguards. But as you look over this very rich agenda for the International Atomic Energy Agency [IAEA] today, where do you place your highest priority?

BRUNO PELLAUD: The highest priorities are not necessarily those that are the most prominent in the public debate. Two issues are very prominent: the Democratic People's Republic of Korea [DPRK] and the Clinton initiatives announced in his speech to the United Nations on Sept. 27, 1993. My key priority is the strengthening of safeguards.

Let me go back to the two issues I just mentioned and why I think they are not of such high priority in the context of our discussion here in the INMM meeting. The DPRK issue is very visible, but basically it is a case of noncompliance with the Nonproliferation Treaty [NPT]. We are frustrated; we cannot do what we are supposed to do: apply safeguards. The DPRK joined the NPT and signed a safeguards agreement in 1992. Normally you would expect a country to fulfil its commitment. The big decision is whether the country should come into the NPT or not. But once they're in, governments comply. They may argue on some detail of the facility attachment to the safeguards agreement but basically that's it. And here, to our surprise, is a country that came in with the expectation that it could do what it wanted and deny us access.

Eventually, we used the ultimate tool we have: the special inspection. It failed. The issue was referred to the Security Council and to bilateral negotiations between the DPRK and the United States government. Knowing the very strong U.S. government support for safeguards, we expect that our case, our interest in the implementation of safeguards, will continue to be defended and protected by the U.S. government.

But in terms of safeguards, there is nothing generic here, nothing of a fundamental nature except its potential political impact. What will be the impact of the DPRK issue on the NPT Review and Extension Conference in New York next year? That's really the key issue, more than all the details about the reprocessing plant in Nyonbyong and the fuel in the reactor and how much one can still measure or not measure. Yes, the real issue is what will be the impact on the NPT Review and Extension Conference next year. If we still have the DPRK albatross around our neck, and I'm talking about the IAEA and all the parties to the NPT, then the discussion in New York may be so loaded that we'll have difficulty focusing on the key issues of treaty extension and nonproliferation in the 21st century.

So the DPRK, as I said, is a case of noncompliance. What can we do at the IAEA? We can only insist on trying to do what we are supposed to do. We are only straightforward, international civil servants with a mandate to fulfil. We have nothing to negotiate; we are just supposed to do our job. We can or we cannot. That's the DPRK. Others may have a broader agenda; not the IAEA.

The other issue deals with the Clinton initiatives on released materials, a cutoff treaty of fissile material production and a test ban treaty. These things are very important. They set a signal to the future of nonproliferation in general, so we support these activities. We help, as we have been asked by the U.N. General Assembly, in the evaluation of these ideas. However, it's still a long way until these agreements will be finalized, signed, ratified and enter into force. In our own assessment and in the planning of resources in our organization, we look to these proposals playing a significant role yes, but tomorrow or the day after tomorrow.

Today, strengthening of safeguards is the main issue. The strengthening of safeguards will draw lessons from the past. That means Iraq on one hand, and on the other hand, it's 25 years of successful safeguards implementation on declared activities. After all, if you read any books on strategic affairs written in the 1960s, the common wisdom was that there would be 20 to 30 nuclear weapon States by the end of the '90s. This is not going to be the case. So safeguards have been of some use, even if the methods are not 100 percent and even if there is still room for improvement.

Strengthening of safeguards became a need after Iraq. The assessment of Iraq in terms of IAEA safeguards has not always been correct. On one hand, as our director general likes to say, "Yes, we did not see that there was a $10 billion program going on in the country. We did not see all the buildings and research centers that were operating in a clandestine nuclear weapon program. However, we are in good company. The intelligence organizations apparently did not see them either."

That being said, we are not just putting our head in the sand. Indeed, we had access to at least a few facilities and more curiosity would have been proper to a certain extent. Therefore, the question was raised after Iraq of what we could do better. Should we go after undeclared facilities? Yes, we have to. The IAEA Standing Advisory Group on Safeguards Implementation [SAGSI] did much work in the last three years to look at possible ways to handle undeclared facilities and to go beyond material accountancy.

SAGSI made its major report on the issue to the IAEA director general on April 30, 1993. I joined the IAEA on May 1, 1993, so I was in the privileged position of having an agenda on the table upon arrival without the need to reinvent everything or to pretend I knew better than others where to go. My job is to turn the SAGSI report into a real proposal. Real in the sense of including cost assessment, implementation procedures, manpower requirements, legal aspects, financial aspects, all of these practical considerations that will help the IAEA Secretariat and Board of Governors to really take a serious look at all these things. Right now there is a unique window of opportunity for safeguards and for the IAEA. The ideas are there. The willingness of the Member States to look at these ideas has greatly increased. We are now talking about things that a couple of years ago would have been completely rejected or ignored. Now it can be discussed. Why? Because Iraq opened eyes and a window of opportunity.

The other window of opportunity, depending on how you look at it, is the deadline set by the NPT Review and Extension Conference next year. When I came to the IAEA, the NPT Conference was two years in the future. Setting such a deadline helped to organize ideas and task forces so that people would come up with ideas that would mature and be available as solid proposals by the time of the conference.

In the first few weeks after I joined the IAEA, I met all 550 people working in the department of safeguards by groups of 20 and 30. I gave a very simple objective to the work we would do: to make it possible for the IAEA director general to report to the NPT Conference not only on what the IAEA did during the past 25 years but also about the solid progress on the ongoing strengthening of safeguards, and also to make the point clear to all the NPT parties that the IAEA can continue to be *the* vehicle, *the* tool of the NPT into the 21st century.

It's a window of opportunity that we have to make use of and that's what we are doing. In June 1993 I launched a special program of strengthening of safeguards. It involves many people across the IAEA and across the department of safeguards. I did as many organizations do: set up a task force. You pull people from the existing organization, put them under a program manager and go ahead. This is working because of the motivation of people, people working 140 percent of their time sometimes. You need the experience of people who have done conventional safeguards for a long time, and it's also nice to have the experience of people who have been on these extraordinary inspections in Iraq or South Africa. This is a time of opportunity to really use and sharpen our skills. This is Program 93+2, as I named it when I started the program in June 1993. I wanted to have kind of a motivating name that would not be too long or too administrative: "93" is the starting date and "+2" is when we must have something solid for the NPT Conference.

So that's our main agenda, the strengthening of safeguards.

DENNIS MANGAN: You already mentioned some of the issues, but what do you think will be the key issues that will be discussed at the NPT Review Conference?

PELLAUD: First of all, it will be the NPT Review *and Extension* Conference. That's really the key issue; the main decision there will be the extension. It's very interesting legally that the NPT does not expire in 1995, even if there is no agreement in New York. It will continue until there is a conference agreeing on things to be done. So the item on the agenda is only to decide how long the NPT should be extended. It can be indefinite, it can be for one or several short periods of time or for long periods of time. Many countries favor indefinite extension. There is reluctance in some others to give a blank check to the nuclear weapon States for eternity, because the NPT is discriminatory. There are also commitments in the NPT for the nuclear weapon States, many countries feel that these States should do more toward nuclear disarmament and remain under observation.

As far as we are concerned, we want a solid NPT. A solid NPT means either it is extended indefinitely or it is extended for a long period of time so it doesn't become hostage to political debate every few years. That would be dangerous. There is a very broad agreement that the contents of the NPT should not be touched, should not be renegotiated. That would be too complicated and the job was well-done from the beginning.

At the same time there will be a review, so a lot of things might be discussed: conventional safeguards, how good they are, how good for what kind of facilities and the strengthening of safeguards. Obviously any decision on the strengthening of safeguards and how it should be done will not be made in New York but in Vienna by the Board of Governors and by the General Conference. However, it would help if the NPT Conference expresses some wishes for the strengthening of safeguards, proposes some measures to be taken, and gives the IAEA a clear mandate and possibly a broader mandate.

As I said before, my concern is that the DPRK issue could overshadow the NPT Conference. Let's hope not. Let's hope that the DPRK issue will be in the background.

CHARLES PIETRI: Assuming that you have a zero-growth budget and that circumstances do not change within the next several years, do you anticipate any internal reorganization within the IAEA to be more effective? Or would your internal goals be changing?

PELLAUD: Internal reorganization? No, not for that reason. There might be other reasons, but I don't see much need there right now. I don't think the budget could force us to change our basic structure in the department of safeguards, a structure that is very sensible when you look at the complementariness between its operations divisions and its support divisions.

A very important point you made is changing our goals. I don't think we are going to touch our safeguards goals. We were not able to fully meet all our goals last year, as revealed in our Safeguards Implementation Report of 1993, for various reasons. One was a failure of equipment. It was not so much lack of money. So, no reorganization, no changing goals. Maybe new tasks and better efficiency.

Fundamental indeed is increasing the efficiency of the operation. For me, this is a basic management function. Any organization, private or public, must look at how things have been done and indeed how they can be improved, the use of equipment to reduce inspection load, for example, or whatever measures can increase the efficiency of doing our work. On the other hand, you know that we have had an agreement since 1992 with EURATOM. EURATOM is a large inspectorate on its own and yet for 25 years, joint inspections have been carried out under the rule of two IAEA inspectors and two EURATOM inspectors — that is full symmetry. From now on, our work load will be reduced, but without delegating the authority. We may make use of results and samples collected by EURATOM. However, on samples, for example, we may well go the next day on a random basis to take our own samples. There will be random checks to ensure that we maintain our independent judgement. That's a key issue. We need to reach our independent judgement and conclusions on all matters related to our inspection in the EURATOM countries.

This brings savings. You know the IAEA is operating at the level of 9,000 person-days of inspection a year. EURATOM is, by the way, at 7,000 person-days, so they are not too far behind us, yet they cover only the European Union. By working more closely with EURATOM, we hope to reduce our inspection load by 10 to 15 percent, maybe by 1,000 to 2,000 person-days of inspection. That will be a way to save some resources that we can then use elsewhere. South America is coming, Argentina and Brazil; the safeguards agreements are signed. Now we have to start. Agreements with the countries of the former Soviet Union are also ready. We are doing a lot of pre-inspection work. So these savings will be absorbed.

It's hard to say where we will stand in a couple of years. If we carry out safeguards more efficiently, we may absorb some of the new inspection loads that are coming. It's quite another picture if we go into strengthened safeguards. That's really the issue because such new activities will cost money. How much we don't know yet. Environmental sampling, for example. There is a whole spectrum of possible environmental techniques. Some of them are cheap, some of them are expensive. Bulk sampling at facilities is cheap. Our inspectors could stop their cars close to a plant, collect some water, pump the water through a filter and in a half hour it's done. It costs a couple of hundred dollars, maybe a thousand at most.

But several questions must first be answered: How should the IAEA use the potential of environmental monitoring with bulk sampling? How good is it? How light is the equipment? How much more inspector work does it mean? I guess it could be done, probably, in a large number of countries in a nondiscriminatory way. But this will have an effect on the budget and somebody will have to decide, we will have to make a case ourselves in the Secretariat and then the Board of Governors will decide. There is little doubt it will cost more money.

But beware of too high expectations. One cannot expect the IAEA to make statements about undeclared facilities with a high degree of confidence. We are operating our safeguards with an objective of a very high confidence level on detecting diversion. But obviously, undeclared facilities would be much less. We'll have to select how much money can we invest, how much we can justify it to reach a certain degree of confidence on undeclared facilities. But at any rate, it will cost more money. So the whole issue of financing of safeguards needs to be revised. And I have to say I'm somewhat concerned right now because we have very sophisticated technical discussions on these issues while in Vienna, here in your INMM meeting and in other places. Yet, there has been no serious discussion about how to finance the strengthening of safeguards.

PIETRI: The expectation is there that you would do this work without any increase — that's why I asked if you were restructuring. You can restructure a certain amount internally but if you're getting out a much larger, more intensive mandate to do things, there has got to be some sort of external contribution toward that. Do you see that?

PELLAUD: Yes, we do receive extrabudgetary contributions, but our official line in the IAEA is to say that whenever we are talking about implementation of safeguards, even strengthened safeguards, we would like the money to come out of our regular budget, not through extrabudgetary contributions. Because it's not quite correct. An organization must operate in a kind of transparency, out of its regular budget. We get extrabudgetary support on equipment developments, research on new techniques in the U.S. national laboratories or similar things. Fine. Those are special kinds of support, something that is outside the political mainstream. But when money is needed for safeguards inspections, it should be out of the budget, it should not be dependent on money being paid into special accounts to allow us to do a job that should be done in any case.

We are still operating under the arrangement agreed on in the early 1970s where 99 percent of our budget is supported by 35 countries, with most developing countries paying only 1 percent. This was an arrangement that was very proper at the time and it did help to bring safeguards forward. It allowed a very stable safeguards system to be implemented. It's remarkable when you think about the way the IAEA has been operating for all these years through consensus in the Board of Governors. A lot has been achieved in decision making. There have been proposals recently, particularly in the United Nations in New York, to bring some nuclear verification function to the United Nations directly under the Security Council with the argument that the Security Council is much more efficient. It's true, the Security Council has become quite efficient in recent years, but will it last? Without any veto rights in Vienna, our Board of Governors has managed to move forward quite effectively in the last 37 years.

But is such a financial arrangement still fair? Still proper? Should we not go back to some kind of GNP financing distribution, along the line of the United Nation's allocation scheme? Or should we keep a skewed system under which countries having nuclear activities are the only ones to pay, to make it dependent on the volume of nuclear activities in a given country? It's sensible in a way. But, nuclear safeguards are really a confidence-building measure for peace. And, if it has to do with peace, all countries — even countries without nuclear facilities — should pay their share.

VINCENT DEVITO: We know you've got to have an anticipated workload in the United States because of the facilities that are being offered up for inspection, etc. Do you expect the workload on the other side, as a result of the Cold War winding down, to be as great or even larger in terms of the fact that there is now not only Russia but other countries that have spun off that have some nuclear programs. Is that workload going to be as great as what you're expecting in the United States, or greater?

PELLAUD: You are talking about released materials and cutoff?

DEVITO: Yes.

PELLAUD: As far as released materials from the military stockpile, we don't expect the Russians to soon grant the same access as the United States has. Not necessarily for political reasons. The Russians have been very candid about the status of their facilities. Many of them that will have to be inspected, in particular under a cutoff treaty, are very old, very poorly safeguardable and very complex, and the Russians are worried about the cost, and they doubt that the IAEA could do a meaningful job on these old facilities. On released materials, it's no excuse, of course, because that's a much simpler job. However, they have not yet committed to releasing materials to the IAEA.

MANGAN: What about the classification issue, the security of the information, and the fact, of course, that the weapons States don't transfer nuclear weapons technology to the nonweapon States?

PELLAUD: And the nuclear weapon States should not transfer weapon knowledge to the IAEA?

MANGAN: (laughing) That was implicit in my question. I didn't think the IAEA was a weapon State, but okay.

PELLAUD: The first material under discussion will involve highly enriched uranium in Oak Ridge. This material will be harmless from a proliferation standpoint. I don't even know if it will be metal or oxide, but it will be in a final form that can be looked at, measured, scanned or whatever. The future will depend on the amount of material to be released. More material will come gradually out of the Pantex plant in Texas at a throughput of about 1,500 weapons per year. Once the pits have been taken out of the weapons they cannot be converted that fast into nonsensitive forms. So we are discussing this issue with the U.S. Department of Energy [DOE]. Two studies are going on at DOE on how much could be declassified. We have looked at the matter on our side, at ways to handle the pits bulkwise. A sealed container would have an unknown number of pits, but we would be able, through nondestructive analysis, to ascertain approximately the mass of plutonium but maybe not the composition.

This is already a long way into being meaningful, because after all, it's a released material agreement. Whether there are 382 kg or 360 kg in a given container is not really relevant when there are still more than one hundred tons of plutonium left in the nuclear arsenal. The objective here is not material accountancy with sigma MUF. It is symbolic. But for us it has to be more than symbolic, it must be tangible with some quantitative assessment. Of course it will be up to the United States government to decide whether to release materials in sensitive form. We are not pressing the issue here — it's a voluntary proposal after all. Placing released materials under safeguards in the United States is good step forward. We hope that it will create a precedent for other countries.

MANGAN: I would think that part of the IAEA's role, a significant role in this area would be assuring the irreversibility of the surplus material going in. Is that how you feel about it?

PELLAUD: For us it's an absolute requirement. It must be irreversible. The U.S. government in one form or another will have to waive its withdrawal rights. The voluntary agreement between the IAEA and the United States allows withdrawals, as with all other nuclear weapon States. In other words, these States can put facilities under IAEA safeguards, and without having to give an explanation they can remove a facility from the list and from then on deny us access. That's the legal basis of the voluntary agreement with the NPT nuclear weapon States. For released materials, this has to be changed. It has to be a one-way street for us, otherwise it's not worthwhile. Some kind of waiver will be needed. The administration is expected to soon submit this intent to release materials to IAEA safeguards to Congress and then there will be a 60-day waiting period and then, if there is no action on the part of Congress, it will be okay to start safeguards inspection, hopefully still this year.

TAPE: Getting into these areas of excess materials, cutoff and the Comprehensive Test Ban Treaty [CTBT], I think the excess materials issue will be relatively straightforward in that it's a discussion between the U.S. government and the IAEA. While there are still issues to be worked out, I think there is strong commitment on both sides. When you get to the CTBT and cutoff, it becomes a multilateral environment and much more complex. I hear that the view from Geneva at the conference on disarmament is not the same as the view in Vienna as to what the appropriate role is of the IAEA and either CTBT verification or cutoff verification. Can you say more about the view from Vienna and what the pros and the cons are of the IAEA role?

PELLAUD: I'll start with the cutoff of the production of fissile materials because I don't fully share your interpretation of what is going on. There is widespread understanding, in Geneva also, that the IAEA should do the cutoff job because, first of all, it is the continuation of our normal activities on similar facilities. In other terms, cutoff verification will just add other reprocessing plants, other enrichment plants, other production reactors and other power reactors. Nevertheless, there is much disagreement as to the extent of the verification. Whether a cutoff agreement should, like the NPT, apply to all civilian facilities as well. So in the U.S., to put it squarely, it's not only Savannah River and Hanford, it will also be the 120 nuclear power plants! This would be a large additional load for the IAEA and that's where people have a strong reaction. A cutoff verification regime will have to start with a less ambitious objective. It's not Vienna vs. Geneva, or Vienna vs. the nuclear weapon States, it's first a lot of money, maybe some $150 million additionally a year. We'd be tripling our safeguards budget if we go in the direction of a full-fledged NPT-like implementation of safeguards under a cutoff treaty. Yet, safeguards under the NPT and under a cutoff treaty will have to ultimately converge. It is a matter of logic in the whole structure of the international nonproliferation regime.

CTBT is something different. Different views have been expressed by delegations at the Conference on Disarmament. Many feel that it would be better to have a separate organization for controlling a test ban treaty. The bulk of the verification would indeed rely on seismic analysis, a field in which the IAEA has only marginal expertise. Since the main tool of verification would not be available in the IAEA, it is argued that the IAEA is not the proper place to have the verification.

Yet the IAEA has the clear advantage of already existing. The infrastructure is there, the culture is there. There are inspectors in the department of safeguards who could very easily change hats and go out on on-site inspections under the test ban treaty in no time. It would cost money anyhow, but it would probably cost less money in Vienna.

So where are we now on the test ban treaty? The latest model is called co-location: namely, to have to an independent organization in Vienna that would subcontract to the IAEA. It sounds commercial but we are allowed to do so. We have an item in our budget called "services rendered to others." If such an organization were entrusted with the task, to whom should the IAEA's staff report? We have a Board of Governors. That Board of Governors is composed of representatives from our Member States, not all NPT parties. Therefore, our Board of Governors goes beyond NPT membership. If the test ban treaty were universal, meaning that it would include almost all our Member States, then one could imagine that our existing Board of Governors could be the governing body of the test ban treaty as well. Anyhow, we are making ourselves available in whatever frame.

PIETRI: What role do you think the INMM could play in your particular area?

PELLAUD: I'm looking at the INMM as a focal point for discussion of ideas. I would say the INMM has a key role to play, first internally for the safeguards community, in focusing thoughts that will emerge in the United States or in your various foreign chapters to make sure that all members have a common understanding — not necessarily common views — on key issues.

At the IAEA we need all these external groups that have a professional interest to look at the nonproliferation issues, independently of governments. We officially deal only with governments. Yet, many of the most interesting ideas on safeguards experimentation have come from other groups, professional associations and national laboratories, which bring into the discussion ideas that we may not otherwise have come across. There is thus a very important role for the INMM in general and for your sister organization ESARDA in Europe.

Then there is an external function: the issue of public information to explain safeguards, a task that is even more difficult than explaining nuclear safety or environment. This has to be done by as many competent people as possible; I hope that the INMM will speak up more to explain at government hearings or to the press what it's all about, to avoid some of the prevailing confusion and over-simplification. For example, the fact that there is so much inspection effort spent on nuclear power plants leads many to believe that they constitute a major source of concern for safeguards proliferation, which you know is not the case. So there is a need for clarification, to put things in perspective, and that's the role of professional associations. Governments can't always do it. Governmental organizations such as the IAEA have to be cautious. That's why an organization like the INMM representing people and not States or other interests has a duty to make its voice heard.

Timely Topics on Spent Fuel Storage

Ivan Selin
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INMM Annual Meeting Plenary Session
July 19, 1994
Naples, Florida, U.S.A.

I'm very pleased to discuss with you a matter of crucial importance to our nation — the storage of spent nuclear fuel from our commercial power reactors. I'm talking not only about spent fuel storage at operating reactors, but also at plants in permanent or extended shutdown. In addressing this issue, I'm hoping to correct numerous current misimpressions some may have about the view the U.S. Nuclear Regulatory Commission [NRC] has on the relative safety of pool and dry long-term storage for older fuel. Both pool storage and dry storage are safe technologies. But there are significant differences. Pool storage requires a greater and more consistent operational vigilance and the satisfactory performance of a larger number of active systems, while dry storage is almost passive.

The history of spent fuel management in this country has taken several turns, with a final resolution still out of reach. Several repository programs started, stalled and stopped. The latest effort at Yucca Mountain is progressing but, at best, is years from the early phases of licensing, much less the actual underground disposal of spent fuel. A monitored retrieval storage [MRS] facility was expected to start accepting commercial spent fuel beginning in 1998, but no such facility is clearly on the horizon. All of these recent developments changed the circumstances that we face in spent fuel management.

The obvious conclusion is that an increasing number of plants, both operating and permanently shut-down reactors, will have to provide for additional spent fuel storage on-site for a longer period than originally planned, and even after plant decommissioning, prudence requires that provision be made for continual, stand-alone, on-site storage. After pool capacity is reached, most utilities opt for some sort of dry storage. But the dry storage option has triggered an unprecedented amount of local opposition at many sites, further taxing NRC and industry resources.

For those plants in premature or extended shutdown, the NRC finds several strong reasons why the interim, on-site storage of spent fuel should often be shifted from the existing fuel pool to a dry storage system. These reasons include the continuing operational support activities needed to keep a fuel pool operating properly. Water chemistry and cleanliness, surveillance of rack and fuel condition, and maintenance and surveillance of support systems are all activities that are second nature to an operating plant, but may not always receive adequate attention in a plant permanently shut down. Let me stress our continued confidence in the safety net of wet pool storage, *if done properly*, remains undiminished, but dry cask storage offers fewer opportunities for things to go wrong. Therefore, the NRC increasingly views dry storage as the preferred method of interim storage of mature spent fuel for plants in permanent shut-down, as well as for supplementary storage in many operating plants.

In other words,

1. The results of calculations and laboratory testing, coupled with our growing operational and regulatory experience, show conclusively that dry cask storage techniques are safe for the interim storage of spent nuclear fuel for many decades.

2. Compared with pool storage, the dry cask storage systems are far simpler, use fewer support systems and offer fewer operational and design challenges, and therefore, are less likely to lead to human or mechanical error. These simpler designs also foster improved operational and regulatory efficiencies. We continue to conclude that pool storage remains an abundantly safe storage method, provided that circulation, corrosion control, and supporting pumps, piping and instrumentation are properly maintained.

3. Based on our safety reviews and actual experience to date, we conclude that dry cask storage is preferred in many instances, especially for operating plants with limited pool storage capacity and for shut down plants.

I would now like to discuss our regulatory policies and practices concerning the interim storage of spent fuel and the increasing use of dry cask systems.

The need for storage capacity

At a number of sites in the United States, existing reactor pool storage capacity has been reached or will soon be reached. An operational high-level waste repository remains years away in a program that suffered substantial delays in the past. The future of the MRS is uncertain. Most plants have expanded their pool storage by re-racking to the extent possible. Clearly, the use of dry cask storage systems at reactor sites is increasingly becoming the only available option for continued operation of many of our nation's nuclear plants.

There are other reasons that this alternative storage technology is attractive. Most obviously, for operating plants, there must be additional room in their pools to support upcoming refueling outages, and transferring some of the older fuel to dry storage is the best way to maintain their full core reserve. (That is, their ability to unload the full core.) In some cases, dry storage may be preferable to re-racking a pool that is approaching thermal, structural and critical safety limits.

Licensees with permanently shutdown plants have a strong desire to be able to empty and decommission their reactor spent fuel pools. But a number of pool support systems, including cooling water, electric power, instrumentation and radiation detection, must remain operable so long as fuel remains in the pool. Neither the pool nor the support systems can be decommissioned, but rather must be maintained, operated and tested as if the plant were operating. For some of the older plants, the spent fuel pools are not lined with stainless steel, the cooling and clean-up systems have increasingly demanding maintenance problems, leakage paths may exist from the pool piping systems in some of the older designs, and the support systems are vulnerable to loss of off-site power or other challenges. In such instances, there is an even more compelling case for moving the fuel to a new, modern, dry storage system.

Dry storage trends

Dry storage designs have developed significantly in the decade since Congress enacted programs for dry storage in the Nuclear Waste Policy Act of 1982. Both in this country and overseas, steel casks, concrete casks and concrete vaults are available in a variety of sizes and shapes. Vendors and utilities continue to talk to the NRC staff about newer dry cask systems, options for storing the unique fuel from certain plants and amendments to existing approved designs. In the very near future, we expect to certify the nation's first dual-purpose cask that is designed for both storage and transportation, a design developed by the Nuclear Assurance Corp. (NAC). The first anticipated use of this dual-purpose NAC cask will be in Spain, under the auspices of Empresa Nacional de Residuos Radioactivos S.A. (ENRESA), the Spanish national waste management company. In addition, we are actively reviewing a second dual-purpose design developed by VECTRA Technologies Inc., for use at the Rancho Seco Nuclear Station. This dual-purpose design is a variant of the NUHOMS system, which was licensed for use at H.B. Robinson, Oconee and Calvert Cliffs. In addition, we expect to receive a major application from the U.S. Department of Energy (DOE) for several different designs for the so-called multipurpose canister (MPC).

DOE foresees obtaining the initial MPC certification for storage and transportation under Parts 71 and 72, respectively; later they would apply for an MPC license as the innermost canister of a disposal package for the high-level waste repository.

We have experienced a strong and steadily increasing trend in licensing dry storage systems at a variety of sites. We have continued to issue site-specific licenses, most recently for the Prairie Island Station in Minnesota. We have a process to approve cask designs by rule, and we are currently in a rulemaking proceeding to certify the seventh cask design approved for use by reactor licensees under an NRC general license. The first utility to store spent fuel under the general license was Consumers Power Company at the Palisades Station. Five other stations are actively pursuing the general license storage option: Arkansas Nuclear One, Point Beach, Davis-Besse, Oyster Creek and Fitzpatrick. Other plants have talked to us informally, indicating their inclination toward dry storage of their spent fuel.

Safety implications

Let me now describe several features of dry storage systems that make their use attractive as an interim fuel storage option. First of all, the systems are all very large and inherently passive. There are no cooling fans or pumps requiring redundancy, piping, ducting, instrumentation, controls and conduction. The size of these cask systems makes them highly stable on the storage pad. The spent fuel is stored in a sealed, inert environment, surrounded by helium gas after air and moisture are evacuated. This helium environment is passive from a chemical corrosion standpoint, and quite effective from a heat removal standpoint. The large shielding designs proved to be well within our dose rate acceptance criteria, and measured dose rates turned out to be a factor of two or three less than that predicted by calculation. Heat-removal performance has been similarly effective. Casks cooled by natural convection often have outlet temperatures significantly and consistently below the allowable design values. Fuel assemblies are collected and stored in a basket, which maintains structural integrity and a safe critical geometry. The dual-purpose and MPC concepts will further reduce fuel handling, packaging and occupational exposure. The passive design features allow a reduced amount of operator surveillance and oversight — human intervention, security checks, radiation surveys and visual inspections. Although we licensed these designs for a 20-year period, we believe that the present designs may eventually be shown to perform satisfactorily for at least 100 years, a much longer time than is likely to be necessary for interim storage before ultimate spent fuel disposal.

Nevertheless, there will continue to be an essential role for pool storage. Dry storage could not replace pool storage entirely even if we wanted it to, principally because the freshly discharged fuel is much more radioactive and, more importantly, much hotter. Freshly discharged fuel must be cooled in a pool at least for two to five years. However, fuel that has cooled sufficiently can be stored safely and effectively in dry storage containers. Furthermore, pool systems and dry cask storage systems can both be designed, constructed, maintained and operated safely. Some utilities have installed sufficient pool capacity to handle all interim storage needs for the lifetime of the plant. Thus, the industry can and will continue to have major reliance on pool storage. Licensees that perform within the respective safety envelopes remain free to choose either wet or dry storage; the NRC does not specify choices among risk-acceptable alternatives.

Safeguards implications

From a domestic safeguards aspect, the large, passive spent fuel casks offer substantial resistance to penetration by an adversary. On-going studies continue to validate that the vulnerability to radiological sabotage or theft of special nuclear material is low. The inherent physical protection provided, in part, by storage casks minimizes the need for additional extensive security. As a result, NRC policy on the protection of spent fuel takes advantage of cask design features in defining adequate protection of spent fuel.

With respect to specific physical protection measures required, we make no special distinction between measures needed for dry cask versus pool storage. This approach assumes that basic capabilities for a trained and equipped security organization, procedural and physical access controls, communications, detection, assessment and response are in place.

From an international safeguards perspective, the operator of a spent fuel storage facility, whether pool or dry cask, is required to provide a listing of the identity, location and content of each spent fuel assembly. The International Atomic Energy Agency (IAEA) must be given the opportunity to maintain containment and surveillance to assure no removal of spent fuel. For a spent fuel pool, these measures are fundamentally straightforward, but do have some complications. In particular, in case of malfunctioning of the surveillance camera, the IAEA has to count the spent fuel assemblies and check the attributes of spent fuel assemblies on a random basis. For dry cask storage, the IAEA provides for surveillance of the storage area, observes the loading of the spent fuel into the cask, and then verifies the seal of the cask thereafter. However, malfunctioning of the surveillance camera will not result in IAEA's re-counting spent fuel assemblies as long as the integrity of the seal of the cask is maintained. This simplifies the IAEA task, as well as easing the burden on the operator.

Conclusion

Spent fuel storage, whether wet or dry, is a regulatory issue that the NRC takes very seriously. When new storage space is needed at a particular operating plant, for the reasons discussed, dry storage is almost certainly preferred as a supplement to wet storage for the older fuel at the site. Dry storage may often be even more desirable at the permanently shutdown plants, where it is a candidate to replace, and not just supplement, pool storage. The technology and process for regulatory review and oversight of spent fuel storage are fully developed. I'm confident that the program for the nation's spent fuel storage is well under control. The storage systems are performing their required safety functions and are protecting the environment.

On a more strategic level, the high level of safety performance of these spent fuel storage systems is not universally recognized. In many areas, public perception of spent fuel storage, and even some professional perception, is unbalanced. One of the more striking examples involved the Prairie Island site, where it was argued that, although it is safe to run a two-unit reactor on the island, it is not safe to store aged spent fuel in dry casks on the same island. This issue requires a better understanding of the very low risk associated with dry spent fuel storage and public confidence that such storage is an interim solution. Better progress in providing long-term disposition of spent fuel is required before the public will understand and generally accept interim on-site storage of spent fuel. The DOE is giving priority attention to the matter of long-term storage and disposition of spent fuel. I am confident that they will continue to pursue this issue diligently and I am hopeful that timely resolution of this issue can be achieved.

Ivan Selin has been chair of the U.S. Nuclear Regulatory Commission since July 1, 1991. Previously he was Undersecretary of State for Management. He has degrees in electrical engineering and mathematics, and speaks six languages.

Ninth Annual INMM Safeguards Roundtable Part II

July 19, 1994
Naples, Florida, U.S.A.

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James Tape
Chair, Institute of Nuclear Materials Management
Los Alamos National Laboratory

Phil Ting
Member at Large, Institute of Nuclear Materials Management
U.S. Nuclear Regulatory Commission

CHARLES PIETRI: What do you anticipate will be the reaction of the public and other political and governmental agencies like IAEA to your announcement?

IVAN SELIN: I have no idea what their reaction will be. I hope they'll all say this is a very good idea, let's make sure we carry it out.

ED JOHNSON: I think they're fools if they don't.
This speech mainly addressed reactor storage.
You did touch on monitored retrievable storage [MRS]. Just for the record, do you see any reason why your statements on the safety of established dry storage wouldn't apply equally to MRS if and when we get a site for such a thing?

SELIN: I think it would. First of all, I would expect monitored retrievable storage to be dry storage. However, some of the arguments in favor of dry storage compared to pool storage for fuel that's more than five years old aren't quite so strong when you talk about monitored retrievable storage. That would be a large, active facility with a lot of people coming and going. I'd prefer to see that under dry storage also, but my preference isn't quite so strong as it is for a shutdown power plant where essentially all you have are the people running the storage facility and the guards, and all the other radioactive materials were taken off the plant. It would be hard for me to imagine why, at an intermediate storage facility, anyone would want to put a pool in where you have to get the fuel wet and bring it back out after a while. There's no economic sense, there's no investment in pools already. The situation is completely different in a power plant — you already have a pool. And what we are effectively saying in regards to a shutdown power plant is that even if you have a pool, even if the pool is adequate to hold the fuel indefinitely, we think you ought to think very hard about replacing the pool with dry cask storage. The MRS hasn't been built yet, and it would be implausible that somebody would put a pool in there for mature fuel to be stored.

JOHNSON: Also it would cost more money.

SELIN: It would cost more money; labor costs would be much higher. It's hard for me to picture that anyone would consider a pool for an intermediate storage facility. We're arguing that even a power plant where there are pools already should still consider replacing these pools with dry storage and as the fuel matures, take the fuel out of the pool and put it in the dry storage.

JAMES TAPE: Can you say more about the background of your paper. You certainly hinted at problems ...

SELIN: There has been a lot of discussion as to whether dry cask spent fuel facilities would be allowed in a number of states at a number of sites. The ultimate was in Minnesota, where there were arguments about whether it would be safe to have spent fuel storage at Prairie Island because the island is in the river and people were concerned about the level of the water in the river. We've looked at that extensively from the point of view of the safety of the reactor site and the situation where the reactor site is found to be safe but people were saying that spent fuel would not be safe on the island. Originally, the state of Minnesota's arguments were different. They were arguing that allowing another long-term storage facility to be built anywhere in the state was tantamount to building a final repository in the state. The state could not be confident that the fuel would ever be taken out of this storage facility and moved someplace else.

I have an opinion on that but the NRC does not. We made a confidence finding that eventually there will be a final geological repository available, so we don't agree with the state, but their argument is a plausible one. When they said "It's okay to build storage, but not at this site," that's a safety argument. It wasn't an argument about having storage in the state. It wasn't an economic argument. It wasn't a disagreement with where the fuel would eventually end up. We didn't think it was a very good argument. We didn't want to get involved in the middle of a specific issue because we realize that people sometimes make one argument when they have some other argument in mind.

But when asked, we did say this, and it occurred to me that we shouldn't have to wait to be asked since this is a generic question and we should come out and say what we think. We really would like to see it. We now have a number of shutdown facilities. There have been problems in maintaining the closed down pool at Dresden 1 and at Indian Point 1. It's just very clear that the question of fuel storage at closed-down sites is becoming an important issue, and we thought it would be a very good time to get out and say what we think about these questions. We still will license and continue to license indefinite pool storage at closed-down sites. But the technology of dry fuel storage has improved and been demonstrated, and we've seen some operational problems with closed-down pools, which I think are basically generic problems. It's hard to get people to pay attention to systems that take so much action when the systems are not, to the outsiders, doing anything. We prefer to call attention to this point relatively early and quite emphatically instead of just letting this float around.

JOHNSON: In the area of centralized storage, the monitored retrievable storage, the DOE originally planned to do it and now some private interests are considering it, including the Native Americans. If any of these parties come to the NRC in the face of a lot of political opposition in their own states, how does that political opposition affect the NRC?

SELIN: Whatever effect it would have would relate to whether the license application would come to us in the first place. Once we get a license application, we will look at it from a strict safety and operations point of view. I wouldn't really expect that we would get a lot of pressure and we wouldn't pay any attention to it if we did.

If that pressure turned into laws, we would follow the laws. Sen. Jeff Bingaman [D-N.M.] floated an amendment that would prohibit our using any money, any of our appropriated funds, to process such a license application. If that became law we would follow it, but absent a signed law, we follow our own regulation. Now this is easy for me to say since it's extremely unlikely that I'll be chair of the NRC at such a time. I think we have a pretty good record — we listen to what the public thinks. Congress is the representative of the public. But that has more to do with policies than it does with operations under those policies.

JOHNSON: So let's say the Mescalero Apaches came in and filed an application. You'd treat that like any other application ...

SELIN: Would we do something different with that application, given the high level of interest in Congress, than if the interest level weren't there? From a safety point of view and a priority point of view, the answer is no.

We would certainly pay a lot more attention to exactly who was on it, how we were doing. People just don't call up and say "We don't want you to do this." They hire some experts and come up with reasons. We listen to the reasons and so the pressure is likely to be translated into technical and professional arguments about the application that might not otherwise be made, and those arguments we'll take seriously.

We'll look at any material that is brought to our attention, regardless of the source, even though, in many cases, we know the motivation for bringing the attention is different. If "reacting to pressure" means would we come up with conclusion different from what we would otherwise come up with, the answer is no. If it means will information arise because it's such a high profile item that would not otherwise arise and will we take that information into account, the answer is yes. The NRC has a pretty good record of having dealt with high-profile applications in the past, and I think it's done a pretty good job of dealing with these in a straightforward fashion.

JOHNSON: I agree. You mentioned the Nuclear Assurance Corp.'s transportable storage cask, and I believe you expected a license to issue on that in the near future.

SELIN: There are several transportation casks that are already certified. There is now a DOE-sponsored design for a multipurpose canister that can be used for both transportation and storage. They would also like it to be used for disposal, but since there's no plan for where it would be disposed, we couldn't possibly consider whether the canister is adequate for disposal. So in their tender document for designs, they have functional or nonprescriptive standards for transportation and for storage, and they call for features they believe will be useful for disposal. But they haven't required that the canister be acceptable as the inside compartment of a disposal system because they haven't been able to specify the rest of the system.

From our point of view, disposal is something we know will be coming down the road if DOE's plans carry out, but it's not an active part of our licensing function. When they get the design done, we will do some work with their specification and design to see if there are any problems, any real show stoppers. They will then have to come to us with the canister design asking for certification for storage and for transportation. We don't see any reason that the same cask can't carry out the two tasks, but we will be silent as to whether that cask would be a suitable container for disposal.

We won't be silent on specific questions, though. In other words, they may say that for disposal we have specified that the cask have certain long-term characteristics, such as freedom from corrosion. We'll look at the design and give what amounts to a second opinion as to whether that design seems to produce the characteristics that they have asked for, but without making a statement as to whether those characteristics are adequate for disposal because we don't know the rest of the disposal design.

So it's DOE's intention that the same cask eventually be licensed for the three tasks, but we feel a little bit like two-dimensional creatures on a three-dimensional space. All we see is the projection of this cask design on the storage dimension and on the transportation dimension. They may have some ideas about how it will perform on the disposal dimension but we don't see that dimension at this point, at least not officially.

JOHNSON: The Nuclear Waste Technical Review Board has been critical of the DOE because they pointed out the peril of trying to make a triple-purpose cask when they don't know all the requirements for disposal at the present time. The DOE took the position that they want to make sure it's adequate for reactor storage, at an MRS, transportation to and from an MRS, if there is one, and even lag storage at the repository. But they recognize they can't make that decision today on whether or not it's suitable for disposal in the repository. Do you think that this is an irresponsible position on the part of the DOE to implement a multipurpose canister until such time as they know exactly what they want?

SELIN: The last thing you said is not their position. I don't know what came first, but I know where they stand today. Where they stand today may not have been their original position, I don't know that. It may or may not have been affected by what the Nuclear Waste Technical Review Board has come up with. Their current position is that they have a tender out for somebody to produce the design of a system that will be certifiable for storage and transportation. They've also identified a number of specific features, like ability to dissipate heat, corrosion resistance, criticality, etc., that they think will be important for disposal purposes. But that's as far as they've gone. I don't know the design well enough to say if the cost of adding these features to the design is overwhelming or is something you just get almost for free if you think about it in advance.

However, when the DOE and Dr. Dreyfus briefed the Commission on this program, we asked him this question and he said no, they think that the features that have been asked for in the disposal are things that, as long as thought of in the beginning, are very easy to add to a canister design that will meet the other two approaches. So the DOE has not said they will not go ahead until they have a design that is adequate for disposal. They have not set a vague requirement on the bidders that says their canister will meet disposal. The DOE just said, "Here are features that we think will be necessary if a canister has the chance to do the disposal function. We want to make sure your design has these features." There may be some assumptions in there that may or may not be true, I don't know that, but the stated policy strikes me as a plausible policy.

JOHNSON: Okay, that's the answer I really wanted to hear. That was what the Nuclear Waste Technical Review Board was critical of, that they weren't including the repository aspect in the design at the present time, and the DOE took the position that they couldn't because they hadn't decided exactly what that would be because of these issues.

SELIN: My personal concern was the other way around, that the repository requirement would drive the design that had a perfectly useful function. It's clear that there's benefit and it's pretty feasible to come up with a dual-purpose canister, but to make it a triple-purpose canister when you really don't have the third purpose defined very well, could slow down what is, from a risk point of view, a good thing. But we never took that position publicly, because it wasn't ours to take. When they did come up with a specification, we specifically asked them this question and the answer, taken at face value, was a plausible and reassuring answer.

Let me ask a quick question about what the INMM does. I know it's more than spent fuel. We have a major materials program in addition to spent fuel that deals with high- or low-level waste. We have a lot of other activities going on that I assume you'd be interested in — I've read your program, so I know the range of things here. Your interest in safeguards goes way beyond what the NRC is in.

MANGAN: We're quite familiar with the people in the NRC: Bob Burnett and that whole crowd in the safeguards activities. But if you take a look at our organization, we're structured into six technical divisions: Waste Management, which Ed Johnson heads; Material Control and Accountancy, headed by Rich Strittmater from Los Alamos; Physical Protection, headed by J.D. Williams of Sandia National Laboratories; Transportation, chaired by Bill Teer from E.R. Johnson Associates; International Safeguards, headed by Cecil Sonnier from Sandia; and Nonproliferation and Arms Control, headed by Ruth Kempf from Brookhaven National Laboratory. We try to focus in these technical areas as our core competencies with regard to addressing all the various issues of nuclear materials management. We're also the secretariat for two ANSI standards.

SELIN: We talked about things I guess you would consider to be waste management but material control and accounting is very big area for us, particularly in the assistance programs. Every time a foreigner who is the head of a country or an important individual from a country that has any kind of nuclear program comes to the United States, we seek to sign an agreement with them to provide material control and accounting systems. The accounting part is pretty easy. It's the control part that's very hard. To put it another way, when dealing with a large nuclear nation, like the Russian Federation or Ukraine, there's a fair amount of detail, but it's not all that complicated to set up a chart of accounts, particularly if there were good information from the individual sites that would allow this information to be integrated into an overall picture. It's how to get that control and accounting site by site that's important, and a lot of time and money goes into that. On the other hand, where the labs are concerned, they concentrate almost exclusively on a site-by-site basis and sometimes forget the fact that you need a nationwide set of accounts if you really want to track material from one site to another, from one location to another. The site systems are the building blocks, but there has to be an overall framework into which the blocks fit.

MANGAN: If I understand it correctly, there is an initiative with the former Soviet Union with regard to a national system, and Jim can talk more about that than I can.

TAPE: Phil [Ting] and I were part of a delegation sent to Moscow two and half years ago to begin the discussion on these issues. The discussion is continuing and I know people from the NRC are playing a major role in helping to develop that national system. It's going more slowly than anyone would like, I would say largely due to bureaucratic inertia on the Russian side, although we have our share of problems, too, regarding who's going to pay for this activity. But some progress is being made.

SELIN: Is your institute involved in programs like this?

TAPE: We are. We have a six or seven Russians here this week, and it's been a fairly explicit desire to bring these people into the international nuclear materials management community, which we like to think we represent. We're a very small institute — about 750 members — but about a third of those are from outside the United States. We have a very active chapter in Vienna and in Japan. We hope that by bringing the Russians in we can begin to acquaint them with the community that has done this in the rest of the world and let them see what our standards are for materials control and accounting and physical protection and so on. We're waiving their membership fees a year at a time because we know they can't afford them right now. I think it's going to take a long time to bring these countries up to our standards.

SELIN: I'm pretty familiar with the international part. What I'm looking for is a forum or a vehicle where the participants, particularly the American groups, can talk about what kind of approach we should be following because at times I felt that the individual laboratories had approaches that were quite different one from the other. I don't mean technical approaches but where their priorities should be, and they are worried more about what a material control and accounting system in an individual facility should look like and less about how they should look as components in a national system.

Even what future existence of a state system would mean in terms of requirements on a system at an individual institute needs to be considered. Because at least the approaches and the measures have to be commensurate, the reporting must be comparable, the plusses and minuses have to be added. If the facility sends material to someplace else you have to know that what is sent and what is received are the same.

PIETRI: Well, we could say this institute is a professional forum to do just that, to collect all of these ideas, and there's a lot of controversy. If you scanned the program you'll see there are quite a lot of views, and that's the purpose of the Institute is to express those in a kind of neutral atmosphere, a comfortable atmosphere. That's one of the reasons why we're here.

MANGAN: There was an example yesterday in the international arena. We had a meeting of the international safeguards group and there must have been 50 non-U.S. participants, different countries expressing different views. As you know, when you get into the international arena there are as many views as there are countries sitting around the table.

We try to picture the INMM as an honest broker in some respects. We all put our INMM hats on when we have to, as opposed to our national lab hats. So we'd welcome the opportunity to be more actively involved in any of the concerns that the NRC has.

SELIN: That might turn out to be okay.

MANGAN: We could have workshops, for example.

TAPE: One thing that I've observed on this specific question is that if you look in the international community — not international safeguards but just international opinion — there is not one opinion on how to best set up this state system of accounting and control [SSAC]. I mean, we have the way we've done it here, but we have some unique aspects because we're a nuclear weapons State. What we've done might be a good model for Russia but hopefully not a good model for Ukraine in the future and so on and so forth. We might sit down and talk to the Swedes who are here and ask them what they think the SSAC should look like in the Ukraine and they might have some differences of opinion with us on that subject. But this is a good forum in which to debate it; none of us come here as an official representative of a government opinion or even a laboratory opinion. It really is a professional exchange.

SELIN: There are other things that the Institute does that may be of interest to us, to make our job a little bit easier.

TAPE: And we'd be very glad to help.

JOHNSON: The thing that distinguishes the Institute from the American Chemical Society, the American Institute of Chemical Engineers, is that we go after a management problem, whether it be nuclear materials control and accounting, waste management, transportation, or special problems associated with those things that require a wide range of expertise — mechanical engineers, chemical engineers, accountants, statisticians and whatnot.

I'd like to applaud you on issuing a statement like this, especially when you see so much misinformation going out and bad understanding of a subject that is really a no-brainer. Dry storage is so overdesigned and imminently safe, and there is no active aspect of it, that's the nice part. You can't have a failure of a pump.

SELIN: We have required things that weren't in the original designs that have come up, usually in terms of auxiliary ventilation, but especially in monitoring and being able to monitor both radioactivity and temperature more fully than was in the original designs. So intrinsically these are attractive designs, but that doesn't mean that the actual designs necessarily carry out their potential, so the certification and licensing process is not trivial.

JOHNSON: I didn't mean to imply otherwise. My point is, compared to a reprocessing plant or a reactor plant, this is a relatively simple activity and vendors are not going to install anything more than they have to. I remember one time somebody asked an official of the NRC how he would recommend solving a certain problem. He said, "We aren't in the consulting business. You make your proposal to us, we'll tell you whether or not it's acceptable. If you overkill, we'll tell you whether or not it's acceptable but we won't tell you it's too much because that's not our role."

SELIN: That's not exactly true because "more than you need" tends to mean systems that can malfunction. Simplicity has some attraction from a safety point of view. My story is fairly clear: We want to see people thinking about not continuing to operate pools after reactors are closed down. I don't think there is much of an issue when an individual site needs additional storage for the lifetime of the reactor operation. If they can expand their current pool they probably will; if they can't, they can't. Nobody's going to build a second pool on a site once they've exhausted the potential of the pool. When they need more storage, we hope they would look at dry cask storage, and there we need to make a pronouncement about the potential attractiveness of such storage.

Looking ahead to what happens after the site comes down, there's a real tradeoff. We want to encourage the operators to think about making that tradeoff. But if they consider it, know what they're doing and still want continue to operate the pool after shut-down, that's fine. But we really want them to consider it, not just to assume that since there's plenty of capacity in the pool the best thing to do is just continue.

Book details groundwater standards

BNA Books, a division of the Bureau of National Affairs Inc. (BNA), published *State Groundwater Regulation: Guide to Laws, Standards and Risk Assessment*. It combines both legal information and technical data on groundwater standards and their use on a state-by-state basis. The 654-page book can be purchased from BNA Books, P.O. Box 6036, Rockville, MD 20850-9914; phone (800) 372-1033.

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Fuel Cycle Conference '95, Hotel del Coronado, Coronado, Calif. *Sponsor*: Nuclear Energy Institute. *Contact*: Conference Office, Nuclear Energy Institute, 1776 I Street, N.W., Suite 400, Washington, D.C. 20006-3708; phone (202) 739-8000.

April 30–May 3, 1995
Nuclear Energy Assembly, Mayflower Hotel, Washington, D.C. *Sponsor*: Nuclear Energy Institute. *Contact*: Conference Office, Nuclear Energy Institute, 1776 I Street, N.W., Suite 400, Washington, D.C. 20006-3708; phone (202) 739-8000.

June 4–6, 1995
22nd Annual Meeting and International Conference on Nuclear Energy, Ponte Verde Inn & Club, Ponte Verde, Fla. *Sponsor*: World Nuclear Fuel Market. *Contact*: Donna Cason, Administrative Director, World Nuclear Fuel Market, 655 Engineering Dr., Suite 200, Norcross, GA 30092; phone (404) 447-1144.

July 9–12
INMM 36th Annual Meeting, Marriott Desert Springs Resort, Palm Desert, Calif. *Contact*: Barb Scott, INMM headquarters, 708/480-9573.

September 17–22, 1995
Fifth International Conference on Nuclear Criticality Safety (ICNC '95), Hyatt Regency Hotel, Albuquerque, N.M. A call for papers is in progress. *Sponsors*: American Nuclear Society and OECD/NEA. *Contact*: R. Douglas O'Dell, ESH-6, MS F691, P.O. Box 1663, Los Alamos National Laboratory, Los Alamos, NM 87545; phone (505) 667-4614.

September 17–20, 1995
American Nuclear Society International Topical Meeting on the Safety of Operating Reactors, Seattle (Bellevue), Wash. A call for papers is in progress. *Sponsor*: American Nuclear Society's (ANS) Nuclear Reactor Safety Division and the Eastern Washington ANS Division. *Contact*: Technical Program Committee Chair Dr. G. Don Bouchey, at *Safety of Operating Reactors*, Box 182, 101B Wellsian Way, Richland, WA 99352; phone (509) 783-1446.

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