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NUCLEAR MATERIALS MANAGEMENT

Journal of the
INSTITUTE
OF
NUCLEAR
MATERIALS
MANAGEMENT

FEATURE ARTICLES

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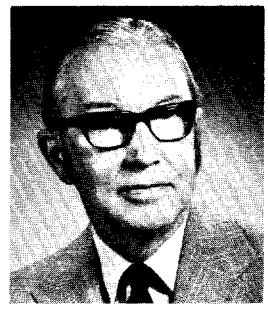
EDITORIAL

DR. WILLIAM A. HIGINBOTHAM
Brookhaven National Laboratory
Upton, New York



Confusion is developing between the terms Non-destructive Analysis (NDA) and Destructive Analysis. These terms should apply to methods which apply to whole objects or to samples taken from whole objects, respectively. However, the term NDA is sometimes used to refer to a measurement method for samples, e.g. the use of gamma- or X-ray absortiometry to measure the concentration of uranium or plutonium in liquid samples, or high-resolution gamma-ray spectrometry to determine the isotopic composition of plutonium in such samples. These two techniques can also be used non-destructively on whole objects, in which case the term NDA is indeed appropriate.

For some reason, very few papers are presented at our meetings or contributed to the Journal on developments in destructive analysis, although such measurement methods are extremely important for the management of nuclear materials and for the calibration of NDA techniques. The analysts involved in developing and using destructive analysis do publish, of course, but elsewhere.

Because of the high cost of publishing, it does not make sense to publish the same article in more than one journal. Somehow, though, the safeguards community, and especially those who fund safeguards R&D, must be made aware of the importance of the destructive analysis of samples, of the state of the art and of the future needs.

This editorial is an appeal for suggestions as to how the Institute may be able to play a suitable role. Should we actively solicit articles on analytical techniques, analytical standards and automation? Should the Institute form a committee on destructive assay techniques, possibly including weight and volume measurements and sampling strategies? We seem to be doing very well in most other safeguards areas such as NDA, physical protection, statistical analysis and systems analysis. Your suggestions will be most appreciated.

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CHAIRMAN'S COLUMN

GARY MOLEN
E.I. duPont de Nemours & Co.
Aiken, South Carolina

It is with mixed feelings that I write this article, my last column for the Journal as INMM Chairman. In some ways I regret that it is my last column because the last two years have been good years for me and, I believe, for the Institute. I have enjoyed the relationships with the Executive Committee, with the headquarters staff, and most of all with you, the membership.

As Chairman, one becomes the focus of attention, deservedly or otherwise. It was through this attention that I got to know some of you and to gain insight on how you viewed the Institute and its inner workings. Because of what many of you expressed as an "aloofness" on the part of the Executive Committee, I began to concentrate my efforts as Chairman on these inner workings. I directed my attention and energies toward smoothing the operations of the Executive Committee. My aim was a more meaningful involvement by the membership through participation in committee activities, workshops, training courses, standards activities and the annual meeting planning and preparation. Generally speaking, many of you responded favorably to these efforts. In some instances, the response was from new members, or even from people who were only considering membership. In any case, there was participation and it wasn't always from the same people. I especially want to thank those who did respond. Your efforts have been greatly appreciated by me and the other members of the Executive Committee.

As I indicated earlier, I have mixed feelings about stepping down as Chairman. While I may regret no longer being Chairman, from many aspects I am gracefully (hopefully) stepping down with almost a sense of relief. I think this is because that being Chairman is not an easy task. It is a challenging task and one which I was not always up to meeting. As I look back over the past two years, I can see both progress and status quo. Obviously, the progress is encouraging and provides a basis for renewed vigor and enthusiasm. On the otherhand, the status quo has been most frustrating.

The progress made by the annual meeting committees, the technical working groups, the safeguards committee and our education committee has been by most any standards simply outstanding. Those individuals involved not only volunteered their time and energy, but they tackled their assigned tasks with such determination and fortitude that they were able to accomplish a great deal in a relatively short time period. I think we owe a debt of gratitude to those individuals involved.

There was another bright spot (very bright) over the last two years and that was the yeoman efforts of the long range planning committee. In the history of the Institute, the efforts of this committee probably will be viewed as pivotal. This committee through its dogged efforts, brought about the formation of a headquarters staff with an executive director, expansion of Institute activities in the fields of transportation and waste management, improvements in the handling of the Journal, increasing membership through broader appeal, and last, but surely not least, the preparation and presentation to the Executive Committee of a five-year long range plan for future activities and endeavors. This committee has done more than any other to help chart the future of the INMM. I am very proud to have been associated with each member of this very fine committee.

Now to my frustration. I guess the most frustrating aspect as Chairman was the general apathy of the membership. It seemed to make no difference what programs were provided, nor what appeals were made, there was no stimulation of the membership in general. Certainly, individuals responded and, in most cases admirably so, but by and large, the membership seemed almost oblivious to the workings of the Institute. It wasn't that they only gave lip service to the INMM, they gave *no* service. In many instances, we could not raise a response even if we threatened to drop them from the membership. (Incidently, many individuals are being dropped as members because of failure to pay dues after repeated attempts to contact them have failed.) It was this membership apathy, which I guess was symptomatic of the nuclear industry and the national economy, that provided the least reward and the least sense of satisfaction to the office of Chairman. This ever present apathy seemed to dull or slightly tarnish even the most significant accomplishments by the Institute. Its pervasiveness was such that there seemed to be no area of activity that it did not exert or at least try to influence a negative outcome. It did not seem to rest in any individual nor in any particular group of individuals. It was difficult and elusive to define and combat. It was ever present and it seemed to endure any corrective or remedial actions taken to eliminate or reduce it.

This apathy, which I, as Chairman, was unable to effect, is a legacy that I wish I didn't have to leave for John Jaech as the new Chairman. However, it is the legacy that I am leaving him unless you as individual members do something to rid us of it. You and you alone can make the difference. Please consider what you can do to serve. Thank you and God bless you!

INMM GATHERS IN WASHINGTON

Attendees at last month's annual meeting gave high marks to this year's invited speakers, presented papers and overall session content. A wide array of local programs offered in the nation's capital were well received by attendees and spouses. Annual meeting attendance of 420 was close to the record of 515 in Albuquerque in 1979. A photographic review of the 1982 annual meeting is enclosed in this issue.

The highlight of this year's annual meeting was certainly the awards presentation at the banquet Tuesday evening:

- Distinguished Service Award — G. Robert Keepin
- Meritorius Service Award — R.D. Smith
- Meritorius Service Award — John Ellis
- Student Award — Paul Benneche
- Special INMM Award — E.R. Johnson Associates

The following cable was sent to Bob Keepin in Vienna on the night of the award:

"The Executive Committee is pleased to announce that the Distinguished Service Award was awarded to you this evening at the INMM annual meeting banquet.

"We are sorry that you could not be here to share with us this great occasion. Because of the great esteem we hold for you and this honor, we will present you the award and give public recognition at an appropriate gathering of your friends and colleagues sometime during the International Safeguards Symposium in Vienna, November 8-12.

"Our sincere congratulations and best wishes."

Dues invoices reflecting the Institute's fiscal year (FY83) were mailed in August. Members who are accustomed to receiving their dues invoices in early June will now find a new due date of October 1, 1982. Dues, once again, remain at $30.00.

Roy Cardwell has been asked to chair the Examining Committee as a part of the Institute's newly developed graded membership program. In the next several weeks, you will receive word of expanded individual membership categories of Senior, Emeritus, Honorary and Fellow. Bill Demerschman and Ev DeVer are also included on the Examining Committee.

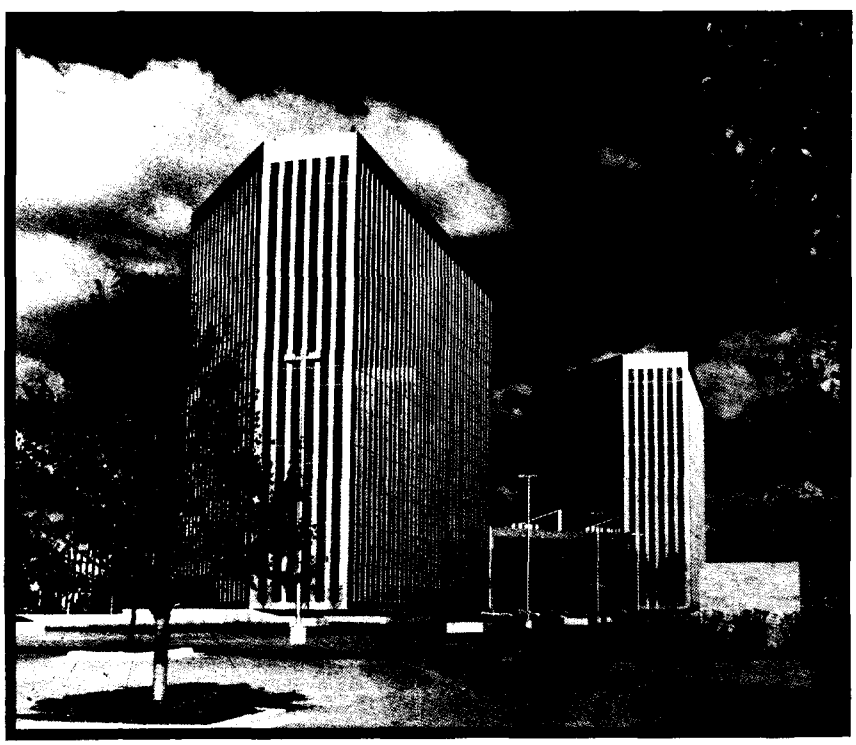
At its July 22 meeting, the Executive Committee recommended that ANSI N-14 and N-15 responsibilities be placed under a single oversight member. Jim Clark of Nuclear Fuel Services chairs N-14, and George Huff of Allied—General Nuclear Services chairs N-15. Each reported substantial progress at the subcommittee level.

INMM has contributed seed money to assist in sponsorship of the ANS/INMM Topical Course, "Safeguards Technology: The Process-Safeguards Interface," to be held November 28-December 2, 1983, at Hilton Head, South Carolina.

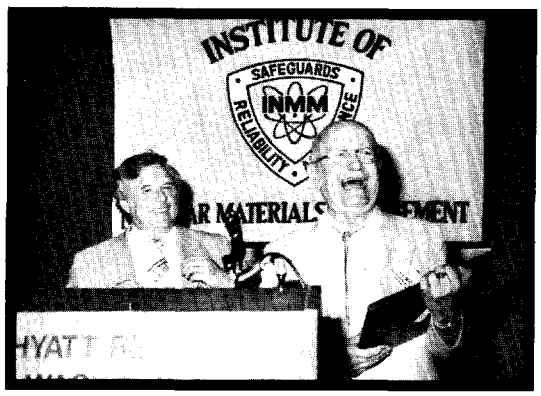
The Institute's membership stands at 738 members. A membership card will be sent to all dues renewals and new members next month.

The next executive committee meeting will be held October 12-13, 1982, in Chicago.

The new INMM headquarters is just minutes from O'Hare International Airport in Chicago.



1982 ANNUAL MEETING

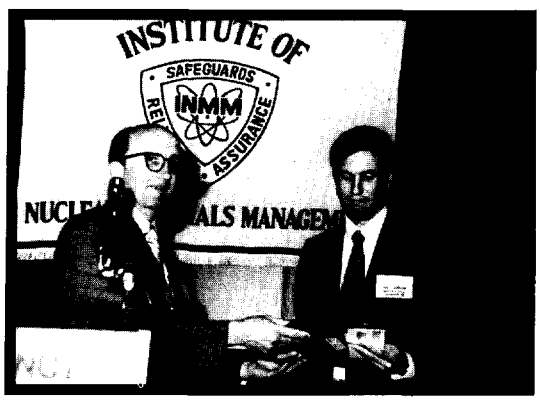


▲ R.D. Smith (r) received the Institute's Meritorius Service Award from presenter Roy Cardwell. Mr. Smith will retire from Union Carbide Nuclear Division, Oak Ridge, on January 1, after serving the nuclear industry for 39 years.

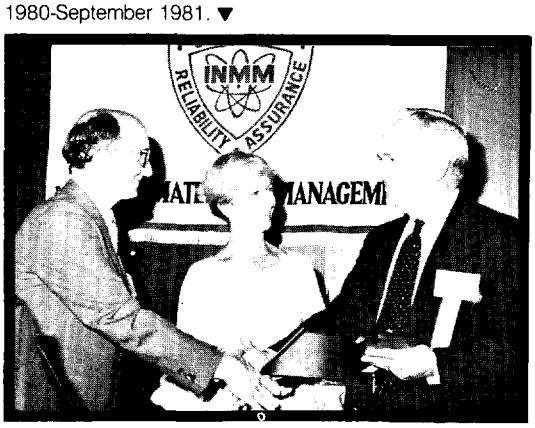
◀ Chairman Gary Molen (l) presente John Ellis, Allied-General Nuclear Services, with the Meritorius Service Award for outstanding and continued contributions to the nuclear materials managemer and safeguards industry.

Paul Benneche received this year' Student Award from Chairman Gary Molen at the 1982 annual meeting. Mr. Benneche presented his award winning paper "Dose Rate Measurement of University of Virginia Reactor Fuel Elements' before the membership. ▼

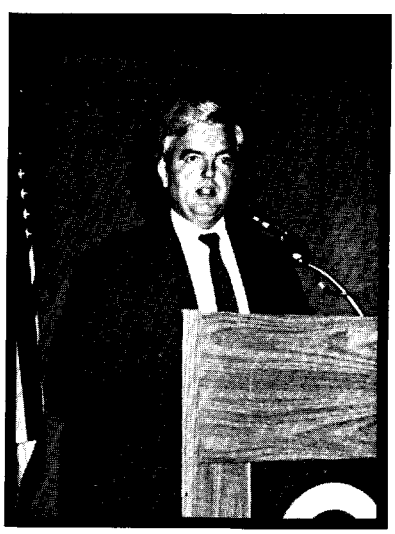
Dr. Yoshio Kawashima, Executive Director of the Nuclear Material Control Center, and Chairman of the Japan Chapter, presented "Nuclear Industry and Safeguards System in Japan" at the Washington, D.C., annual meeting. ▶

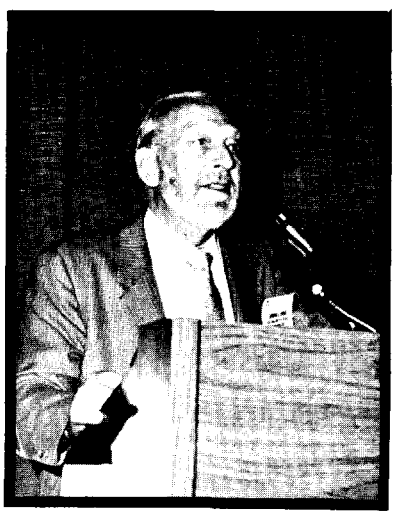


Ed and Jerry Johnson received a Special Institute Award on behalf of E.R. Johnson Associates from Chairman Gary Molen. E.R. Johnson Associates served as secretariat for the Institute March 1980-September 1981. ▼



▶ John M. Marcum, Assistant Director, Energy and Natural Resources, Office of Science and Technology Policy, Executive Office of the President, presented "The State of Nuclear Energy Under President Reagan."





▲ Plenary Speaker Herman E. Roser, Assistant Secretary for Defense Programs, U.S. Department of Energy, addressed the membership on "The Peaceful Atom and National Security".

23RD ANNUAL MEETING EXHIBITORS

Globe Security Systems
Philadelphia, Pennsylvania

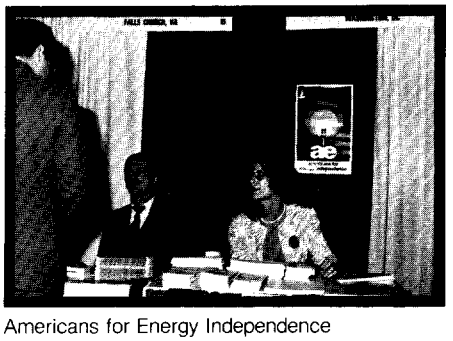
IRT Corporation
San Diego, California

Video-Tek, Inc.
Parsippany, New Jersey

Identicator Corporation
Santa Monica, California

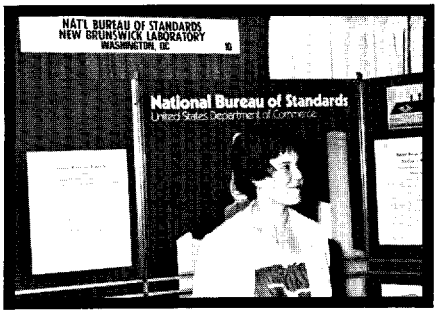
Federal Signal Corporation
Blue Island, Illinois

Sentex-Sensing Technology, Inc.
Ridgefield, New Jersey



Americans for Energy Independence
and Americans for Nuclear Energy

Nuclear Data Inc.
Schaumburg, Illinois



National Bureau of Standards
New Brunswick Laboratory, Washington, D.C.

SHORT ITEMS OF INTEREST...

The DOE Technical Information Center has announced the availability of the publication "Nuclear Reactors Built, Being Built, or Planned in the United States as of December 31, 1981". The publication contains information about facilities in the United States for domestic use or exports which are capable of sustaining a nuclear chain reaction. Civilian, production and military reactors are listed, as are reactors for export and critical assembly facilities.

"Nuclear Reactors" is available as PB82-903001 for $10.00 from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

Sandia has announced that a new package designed for transport of transuranic (TRU) nuclear waste to federal storage sites or repositories will begin limited use in mid-1984.

The Transuranic Package Transporter (TRUPACT) is being designed by the Transportation Technology Center (TTC), with the assistance of General Atomic Company, San Diego, California, for use on standard flatbed trailers and standard flatbed railcars. General Atomic is under contract to the TTC, located at Sandia National Laboratories.

TRUPACT development, underway for three years, is continuing with testing of one-fourth-scale models and a full-scale prototype and refining of computer models that predict the system's behavior in accidents.

Battelle-Columbus is extending its technical services offered in support of the nuclear power industry. Included are task order agreements for utilities, in which quick response technical services can be provided on site or at Battelle. According to Dr. Louis A. Rancitelli, manager of the Nuclear Technology Section at Battelle-Columbus, nuclear services are being extended with special emphasis on problem solving and prevention. These include specific services in post-irradiation examination, radiochemistry, environmental monitoring/site survey, radiation monitoring systems, equipment qualification, reliability, quality assurance, health physics, transportation, human factors and training. Additional information is available from Dr. Louis A. Rancitelli, 614/879-5163.

NUSAC has announced that Edwin W. Blocker has been appointed Senior Engineer and Project Manager within the Quality Programs Division. NUSAC also announced that Lynn Hurst has been appointed manager of the General Consulting Division with responsibility for administrative and technical management of the division services to nuclear material safeguards, safeguards engineering and quality assurance auditing.

Dr. Bernard K. Kokenge has been promoted to the position of Director, Nuclear Operations, at Monsanto Research Corporation, Mound. He assumed the position formerly held by Dr. William T. Cave, who retired June 30. The announcement was made by Larry R. Baird, Vice President and Director, Mound. Dr. Kokenge will be responsible for Mound operations related to nuclear technology, energy related programs, and technical applications and development.

We regret to announce the passing of J.W. Handshuh, a long time member of INMM. Mr. Handshuh died in Southern California last June.

INMM CALENDAR OF EVENTS

OCTOBER 5-8, 1982
Physical Protection Review Workshop
Sheraton Old Town
Albuquerque, New Mexico

OCTOBER 20-22, 1982
Spent Fuel Management and
Waste Disposal Seminar
Hyatt Regency on Capitol Hill
Washington, D.C.

JULY 10-13, 1983
INMM 24th Annual Meeting
Denver Marriott City Center
Denver, Colorado

NOVEMBER 28-DECEMBER 2, 1983
ANS/INMM Topical Course
Safeguards Technology: The
Process-Safeguards Interface
Hilton Head Island, South Carolina

THE N14 STANDARDS COMMITTEE

J.R. CLARK, CHAIRMAN
Nuclear Fuel Services, Inc.
Rockville, Maryland

In the Summer of 1981, the Institute of Nuclear Materials Management (INMM) became the Secretariat for the American National Standards Institute's Committee N14, "Packaging and Transportation of Fissile and Radioactive Materials". The scope of N14 is obviously extensive but does not include movement or handling during processing and manufacturing operations. Today, I want to provide you with information about: the organization of N14, the structure through which N14 develops potential national consensus standards, the activities that N14 has underway, and why such standards could be important.

ANSI

The American National Standards Institute Inc., (ANSI), does not write standards. Rather, ANSI acts as a coordinator of voluntary standards development and as a clearinghouse for information on standards. Perhaps most importantly, ANSI provides the formal structure to ensure that standards that are designated "American National Standards" *have national consensus of affected interests.* ANSI recognizes three methods for the development of evidence of the consensus necessary for approval of American National Standards. These are:

- Accredited Organization
- American National Standards Committee
- Canvass

N14 is an American National Standards Committee as contrasted, for example, to ASME which is an Accredited Organization.

The Secretariat

N14 like all such committees is administered by a Secretariat which is responsible for compliance with the ANSI procedures. ANSI has delineated fifteen specific responsibilities to a Secretariat. The responsibilities that this audience is probably most interested in are:

- Organize the Committee,
- Develop and maintain the standards within the approved scope of the Committee, and
- Keep interested parties informed about the activities of the Committee.

ANSI actually monitors the performance of the Secretariats and their Committees through Standards Management Boards which for nuclear standards such as N14 (and N15) is the Nuclear Standards Management Board (NSMB). The functions of NSMB include:

- Stimulating the development of needed national standards
- Discouraging the development of unneeded standards
- Minimizing the duplication of efforts

Art Trujillo of the Transportation Technology Center at Sandia and Ed Tarnuzzer of Yankee Atomic Electric Co. accepted the Secretary and Vice-Chairman positions, respectively.

The actual members of N14 are those organizational representatives and individuals who ballot proposed standards towards a consensus where consensus is more than a simple majority but probably not unanimity. As the officers of N14, we have been liberal in accepting members for the Committee. Reflecting ANSI guidance we look for 1) organizations willing to participate and which have substantial concern and competence within the scope of N14, and 2) individuals having expert knowledge. This has resulted in a large membership. There are presently twenty-five organizational members and about twenty-one individual members. John Arendt, Union Carbide—Oak Ridge is the INMM representative member in N14.

To achieve an efficient organization, an administrative adjunct, "The Management Committee" was established. The N14 Management Committee coordinates the performance of the writing groups and performs the seemingly unending task of securing writing group chairmen. Otherwise, the Management Group is purely advisory and does *not* intrude upon the consensus-making responsibilities of the N14 Committeee. The present Management Committee consists of the N14 Officers and: Cal Brantly—New England Nuclear Corporation; Arvil Crase—U.S. Ecology Inc.; Phil Eggers—Ridihalgh, Eggers & Associates, Inc.; Dick Haelsig—Nuclear Packaging Inc.; and Jim Lee—Transportation Consultant.

At the November 1981 meeting, the N14 Committee approved the formation of an Ad-Hoc subcommittee under Ron Pope of Sandia to assess: 1) the need for new standards, 2) the need for consolidation of existing standards, and 3) the potential for deleting standards that are no longer necessary. The U.S. Department of Energy has already contributed significantly to this reassessment effort via a review of N14 standards by each of DOE's Operation's Offices and the feedback was influential in our initial assignment of priorities.

The Writing Groups

A standards Writing Group is a standing unit of N14 and is responsible for the preparation of a proposed standard. Specifically, the Writing Group becomes responsible for the technical adequacy and quality of the document; obtains reviews; demonstrates, in cooperation with the N14 Officers, that a consensus has been achieved; and, maintains the standard after it has been approved. While each Writing Group is responsible for its own staffing and the conduct of its business, both ANSI and N14 provide guidance and direction. ANSI publishes formal guidance via its "Style Manual" and a series of guides (the "rainbow" books) addressing practices and procedures. N14, in conjunction with NSMB, provides: a numerical designation for the project, a title for the proposed standard, and a description of the project in the form of a charter.

A major task of the N14 Management Committee is obtaining Writing Group Chairmen, who obviously play no small part in this standards development effort. The Writing Group Chairman is the heart of voluntary standards development. In summary the Chairman manages the Writing Group; however, ANSI delineates the Chairman's responsibilities as:

- Managing the development and maintenance of the project assigned to the group
- Scheduling and expediting work
- Evaluating participation of group personnel
- Monitoring progress
- Adjudicating conflicts
- Ensuring coordination at interfaces with other committees and standards projects

All this from a volunteer! The present and recent Writing Group Chairmen and their affiliations are identified in the attached status listing.

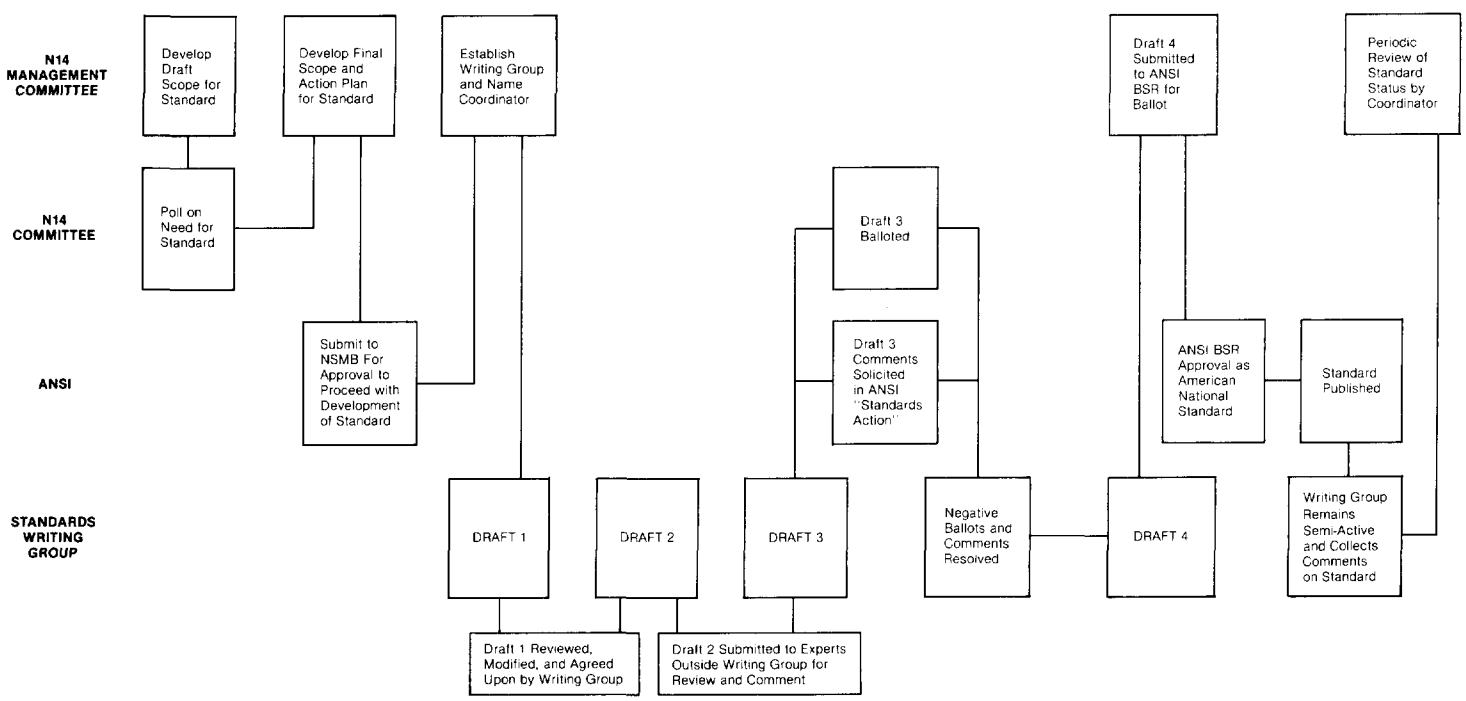
The Standards

N14 exists to produce national consensus standards. The status of this effort is shown on the attached listing. A similar listing is published quarterly by ANSI as "ANSI-NSB, Status Report of Nuclear Standards" and given wide dissemination. The development of almost all of the twenty listed N14 standards began under N14's predecessor Secretariat, the American Insurance Association (AIA). Special thanks are due AIA for keeping N14 going for a dozen or so years when the interest in the transportation and packaging of radioactive materials was far less intense than it is today. During our first year, we've acted to withdraw or delete five standards projects while adding one. Several more changes may soon occur as our reassessment activities are to be completed by the end of 1982 or at least early 1983.

The attached schematic "N14 Standards Development Procedure" indicates the route we follow. It is time consuming! It is also necessary to achieve the consensus and due process goals of a national standard.

Presented at INMM 23rd Annual Meeting July 20, 1982

N14 Standards Development Procedure



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Status of ANSI N14 Standards Writing Groups
June 1982

N14.1 *Packaging of Uranium Hexafloride for Transport,* Chairman: J. Arendt, Union Carbide Corporation, Coordinator: E. Tarnuzzer.

C Standard revised and is in ANSI hands for publication.

N14.2 *Tiedowns for Transport of Fissile and Radioactive Material Containers Greater than One-Ton Truck Transport,* Chairman: G. Chalfant, E.I. Dupont de Nemours & Company, Inc., Coordinator: J. Lee.

A This standards writing group is still active. A coordination meeting involving N14.2, N14.23 and N14.25 took place in April 1982.

N14.3 *Packaging and Transportation of Radioactively Contaminated Biological Materials,* Chairman: F. Bradley, New York State Department of Labor, Coordinator: C. Brantley.

C Standards writing group working on draft revision. Second one year extension on five year review will need to be requested.

N14.4 *Quality Assurance in the Fabrication, Use and Maintenance of Shipping Containers for Radioactive Materials,* Chairman: R. Schmidt, Union Carbide Corporation, Coordinator: P. Eggers.

C Further discussion required on whether this activity should continue. Need to review scope in light of ASME QA activity. New chairman will be required.

N14.5 *Leakage Tests on Packages for Shipment of Radioactive Materials,* Chairman: None, Coordinator: A. Trujillo.

A One year extension to five year review requested. New scope, chairman and committee required.

N14.6 *Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 Kg) or More for Nuclear Materials,* Chairman: G. Townes, Allied General Nuclear Services, Coordinator: J. Lee.

B Due for five year review in 1983. Writing group met in March 1982 to begin review process.

N14.7 *Guide to the Design and Use of Shipping Packages for Type A Quantities of Radioactive Materials,* Chairman: F. Flowers, General Electric, Coordinator: J. Lee.

C Five year review is due. Chairman is currently organizing writing group.

N14.8 *Fabricating, Testing and Inspection of Shielded Shipping Casks for Irradiated Reactor Fuel Elements,* Chairman: None, Coordinator: P. Eggers.

B New scope, chairman and committee required.

N14.9.2 *Packaging of Nuclear Power Plant Radioactive Processed Wastes for Transporation,* Chairman: P. Mayo, Stone & Webster Engineering Corporation, Coordinator: E. Tarnuzzer.

B Draft voted upon. As a result of many comments and a number of negative ballots, draft will have to be rewritten and reballoted.

N14.10 *Guide for Liability and Property Insurance in Shipping Nuclear Materials,* Chairman: J. Quattrochi, American Nuclear Insurance, Coordinator: E. Tarnuzzer

C One year extension on five year review granted by NSMB.

N14.10.1 *Administrative Guide for Packaging and Transporting Radioactive Materials,* Chairman: None, Coordinator: A. Crase.

C As a result of NRC rulemaking on disposal, action on this standard might be premature. Writing group needs to be reconstituted.

N14.19 *Ancillary Features of Irradiated Fuel Shipping Casks,* Chairman: K. Goldmann, Transnuclear, Inc., Coordinator: P. Eggers.

C Submitted to ANSI for action by Board of Standards Review (BSR). If approved by BSR, standard will be ready for publication.

N14.20 *Control of Contamination of Transport Vehicles,* Chairman: L. Jackson, Military Traffic Management Command, Coordinator: J. Lee.

C N14 committee polled to solicit comment relative to continuing this standard. Results of poll were affirmative so work on standard will continue under new chairman.

N14.23 *Design Basis for Resistance to Shock and Vibration of Radioactive Material Packages Greater than One Ton in Truck Transport,* Chairman: D. Ahlbeck, Battelle, Columbus Labs, Coordinator: A. Trujillo.

A Published as draft standard for review and comment. As soon as comments are compiled, standard will be prepared for ballot. A coordination meeting involving N14.2, N14.23 and N14.25 took place in April 1982.

N14.24 *Marine Transportation of Radioactive Material,* Chairman: E. Wilmot, Sandia, Coordinator: A. Trujillo.

B Extension requested until March 1983. Need revision of draft by the new chairman.

N14.25 *Tiedowns for Rail Transport of Fissile and Radioactive Material,* Chairman: G. Chalfant, E.I. Dupont de Nemours & Company, Coordinator: P. Eggers.

B This standard writing group is still active. A coordination meeting involving N14.2, N14.23 and N14.25 took place in April 1982.

N14.26 *Inspection and Preventative Maintenance of Packaging for Radioactive Materials,* Chairman: None, Coordinator: A. Crase

C This standard might not be required in light of NRC Appendix E. Effort will be made to draft new scope for submission to N14 Committee.

N14.27 *Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents Involving Truckload Quantities of Radioactive Materials,* Chairman: P. McCreery, Allied General Nuclear Services, Coordinator: J. Lee.

A Published as draft standard for trial use and comment. Comment period ended May 1982. Chairmen of N14.27 and N14.28 met in April to coordinate activities.

N14.28 *Carrier and Shipper Responsibilities and Emergency Response Procedures for Highway Transportation Accidents Involving Less Than Truckload Quantities of Radioactive Materials,* Chairman: E. DeMaria, New England Nuclear Corporation, Coordinator: C. Brantley.

B Committee formed and standards writing activity inititated. Chairman of N14.27 and N14.28 met in April 1982 to coordinate activities.

N679 *Guide for Writing Operating Manuals for Radioactive Materials Packaging,* Chairman: R.T. Waite, American Nuclear Insurance, Coordinator: None.

C Due for five year review; need being reconsidered.

THE N15 STANDARDS COMMITTEE

GEORGE A. HUFF, CHAIRMAN
Allied-General Nuclear Services
Barnwell, South Carolina

The INMM N15 Standards Committee (Methods for Nuclear Material Control) has been undergoing some organizational changes. There are currently twelve active subcommittees with about 200 individuals participating in preparing and reaffirming standards.

In July, 1981, Ralph Jones was appointed to serve as chairman to replace Dennis Bishop. Earlier this year, as a result of an appointment to the IAEA in Vienna, Ralph resigned. George Huff has been appointed to serve, and is currently working with the help of secretary Robert Kramer and the subcommittee chairmen to keep committee activities progressing.

The status of standards work for the past year is shown below.

Standards Issued

1) N15.37-1981	Guide to the Automation of Nondestructive Assay Systems for Nuclear Material Control
2) N15.38-1981	A Generic Standard for Auditing Nuclear Materials Safeguards Systems
3) N15.40-1981	Definition of Terms and Symbols Associated with the Physical Protection of Nuclear Materials and Facilities

Standard Reaffirmed

1) N15.15-74(81)	Assessment of the Assumption of Normality (Employing Individual Observed Values)

Standards Closed for Public Review and Comment

1) P/N15.35	Nondestructive Assay Physical Standards
2) P/N15.36	Guide to Preparing Calibration Material for Nondestructive Assay by Counting Passive Gamma Rays

Charter Submitted to ANSI

1) P/N15.48	Guide to the Identification of Vital Areas at Nuclear Facilities

A number of subcommittees are scheduled for July meetings in Washington, and we are looking forward to an accelerated effort during the coming year. Your continued contributions are vital to the success of N15. Please take the initiative to become involved in your areas of interest.

CERTIFICATION COMMITTEE

DR. FRED TINGEY, CHAIRMAN
University of Idaho
Idaho Falls, Idaho

The Certification Board met on July 19 in conjunction with the annual meeting of the Institute. Concern was expressed by all in attendance relative to the absence of applicants for either the Intern or Specialist examination. The consensus was to continue to supplement the test library and assemble limited bibliographies with regard to each of the areas of testing and to encourage and possibly participate with Harley Toy in a training seminar specific to the Safeguards examinations. Failing to generate support for the program through this means, consideration should be given to a major restructuring of the program to provide the certification on a piecemeal basis or only in the area of speciality, or other changes which might make the program more attractive to the membership. An alternative would be to abandon the program altogether. In the meantime, since last year's annual meeting, Ron Hawkins was certified as a Safeguards Specialist with speciality in material control. More recently (July 19), Robert Eggers of Battelle completed the requirements for certification as a Safeguards Specialist with speciality in statistics.

In view of the lack of interest in the program there are no certification exams scheduled for the immediate future.

SAFEGUARDS COMMITTEE REPORT

ROBERT J. SORENSON, CHAIRMAN
Battelle Pacific Northwest Laboratories
Richland, Washington

The Safeguards Committee met on Thursday, July 22, at the Hyatt Regency Washington Hotel in conjunction with the annual meeting of the INMM. We had good attendance by the Committee members, and an excellent meeting. A few of the highlights from the meeting are summarized below.

Dick Duda gave a status report on the activities of the Government Liaison Subcommittee. Their work on the International Plutonium Storage (IPS) has been very active. A position statement is being prepared by the Subcommittee at the request of State and ACDA. The bimonthly meetings with ACDA and State are continuing, with the next one scheduled for late September. Some new subjects being discussed are the safeguardability of large reprocessing plants, and the U.S. experience with the IAEA verification activities at LEU fuel fabrication plants.

Roy Nilson discussed the recent activities of the LEU Subcommittee. The proposed LEU rule change was reviewed and seems to be nearing consideration by NRC management. The rule is more performance oriented and less prescriptive than the current rule. The LEU fuel fabricators seem pleased with the results, and Bud Evans of the NRC indicated that he found the Subcommittee's participation to be very helpful.

Leon Chapman of Sandia has agreed to form a new subcommittee with representation from the Category I (HEU/Pu) fuel fabricators. Initially it would consider both (a) the newly proposed Part 11 rule change regarding clearances, and (b) the reform amendment for Category I licensees.

We also discussed a number of other subjects including skill registry, ESARDA interface, policy statements, and new topics for the Committee. Our next meeting is scheduled for October 1, 1982 in Washington, DC. The Government Liaison Subcommittee will be meeting on September 30, also in Washington, DC.

My thanks to everyone on the Safeguards Committee and the Subcommittees for their continued support and hard work.

MEMBERSHIP COMMITTEE REPORT

JOHN E. BARRY, CHAIRMAN
Gulf States Utilities
Beaumont, Texas

Another successful Annual Meeting! Washington is a hot place during July and provided the unique environment for this year's get-together. President Reagan's "balanced budget" rally on the Capitol steps was the domestic counterpoint to John M. Marcum's remarks that same Monday morning on the Administration's efforts to promote international cooperation in nuclear energy. As Assistant Director for Energy and Natural Resources in the President's Office of Science and Technology Policy, Mr. Marcum's comments on future DOE enrichment operation to favor higher consumption of uranium demonstrated that the government is moving to relieve the depressed U.S. uranium industry while trying to avoid the need for foreign uranium use restrictions potential under the still-pending NRC Authorization Bill Amendment.

Under our Executive Director, John Messervey, the membership-related services provided at the meeting worked smoothly. The extension of membership renewals until September eliminated the flurry of receipt-making and cashbox balancing of past meetings and allowed more time for indepth discussions with attendees. In one such conversation with Mary Dodgen it was revealed that there have been several utility group meetings on the fuel cycle backend in the Augusta-Barnwell-Savannah River area earlier this year of which the Southeastern Chapter should have been apprised.

Speaking of such meetings, all interested parties please note and plan to attend the INMM-sponsored seminar on spent fuel management and waste disposal on October 20-22, 1982 in Washington.

Charles V.G. Allport, President, Elkron International, Elkron Security Ltd., Unit 1A, Deseronto Wharf, St. Mary's Road, Langley, Slough SL3 7EW Berkshire, United Kingdom

Paul Eric Benneche, Research Engineer B, U. of Va., Dept. of Nuclear Engr., Reactor Facility, Charlottesville, VA 22901, (804) 924-7136

Richard N. Brunasky, Security Specialist, U.S. Army, Test & Evaluation Command 308 Harlan Square, Bel Air, MD 21014, (301) 278-2776

David W. Brunson, Physical Security Specialist, South Carolina Electric and Gas, V.C. Summer Nuclear Station, P.O. Box 88, Jenkinsville, SC 29065, (803) 345-5209, Ext. 4279

E. Ruth Cary, SS Materials Representative, Union Carbide Nuclear Division, P.O. Box P, ORGDP K-25, Oak Ridge, TN 37830, (615) 574-8938

C. Alton Coulter, Staff Member, Los Alamos National Laboratory, P.O. Box 1663, MS E541, Q-4, Los Alamos, NM 87545, (505) 667-4964

Donald Lee Davis, Security Specialist, Bechtel Power Corp., 912 Bancroft Road, Concord, CA 94518, (415) 768-4434

Deborah Anne Dickman, Specialist, Nuclear Materials, Rockwell Hanford Company, P.O. Box 800, Richland, WA 99336, (509) 373-2204

Charles Patrick Gallagher, Manager of Security, Bechtel Power Corporation, 50 Beale St., San Francisco, CA 94105, (415) 768-5146

Dolores G. Hoffman, Supervisor, Material Systems Division, Sandia National Laboratories, Organization 3431, P.O. Box 5800, Albuquerque, NM 87185, (505) 844-7609

Masaru Ido, Director & Manager of System, Engineer Dept., I.S.L., Incorporated, Akabanebashi Bldg., 1-26-6, Higashi-Azabu, Minato-Ku, Tokyo 160 Japan, (03) 583-6728

Koji Iwasaki, Director, Power Reactor and Nuclear Fuel Development Corporation, 9-1, 1-chome, Akasaka, Minato-ku, Tokyo, Japan, (03) 586-3311

Atsushi Kawano, President, I.S.L., Incorporated, Akabanebashi Bldg., 1-26-6, Higashi-Azabu, Minato-ku, Tokyo 160 Japan, (03) 583-6728

Heinz Kschwendt, Head of Informatics Branch, Commission of the European Communities, L-2920 Luxembourg, Europe, Luxembourg 43011

Masuda Manabu, Safeguards, Japan Nuclear Fuel Services Co., Fukokuseimei Bldg., Uchisaiwaicho 2-2-2 Chiyoda-Ku, Tokyo-100 Japan, 03-580-6911

Richard L. Moe, Security Manager, Argonne National Laboratory-West, 1791 Coronado, Idaho Falls, ID 83401, (208) 526-7347

Richard A. Muller, Marketing Manager, Litton Systems Canada, 25 Cityview Drive, Rexdale, Ontario, Canada M9W 5A7, (416) 249-1231, Ext. 377

Toru Murata, Chief Researcher, Nippon Atomic Industry Group Co., 4-1 Ukishima-Cho Kawasaki-Ku, Kawasaki Japan 210, (044) 277-3131

Hiromasa Nakano, Senior Staff, Power Reactor & Nuclear Fuel Development Corporation, c/o P.N.C., 9-13, 1-chome, Akasaka, Minato-Ku Tokyo, Japan, (03) 586-3311

William M. Olliff, Department Superintendent, E.I. duPont DeNemours & Company, Savannah River Plant, Aiken, S.C. 29801, (803) 450-3111

Kevin M. Power, Marketing Administrator, Litton Systems Canada Ltd., 25 Cityview Drive, Rexdale, Ontario M9W 5A7, Canada, (416) 249-1231

Susan S. Redfield, Staff Analyst, General Physics Corporation, 2405 Earlsgate Ct., Reston, VA 22091, (301) 730-4055, Ext. 323

Katsutoshi Shimizu, Asst. Mgr. of Engineering Section, The Japan Atomic Power Company, 335-7, Shimokizaki, Urawa, Saitama Pref. 338, Japan, (03) 201-6631

Toshihide Takeshita, Senior Researcher, Institute for Policy Sciences, Japan, 2-4-11, Nagata-cho, Chiyoda-ku, Japan, (03) 581-2141

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Barbara H. Thomas, International Safeguards Analyst, U.S. Nuclear Regulatory Commission, Nuclear Materials Safety & Safeguards, Washington, D.C. 20555, (301) 427-4004

Joseph F. Tinney, Manager, Business Development, Science Applications, Inc., 1710 Goodridge Drive, McLean, VA 22102, (703) 734-4017

Larrie Kent Trent, Manager, Nuclear Materials Control, Babcock & Wilcox, P.O. Box 785, Lynchburg, VA 24505, (804) 522-5063

Masayori Tsutsumi, Chief Engineer, Senior Staff, Power Reactor & Nuclear Fuel Development Corporation, PNC Tokai Works, Tokaimura, Nakagun, Ibarakiken, Japan, 02928-2-1111

Dennis Lee Vernon, Supervisor, Security Systems & Controls, UNC Naval Products, 18 Avon Place, Mystic, CT 06355, (203) 848-1511, Ext. 848

Elaine Y. Wagenaar, Specialist, Rockwell Hanford Operations, 2704-Z Bldg., 200-W Area, Richland, WA 99352, (509) 373-1789

INSTRUCTIONS FOR CONTRIBUTORS TO NUCLEAR MATERIALS MANAGEMENT

News items, comments, reports on committee activities and chapter activities, etc. are solicited for the four regular issues of NUCLEAR MATERIALS MANAGEMENT. Please submit these to:

Editor: NUCLEAR MATERIALS MANAGEMENT
INMM Headquarters
8600 West Bryn Mawr Avenue
Chicago, Illinois 60631 U.S.A.
312/693-0990

Technical manuscripts, notes or comments submitted for the regular issues of NUCLEAR MATERIALS MANAGEMENT will be reviewed before publication. Three copies must be submitted to:

Dr. W.A. Higinbotham
Technical Editor
Brookhaven National Laboratory
DNE/TSO, Building 197C
Upton, New York 11973

One copy should be sent to INMM Headquarters at the above address. Instructions regarding contributions for the Proceedings of the annual meeting will be announced elsewhere in NUCLEAR MATERIALS MANAGEMENT.

In order to keep the cost of dues and subscriptions as low as possible, the author's institution is requested to pay a page charge of $75 per page. Reprints are available (minimum order is 100). When notified of acceptance, authors will be requested to present contributions on mats which will be supplied to them by INMM Headquarters. Preferred form is two column, produced in prestige elite type. Sample will be forwarded to the author with instructions.

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If there are questions on preparing a manuscript for contribution, please contact the INMM Headquarters at 312/693-0990.

TECHNICAL WORKING GROUP ON PHYSICAL PROTECTION REPORT

JAMES D. WILLIAMS, CHAIRMAN
Sandia National Laboratories
Albuquerque, New Mexico

The presently scheduled and planned workshops of the Technical Group on Physical Protection are listed below:

- Physical Protection Review—Getting the Most for Your Money, October 5-8, 1982
- Central Control and Information Display, Early 1983 (Tentative)
- Security Personnel Training, Summer 1983 (Tentative)
- Integrating the Elements of Delay, Intrusion Detection and Entry Control into Physical Protection Systems, Fall 1983 (Tentative)

Workshops on other subjects of interest to physical protection personnel will be considered if enough interest is expressed Additional details about the group activities are given below.

General
The purpose of a physical protection system is to provide physical protection against acts of sabotage to a facility and/or theft of valuable or hazardous material. Five elements, which must react in a timely manner, form the foundation for an effective Physical Protection System:

1. *Detection and Assessment* systems must detect and verify any authorized intrusion attempt by outsiders or any serious malevolent acts by insiders or outsiders.
2. *Entry Control* systems must control authorized personnel entering a facility, detect unauthorized personnel attempting to enter in the same manner as authorized personnel, and detect contraband being taken in or out of a facility. These systems can also be used to detect and/or prevent malevolent acts by insiders.
3. *Communication* systems must ensure that all pertinent information is transferred to the point(s) where appropriate action can be taken.
4. *Delay* systems must impede continued adversary penetration into, or exit from, the area being protected.
5. *Response* systems, or forces, must counteract adversary activity and neutralize the threat.

These elements are equally important and none of them can be eliminated or compromised if an effective Physical Protection System is to be achieved. Intrusion detection and entry control are important elements since any delay scheme can eventually be penetrated, and without detection the response force would not be alerted. Delay elements must provide sufficient time after detection to allow the response force to arrive. Finally, the response force must be adequately prepared to neutralize the adversary actions.

During the INMM Twenty-Third Annual Meeting which was held July 18-21, 1982, at the Hyatt Regency Washington on Capitol Hill, Washington, D.C., the activities of the INMM Technical Working Group on Physical Protection were reviewed in a series of papers. Interest was very high in a paper entitled "Denial Technology, the Neglected Security Element" by C. Herman Mauney. As a result of this interest, the steering committee for the Technical Working Group tentatively planned a workshop on Integrating the Elements of Delay, Intrusion Detection and Entry Control into Physical Protection Systems. The meeting is tentatively being planned to be held during the fall of 1983.

Physical Protection Review—
Getting the Most for Your Money
This workshop is being held at the Sheraton Inn-Old Town, Albuquerque, NM, October 5-8, 1982. It is being sponsored by the INMM Technical Working Group on Physical Protection with the cooperation of the Departmenty of Energy, the Nuclear Regulatory Commission, the Edison Electric Institute, and the American Gas Association. The workshop will focus on technical and operational problems related to cost-effective physical security. The official closing date for registration was in early July 1982, however if you have not registered and would like to attend, please contact Marlene Yadron or Terry Olascoaga at the address listed below.

Marlene Yadron
Institute of Nuclear Materials Management
8600 West Bryn Mawr Avenue
Chicago, Illinois 60631 U.S.A.
312/693-0990

Terry Olascoaga
Division 9259
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185
505/844-1379 FTS 844-1379

Central Control and Information Display Systems
This workshop is tentatively planned to be held in early 1983 and is presently in the planning stage. The topics planned relate to controlling and displaying security, fire, safety, and other information on how to integrate such systems into a facility operation plan. A questionnaire has been mailed to a group of persons who are known to have interest in the subject matter mentioned. If you would like to receive a questionnaire and an invitation to this workshop, please contact Larry Barnes, Allied General Nuclear Services, P.O. Box 847, Barnwell, SC 29812 803/257-1711.

Security Personnel Training
Summer 1983 (Tentative), Contact Dr. L. Paul Robertson
Division 1716, Sandia National Laboratories
P.O. Box 5800, Albuquerque, NM 87185
Telephone (505) 844-7706, FTS 844-7706

The third workshop concerning the training of security personnel is in its very early planning stages. If you have ideas of topics to be covered or suggestions to make about this workshop, please contact Paul.

Integrating the Elements of Delay, Intrusion Detection and Entry Control into Physical Protection Systems
Fall 1983 (Tentative), Contact James C. Hamilton
Goodyear Atomic Corporation, P.O. Box 628, Mail Stop 1231
Piketon, Ohio 45661
Telephone (614) 289-2331, Ext. 2204, FTS 975-2204

This workshop will be the fourth workshop on intrusion detection and entry control. During this workshop, the delay element (fixed barriers and activated barriers) will also be discussed. If you have ideas of specific topics to be covered or suggestions to make about this workshop, please contact Jim.

JOURNAL ARTICLE DEADLINES

Deadlines for technical manuscripts (requiring review) and news articles, etc. (not requiring technical review) are given in the annual schedule noted below. As a convenient reminder to colleagues in your organization, you may wish to post this schedule.

Issue	Technical* Manuscripts Due	News** Articles, etc. Due	Publication Mailing Date
Spring	January 1	March 1	May 1
Summer	April 1	June 1	August 1
Fall	July 1	September 1	November 1
Winter	October 1	December 1	February 1

*To submit a technical article (requiring review), send three copies to Dr. William A. Higinbotham, TSO, Building 197, Brookhaven National Laboratory, Upton, Long Island, New York 11973 (phone 516/345-2908, or FTS 666-2908). One copy should be sent to Editor, NUCLEAR MATERIALS MANAGEMENT, INMM Headquarters, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631 U.S.A. (phone: 312/693-0990).

**News articles, photos (with captions, of course), book reviews, summaries of technical presentations, guest editorials, technical notes, etc. should be submitted by the appropriate deadline to the Editor at INMM Headquarters.

SOUTHEAST CHAPTER

MARY S. DODGEN, CHAIRMAN
E.I. duPont de Nemours & Company
Savannah River Plant
Aiken, South Carolina

The Southeast Region Chapter held a dinner meeting on June 22, 1982 in conjunction with John Jaech's leading a seminar on statistics as used in nuclear material accounting. During the meeting John led an informal discussion about membership involvement, meeting the needs and interest of the membership and the purpose of INMM. Twelve members and guests were in attendance.

The seminar which lasted five days was attended by about 30 persons from SRP, SRL, AGNS and DOE. The Chapter cooperated with the SRP Personnel Department's Training Division in making arrangements for the seminar, thus achieving the objective of providing an opportunity for training in statistics in the Southeast which was set last year.

Twelve members and guests attended the dinner meeting (from left): Bob Hobert, SRP-retired; Newt Seebeck, SRO-DOE; Charles Moeller, retired; Karl Bambas, AGNS; Ralph Hemmer, SRO-DOE; Ann Gibbs, SRL; Jilene Weber, SRP; Tom McDaniel, SAI (La Jolla, CA); John Jaech, Exxon; Mary Dodgen, SRP. Not pictured: Bill Dickenson, SRP and Bill Dodgen, photographer.

JAPAN CHAPTER

YOSHIO KAWASHIMA, CHAIRMAN
Nuclear Material Control Center
Tokyo, Japan

The annual conference of the INMM Japan Chapter was held on February 10 in Tokyo. Approximately 90 participants were registered from government organizations, universities, electric utility companies, nuclear fuel fabricators, manufacturing companies and trading houses. The active atmosphere of the conference reflected growing interests by the Japanese nuclear energy circle in nuclear materials management and safeguards.

The program was organized by the program committee led by Dr. K. Nakajima, a director of PNC, and included the following presentations:

- Introductory speech by Mr. Y. Kawashima, chairman of the Japan Chapter;
- Report of the 22nd INMM General Conference by Dr. K. Ikawa of JAERI;
- Recent international situation in the field of nuclear safeguards by Mr. M. Kawasaki, a director of Safeguards of Science and Technology Agency;
- Recent development on the non-destructive measuring techniques for fissile materials by Prof. A. Sekiguchi of the University of Tokyo;
- Protection at nuclear power stations by Mr. N. Kaseda of Nuclear Materials Control Center;
- Recent activities of the U.S. INMM by Dr. D.M. Bishop of GETSCO;
- Measurement of fissile material balance at Tokai Reprocessing Plant by Mr. M. Hayashi of PNC.

Address by Mr. K. Nakajima, Program Chairman

Panel discussion

After the presentations, the panel meeting was arranged to discuss suggestions from recipients of nuclear safeguards inspection.

The panel members were:
Prof. H. Wakabayashi of the University of Tokyo, Chairman
Mr. M. Tsutsumi of PNC
Dr. H. Kuroi of JAERI
Mr. Y. Sakakibara of Tokyo Electric Power Co.
Mr. T. Osabe of JNF

There were active discussions and suggestions based on actual experiences to accept safeguard inspection.

The activities of the Japan Chapter were reported by Dr. M. Hirata of JAERI and the secretary of the INMM Japan Chapter. The conference was closed with the closing remark by Mr. K. Nakajima, program chairman, wishing for further growth of the activities of the Japan Chapter and the INMM.

BOOK REVIEW

JOSEPH P. INDUSI
Brookhaven National Laboratory
Upton, New York

Nuclear Arms in the Third World
U.S. Policy Dilemma
By Ernest W. Lefever, The Brookings Institution
Washington, D.C. (1979). 154 pp.

This book is an interesting look into the issue of nuclear proliferation from a U.S. policy perspective. Chapter 1 defines the problem in general terms from the point of view of the U.S., the USSR, France, and China. The role of the IAEA, levels of nuclear arms capabilities, technical considerations, economic factors, and incentives for developing a nuclear arms capability are also briefly discussed. Chapters 2 through 6 discuss the history, technical developments, incentives, and future relations of nine Third World countries that have the potential for the acquisition of nuclear arms. Chapter 7 concerns the range of U.S. policy options for deterring nuclear arms acquisition. The final chapter discusses policy options for restraining new nuclear forces.

The U.S. interest in nuclear arms control is briefly traced from the Baruch plan of 1946 to the present. The author introduces the concept that U.S. policy is based on the premise that the risk of nuclear war increases as the number of nuclear states increases; however he indicates that this assumption is not universally accepted. This issue is dropped at this point but is taken up briefly again in Chapter 7 where the point is made that just the acquisition of nuclear bombs by a nation is not sufficient in analyzing the impacts associated with it and that other political factors must be taken into account. While the issue is not argued at length, it is pointed out that the acquisition of nuclear arms by Britian, France, and China did not appear to have an adverse effect on strategic stability. Having made these points the discussion is terminated and the current U.S. policy of deterring the acquisition of any new nuclear capability is the basis for the remaining discussions. The International Atomic Energy Agency (IAEA) is briefly discussed as part of an overall U.S. policy approach toward controlling nuclear proliferation. The lack of IAEA enforcement powers, its inability to prevent the construction of nuclear explosives, and "its inherent weaknesses and imperfections" are mentioned but the author concludes that the system is worth preserving and strengthening. Clearly the author understands the objectives of the IAEA and recognizes the important, though perhaps limited, role it plays in deterring the proliferation of nuclear weapons. This is refreshing in view of how frequently its objectives and purposes are erroneously expanded to include the prevention of nuclear proliferation and the ability to serve all the needs of U.S. nonproliferation policy. Since no international organization relying on voluntary cooperation can be all things to all nations, it is senseless to criticize the IAEA for not having capabilities and powers that it was never intended to have.

The destabilizing effect of any particular nuclear acquisition is dependent to some degree on the level of the nuclear capability in question. The author defines three levels; Threshold State, Token Nuclear Force, and Militarily Significant Force. A Threshold State is developing nuclear technology, building facilties, and accumulating special nuclear material for weapons construction. A nation becomes a Token Nuclear Force when it conducts its first successful test. A Militarily Significant Force requires a credible and survivable delivery system for its nuclear weapons. The ability of a nation to move from one level to another is dependent on factors such as its level of scientific technology, costs of nuclear arms, and the incentives for developing a nuclear capability. In regard to scientific technology, the author concludes that few Third World countries possess the technology in chemistry and explosives, metallurgy, and nuclear physics as well as a high degree of engineering skill to develop reliable and moderately sophisticated bombs. This assessment of course is likely to change over the years in spite of any efforts to withhold nuclear technology by the superpowers. The costs of developing a nuclear arms capability is high and the military budgets are compared to the GNP for eleven Third World nations of interest. This comparison allows one to see how truly burdensome a nuclear arms program can be for certain states. However, given strong enough incentives, even these heavy costs would be sustained in order to develop nuclear weapons. The discussion on incentives is perhaps the most important in this book since it is in this area where U.S. policy options may have the greatest impact. The author proposes that the incentives for Third World candidates to develop a nuclear capability are in large part dependent on four interrelated assumptions: 1) there will be a loosening of ties between each of the two superpowers and its allies; 2) Third World nations will feel less protected by superpower security guarantees; 3) Third World regional competition will intensify; and 4) this rivalry will be exacerbated by the acquisition of nuclear weapons by one or more additional states. Eleven candidate states are ranked by consideration of these factors as either high, medium, or low although it is not clear how useful this ranking is.

With these concepts of scientific technology, economic costs, and incentives in mind the author analyzes a number of Third World nations that are considered nuclear arms candidates. A chapter is devoted to India and Pakistan, Iran under the Shah, Israel and Egypt, South Korea and Taiwan, and Brazil and Argentina. In each case there is a brief discussion of the recent history, nuclear status, incentives, and nuclear future. This was interesting reading but one is nagged by the fear that these assessments may contain serious errors since it appears difficult to believe that an outsider may have correct knowledge about the innermost feelings of a nation's leaders. This, however, may be the prejudice of an engineer or scientist toward any analysis not grounded in physical fact and expressed in mathematical formulas. The discussion about Brazil raises an interesting point concerning the IAEA and the nonproliferation treaty in regard to the vertical proliferation issue. The point is made that one of Brazil's objections to the treaty is that it permits the nuclear powers to keep on increasing their arsenals while denying nuclear arms to other States. The NPT does speak of the superpowers engaging in arms control although in practice little is done in this regard. One is tempted to suggest that perhaps the IAEA can initiate discussions with the superpowers and begin to assemble the mechanisms for reporting

and inspection for the vertical proliferation problem that it now has in place for the horizontal proliferation problem.

The major points of the book are given in the last two chapters and these describe the range of U.S. policy options that may be applied to deter the spread of nuclear weapons. The major options to help deter nuclear arms acquisition are: 1) to reduce the pressure in threshold states by offering to provide U.S. security assistance and guarantees; 2) encourage nuclear abstinence by promoting international agreements; and 3) increase the difficulty of making nuclear weapons by denying the technology to do so. The author claims that the most effective of these is the first, although this is the one that has been least seriously examined. This is in large part due to the mood of disengagement and withdrawal in the U.S. following the end of the war in Vietnam. Exercising this policy option would require expanding the U.S. military system, perhaps stationing additional U.S. troops abroad, and weathering the domestic effects of such policies. If in fact the concern about security is a strong incentive for Third World countries to develop a nuclear arms capability then this policy option should be seriously studied. The promotion of international agreements includes the NPT and treaties establishing nuclear-free zones. There has been considerable success in these areas and additional effort and improvements appear to be worthwhile. Denying nuclear technology has had some success although in time this would appear to be less effective since the U.S. does not have a monopoly on technologies and materials. Certain punitive policies have been tried, although the U.S. has more often used positive incentives to induce nuclear arms restraint, including the promise of more nuclear, military, or economic assistance. The author strongly supports the viewpoint that the provision of security assistance by a nuclear guarantee, defense pact, military assistance, and possibly the presence of U.S. troops is the single most effective method to encourage nuclear abstinence.

The final chapter discusses U.S. policy options in restraining new nuclear forces. In this case U.S. policy would strive to mitigate any destabilizing effects brought about by the new nuclear arms acquisition. This might involve efforts to induce the new nuclear state to pursue a nonaggressive foreign policy, provide support and assistance to neighboring states in order to allay their fears, taking punitive action against the offending state, and requiring stricter safeguards for new nuclear facilities.

In summary, this book represents a serious look at U.S. policy options to deter nuclear proliferation in a changing world. Even though the book was published in 1979, most of the analysis and discussion remains valid. Persons interested in or working in international safeguards will find in this book an informed background and perspective on deterring nuclear arms proliferation.

A number of outstanding papers from the annual meeting are included in this issue of NUCLEAR MATERIALS MANAGEMENT (pages 22-90). These papers were unavailable for inclusion in the Proceedings issue. We are grateful to the authors for their contribution. INMM members who did not attend the annual meeting will receive the Proceedings by mail in September.

THE STATE OF NUCLEAR ENERGY UNDER PRESIDENT REAGAN

JOHN M. MARCUM
Office of Science and Technology Policy
Executive Office of the President
Washington, D.C.

The use of commercial nuclear energy continues to be both a technically important and a politically volatile issue in the 1980s. Although the expectations of the early days of this commercial enterprise have not been realized, in terms of the number of reactors and the establishment of a closed fuel cycle, the contribution and future needs from this energy resource remain substantial.

The United States has played and continues to play a pivotal role in the international nuclear community by virtue of its long standing leadership in many areas of this technology -- a leadership that has been understandably eroded in recent years as other nations have, in essence, caught-up, often with the help of U.S. companies, technology or education. In a simple sense, the current operating and construction status of commercial nuclear plants puts this nation in a position where technical, safety and policy initiatives have great significance throughout the world. While we do not occupy the position of dominance of years past, the fact is that the United States now operates 40 percent of the world's commercial reactors, and furthermore, 40 percent of all reactors under construction are within these borders.

This Administration recognizes the role this nation plays by virtue of these facts, and the role we must play with respect to cooperating with and assisting our allies, and, not insignificantly, the role our allies can play in assisting us.

In that regard, I would like to provide you with a brief overview of the current status of commercial nuclear energy as this Administration sees it, and the specific initiatives and actions we see necessary to ensure the prudent and essential use of this important resource, both domestically and internationally. This Administration is committed to economic recovery, including long-term stability in energy supply and prices, and to ensuring that nuclear power can make its essential contribution to this goal.

Let me start with some background regarding the state and role of commercial nuclear energy, since policy discussions about special nuclear materials will be clearly dependent on the overall activities and health of this industry.

It is interesting to note that the most depressed sectors of the economy, housing, steel, autos and metals, both domestically and internationally, are also the highest users of energy per unit of G.N.P. Consequently, economic recovery will demand that we sustain impressive performance from the oil and natural gas sectors and ensure that new sources of energy are available for growth.

As a result of the effect of deregulation of oil pricing and future deregulation of natural gas, it is likely that we will be able to maintain oil and natural gas production at current levels for the next several decades. However, we will need new sources of energy to meet our growing needs as economic recovery proceeds.

In that regard, it is equally clear that coal and uranium are the two resources that the United States will need to turn to with increasing reliance in years to come. Although the current oil glut and weakening of OPEC control are very positive developments, we must not be complacent. Energy security can be maintained only by making the fullest use of all domestic resources. When one considers that this nation has one-fourth of the free world's uranium and coal resources, the potential is significant.

While all of us here understand the magnitude of the current difficulties that face the commercial nuclear industry, the most significant of which is economic, it is nonetheless at least a little bizarre to pronounce nuclear energy dead when one considers that:

- it currently accounts for 41 percent of all new generation planned for this nation;

- it has the potential, using existing and expected reactors, to supply energy for a century, and with breeder reactors, for thousands of years;

- it experienced last year the highest growth of any form of electrical generation, surpassing oil-generation for the first time;

- it will supply about 15 percent of the world's electricity before the end of the decade.

It is, of course, this tremendous potential and the continued need to expand domestic sources of energy that makes the problems of the nuclear industry so critical for this nation and many others.

For the United States, the fundamental problems facing the commercial nuclear industry relate to economics -- a problem faced by essentially all large energy projects, witness for example recent global failures of capital-intensive synfuels projects, even with government subsidies. In addition, federal regulation is another area that has significantly impacted the cost of energy.

Over-regulation has burdened the nuclear industry, like so many others, and adversely impacted its economic performance. As I am certain you all know, the President has directed that there be substantial reforms in this area. In response, the Department of Energy and the Nuclear Regulatory Commission, in cooperation with our Office, have essentially completed comprehensive near- and long-term regulatory reform proposals which we expect to forward to the Congress within the next few months.

In today's climate, however, many utilities would now choose to avoid new nuclear construction -- the number of recent plant cancellations at early stages of construction have dramatically driven this point home.

Without intending to discuss them in any detail, let me identify the three broad types of risk that need to be reduced in order to ensure that commercial nuclear energy can make its proper contribution in the future:

i)-The investment risk a utility faces when billion dollar plus projects are undertaken;

ii)-The public's perception of risk from commercial nuclear operations;

iii)-The risk a utility could face if it experienced a Three Mile Island type of accident in its future.

In large measure, the solutions to the problems that fall under these three categories are within the control and capability of the commercial nuclear industry. Investment risk, while effected by general economic conditions and federal regulations, can also be greatly reduced by such actions as improved standardization of reactor designs, and most importantly, efficient management and meeting construction schedules.

Modest efficiency improvements can also contribute greatly. For example, a recent EPRI study showed that the nation could, by 1985, realize savings of more than $5 billion with a one percent reduction in transmission and distribution losses, and outrage rates and a one percent improvement in output efficiency.

With respect to the public's perceptions of risks, it is clear that one of the most important actions will be to finally establish legislation and a program for commercial nuclear waste disposal. In this regard, the U.S. Senate has passed legislation that the Administration strongly supports. We are now awaiting appropriate action from the House to see this necessary legislation put in place. The risk of an accident, both with regards to its potential health impacts and staggering financial impacts can be addressed by improved engineering, maintenance and operations, and improved industry research and inter-utility cooperation.

In general though, the two broad areas of government and industry involvement that will require sustained cooperation and some significant innovation are the closing of the nuclear fuel cycle, and R&D for the future. We believe that the latter, long-term research, is clearly an appropriate area for federal funding support. Let me leave the subject of R&D for another time and more directly address the theme of this conference by discussing the aspects of the nuclear fuel cycle that clearly impact policies and initiatives in using and dealing with special nuclear materials.

The President's message to Congress with regards to nuclear waste legislation included statements calling for the federal government to take title of vitrified high-level waste and to take title of encapsulated spent fuel only if vitrification facilities are not yet available. As the President noted:

> "These federal actions are consistent with our basic effort to encourage private sector reprocessing in order to provide access to significant remaining fuel value for future generations, as well as significantly reduce the volume of high-level waste."

We are confident, based on continuing discussions with many parties, that a formula can be found for a successful private venture into reprocessing. In order to help provide a conducive climate, we are moving ahead with a number of appropriate federal incentives. We are considering, for example, providing a stable market by offering to purchase a substantial amount of the plutonium output from the Barnwell facility which should facilitate the capital formation needed for start-up. We will also provide the private sector assurances against further instabilities in domestic plutonium policies by way of contractual agreements.

The plutonium produced in such reprocessing would be for DOE civil programs, especially CRBR and other advanced reactor needs. Let me be

clear that this Administration, contrary to press reports indicating otherwise, will not countenance the use of this civil plutonium for military needs.

As for other reprocessing incentives, we will also encourage and facilitate foreign participation and provide technical incentives that relate reprocessing to the ultimate disposition of nuclear waste. These measures should provide the stable market and the investor confidence necessary for reprocessing to proceed.

We also believe that the time has come to transfer uranium enrichment programs from the federal government to the private sector. This is a mature business activity and in the months ahead we will be developing initiatives aimed at facilitating a commercial operation in this area. We will also be reviewing the operating parameters at our gaseous diffusion plants in light of the changed economic conditions. Over the last few years, electricity has become much more expensive while uranium feed prices have declined sharply. By adjusting the plant operation to meet these changed conditions, we will be able to offer substantial relief to our depressed uranium mining industry.

Now, turning to the arena of international nuclear policy, I would like to make a few remarks relating to the President's directives of last July. This Administration has continued developments of new policies aimed at providing a more stable basis for international development of nuclear power and more effective non-proliferation policies. These include a new policy relating to the commercial use of plutonium in the international arena.

The general posture of our actions in this direction will fall under the more realistic and, we believe, more productive and more stabilizing recognition of the needs and resource realities of our allies. We will be seeking to cooperate more fully with our allies in commercial nuclear technology in general, and with respect to reprocessing and plutonium use in particular.

Past Administrations have treated our allies as a risk and attempted to dictate to them economic and technical decisions with respect to their domestic fuel cycles. It is our intent to assist in the achievement of the energy goals of our allies that are also strong supporters of our non-proliferation objectives. Through these improved relationships, we will seek and expect improved cooperation from our allies in accomplishing the real objective of making it more difficult for troublesome nations to acquire sensitive technology and materials.

The new plutonium use policy will provide a basis for long-term programmatic approval for advanced nations and allies to acquire reprocessing facilities on the basis of full safeguards and strong support for non-proliferation efforts. It will also provide a basis for the use of plutonium as an energy resource as fuel for fast reactor programs and eventually for thermal re-cycle in light water reactors.

I would like to conclude my remarks by bringing the specifics of this Administration's plutonium use policy into the broad perspective that I began with.

The United States enjoys a remarkable degree of energy security -- last year we produced about 90 percent of all the energy we consumed. Furthermore, the Strategic Petroleum Reserve now stands at more than 6 months worth of oil that we currently import from Arab OPEC sources.

From an overall viewpoint of dependency, oil imports from OPEC sources account for less than 5 percent of our nation's energy needs. By comparison, Western Europe depends on OPEC oil for more than one-third of all its energy needs; for Japan the dependence is over 40 percent. In light of these simple facts, it is clearly unrealistic and unreasonable, and perhaps dangerous not to assist our allies in utilizing the vast energy potential of plutonium fuels in particular and nuclear energy in general.

In these remarks, I have not intended to minimize the significant technical and political problems surrounding all aspects of commercial nuclear energy. Rather, I have intended to provide a framework within which we must consider the solution to these problems. I am confident that we can solve them. Further, I am confident that you can expect the continued support of the President and this Administration.

NUCLEAR INDUSTRY AND SAFEGUARDS SYSTEM IN JAPAN

YOSHIO KAWASHIMA
Nuclear Material Control Center
Tokyo, Japan

ABSTRACT

Nuclear industry is steadily growing in Japan with nuclear power stations and related nuclear fuel cycle facilities. Early in 1960's, practically all nuclear materials in Japan were placed under IAEA safeguards. The safeguards system in Japan started to grow in response to the IAEA safeguards and has been developing further particularly since Japan's participation in NPT in 1976. As nuclear industry expands, safeguards system is expected to incorporate the new requirements. It is useful to trace the development of safeguards system and foresee the future prospects of safeguards system in the age of growing nuclear industry in Japan.

INTRODUCTION

I am greatly honored to be given an opportunity to address the distinguished members of the INMM at its Annual Meeting. First of all I should like to report to you that the Japan Chapter was established in 1976 and has gradually increased its members to 72 in 1982. It is really important for a country like Japan, with its nuclear industry developing fast, to have more people interested in the subject of nuclear materials management and on this point the INMM has served as a magnet to attract people. In the Annual Meeting of the Japan Chapter, which was held in February this year, around 90 persons participated for one full day of discussion. We would like to maintain an open channel of communication with the INMM and would encourage the members of the INMM, when visiting Japan, to make contact with the Japan Chapter.

NUCLEAR INDUSTRY

My subject for today is the Nuclear Industry and Safeguards System in Japan. As I believe that a safeguards system should be designed to suit the needs of nuclear industry, first I should like to present to you an overall picture of the nuclear industry in Japan.

At present 24 nuclear power plants of about 17 thousand MW are in operation in Japan. Let us briefly look at our history. Nuclear development started in Japan in 1955. The Atomic Energy Basic Act, which became effective in 1955, stipulated the principle that the development and use of atomic energy should be confined to peaceful purposes only. This most important principle, which was established at the outset, has governed, and will continue to govern the use of nuclear energy in Japan. Subsequently, legislation for the control of nuclear reactors and nuclear materials was enacted and principle was put into practice.

The first ten years from 1955 to 1965 was a period of research and development. In 1966, the first nuclear power plant of 166MW, introduced from the U.K., started to operate. The period from 1966 to 1970 is regarded as the embryonic stage of our nuclear industry. In 1970 the first nuclear power plant was introduced from the U.S., and started to operate. Since then almost every year one or more nuclear power stations of the light water type have been added to the plants in operation. The nuclear power capacity increased in the ten year period from 1970 to 1980 by 20 units to 15,511MW which was 20% of the total of electric power plants built during the same period. The sales of the nuclear manufacturing industry during 1971-80 rose from 73 billion yen to 788 billion yen, increasing by almost a factor of 10, and the number of employees of nuclear industry increased by a factor of 3 from 16 thousand to 47 thousand. It may well be said that the nuclear industry started to grow and established the basis for further development during the 1970's. The nuclear industry during the period had to face the initial technical difficulties and to exert great effort to overcome these difficulties. For example, in the years of 1975 and 1977 the average capacity factor of the whole nuclear power plant system fell to below 40%.

Now let us turn to the future of the nuclear industry. According to the Interim Report of the MITI Advisory Committee on Energy published in April 1982, it is expected that nuclear power will be increased from 15,511MW in 1980 to 46,000MW in 1990 and 90,000MW in 2000. The strategy for the overall energy plan is that

by keeping consumption of oil at the level of 1980, the part played by oil will be reduced from 66.4% in 1980 to 49.1% in 1990 and to 38% in 2000, while the share of nuclear power will increase from 5% in 1980 to 11.3% in 1990 and 18% in 2000, respectively. If you look at the figures in terms of the electricity supply industry, the proportional change of oil versus nuclear are more significant. Nuclear power plants provided 12% of the total generating capacity in 1980 and this proportion will increase to 22% in 1990 and 30% in 2000. The electricity actually produced by nuclear power will increase from 16% of all electricity generated in 1980 to 30% in 1990 and 43% in 2000. Electricity produced by oil will decrease from 44% in 1980 to 17.6% in 1990 and 11% in 2000. If the nuclear power target of 46,000MW capacity could be achieved, nuclear power would be the single largest contributor to the generation of electricity in 1990. Whether the goal may be attained or not depends on several factors, including the problem of sitting. Of 46,000MW in 1990, 33,000MW are either in operation, under construction or in preparation for construction, but 13,000MW are still at a planning stage. Much effort will be needed to reach target in 1990.

Two factors affect the shift in priority from oil to nuclear power. The first is the financial stability of electric power companies. In Japan the electric utilities were nationalized in 1938, but denationalized after World War II. Nine private electric power companies, based on nine regions and connected to a national grid, are responsible for the generation, transmission and distribution of electricity in their own regions. While placed under strict government control as public utilities, they enjoy financial stability. The second is the economics of nuclear power which has certainly accelerated the trend. It is estimated that the cost of electricity produced by oil fired power stations is 20 yen per KWh, while in the case of nuclear power stations, it is 12 yen per KWh and, in the case of coal, 15 yen. Because of economic considerations, priority is being given to nuclear power by the electric power companies.

Let us now turn to the nuclear cycle.

First, uranium. In spite of extensive exploration carried out by the government and the Power Reactor and Nuclear Fuel Development Corporation, uranium reserves confirmed to date in Japan are only 10,000 short tons of U_3O_8, which is not at all sufficient for our requirements. Electric power companies have secured the supply of 193 thousand tons of uranium from Canada, Australia, the U.K. and some other countries by long term contracts, which cover the uranium requirements of Japan up to the middle of the 1990's.

Second, the enrichment of uranium. Enrichment services are mainly provided by U.S. and supplemented by France. The U.S. Department of Energy will provide enrichment services corresponding to the requirements of nuclear power plants totaling 51,000MW, while the French Eurodif will meet the enrichment requirements for the nuclear power plants totaling about 9,000MW. The U.S. and French enrichment services will cover the needs of the nuclear industry until about 1990. In Japan, a centrifuge enrichment pilot plant of the PNC, with 7,000 units, started in operation in March 1982. A commercial enrichment plant is expected to be in operation by the end of the 1980's and its capacity will be increased gradually to approximately 3,000 ton SWU/year by the year 2000.

Third, the fabrication of nuclear fuel. Four private companies are in charge of reconversion and fabrication of nuclear fuel. Two companies undertaking a major part of the fabrication of nuclear fuel for light water nuclear power plants are joint ventures with U.S. companies. This is the area where commercial operation of the nuclear fuel cycle industry has been established.

Fourth, reprocessing. In Japan, a small reprocessing plant owned by the Power Reactor and Nuclear Fuel Development Corporation with a capacity of 0.7 tons per day has been in operation since 1977. As the plant is too small to meet our reprocessing demands, most of the spent fuel from the nuclear power plants in Japan is sent to BNFL in the U.K. or COGEMA in France for reprocessing. 4,300 tons of spent fuel from the light water reactors are scheduled for reprocessing in Europe. In 1980, the Japan Nuclear Fuel Service Co. Ltd. was set up by the electric power companies and other companies within the nuclear industry and is planning to start the operation of a commercial reprocessing plant of 1,200 tons per year around 1990.

Fifth, the fabrication of MOX fuel. At present, the plutonium separated during reprocessing is used as fuel for an experimental fast breeder reactor "JOYO" and for a prototype advanced thermal power reactor "FUGEN". The MOX fuel fabrication plant owned by PNC has a production capacity of 1 ton per year for JOYO and 10 tons per year for FUGEN. Since the construction of a 280MW prototype breeder power plant is about to be started, an additional MOX fuel plant will be built to fabricate fuel for the prototype FBR.

As one looks at the nuclear fuel cycle in Japan, it is clear that each section is in transit from development to industrial capability. While nuclear power plants in the 1970's went through the process of industrialization, the nuclear fuel cycle services are moving towards industrialization in the 1980's. In Japan, the Power Reactor and Nuclear Fuel Development Corporation, the government corporation, has undertaken the development of domestic enrichment, reprocessing and MOX fuel plants, while the utilities have depended on overseas supplies of their fuel cycle needs. New private companies set up or to be set up by the electric power companies and others, will start building and operating commercial plants in the field of enrichment and reprocessing.

According to the long term program of the Atomic Energy Commission, approximately 20,000 billion yen will be required for the years to 1990, of which 14,000 billion yen for nuclear power plants and related facilities and 5,400 billion yen for research and development. It is foreseen that the nuclear industry will grow up in the 1980's with more nuclear materials circulating around nuclear fuel cycle.

SAFEGUARDS SYSTEM

Keeping in mind the development of the nuclear industry, we would like to outline the safeguards system in Japan.

As mentioned before, to use nuclear energy for peaceful purposes only was set as the basic principle in Japan. A regulatory system for this purpose has been developed from the outset. It is based on requirements within Japan. However, there have also been similar requirements to confine the use of nuclear energy to peaceful purposes from outside Japan. They are of two kinds. First, there are requirements under bilateral agreements, and second, there are requirements under multilateral agreements.

In the latter part of the 1950's, Japan concluded atomic energy agreements with the U.S., the U.K. and Canada. Safeguards measures were provided in the agreements to verify the fulfillment of such requirements of nuclear energy for peace. In the 1960's, the implementation of these bilateral safeguards was transferred to the International Atomic Energy Agency. As practically all the nuclear material in Japan was imported under bilateral agreements and subsequently placed under IAEA safeguards, Japan was the biggest and best "customer" of IAEA safeguards in the 1960's.

In 1970, the Non-Proliferation Treaty came into force. New safeguards measures required by multilateral agreements emerged. Concerning NPT safeguards, the unique idea was introduced that the IAEA should make the best use of national safeguards systems and that IAEA safeguards should be implemented to verify findings of the national safeguards systems. The appropriate safeguards system for Japan was much discussed before Japan joined the NPT. In 1976, Japan ratified the NPT. When the safeguards agreements were concluded between Japan and the IAEA at the end of 1977, the legal framework for the national safeguards system was also further strengthened.

From the explanation above, it is quite clear that the safeguards system in Japan is designed not only to ensure that nuclear materials are used for authorized purposes, just as in the case of U.S., but also to facilitate implementation of IAEA safeguards. This second aspect is important in our safeguards system.

The organizational structure and functions of the safeguards system in Japan are shown in Fig. 1.

Two characteristics may be observed. The first is that the national safeguards system is a comprehensive system containing not only a reporting system but also verification measures. Second, while the Safeguards Division of the Science and Technology Agency is responsible for the implementation of safeguards, a substantial part of the work is entrusted to the Nuclear Material Control Center. The NMCC, equipped with a computer center and a Safeguards Analytical Laboratory, undertakes the technical part of safeguards implementation.

As of December 1981, 4,076 tons of enriched uranium and about 9 thousand Kgs of plutonium circulated in the nuclear fuel cycle. About 6 thousand Kgs of plutonium are stored in the cooling ponds of the power reactors.

Let me explain what safeguards implementation involves.

1) Reporting

203 nuclear facilities of 112 companies or institutes in Japan submit to the government monthly reports on material accountancy and also the reports at the time the physical inventory is taken. These reports on accountancy data per batch increase in number every year, from 53 thousand in 1978 to 112 thousand in 1981; they more than doubled in three years and there was an accumulated total of 379 thousand in 1982. All the reports are processed and collated by computer at the NMCC and then sent to the IAEA.

2) Verification

The Minister of the Science and Technology Agency designates 15 national inspectors who inspect all the nuclear facilities in Japan, including the reprocessing plant, and appoints 81 safety inspectors from the Ministry of International Trade and Industry as inspectors who carry out safeguards inspection on commercial nuclear power plants. National inspection efforts have been gradually increasing from 830 man-days in 1979 to 1,289 man-days in 1981, so that IAEA inspections could depend more on national inspection. Inspection efforts on the reprocessing plant is much higher than that on the rest of the facilities, occupying 40% of the total and surpassing IAEA inspection effort.

Samples taken by the inspectors are sent to the Safeguards Analytical Laboratory on NMCC for analysis. In 1981, the analysis of 498 uranium samples and 165 plutonium samples was carried out. Also, the inspectors apply seals and install cameras at appropriate places in the facilities for containment and surveillance purposes. The results of the inspections are analyzed for verification.

Through the discussion at INFCE, IAEA safeguards have come to attract more attention than before. An improvement in safeguards has come to be a necessity. The Safeguards Committee

of the Atomic Energy Commission of Japan last October produced a report on how to improve our national safeguards system, with a view to increasing the effectiveness of IAEA safeguards, and taking into consideration the foreseeable growth of the nuclear industry. The following suggestions were made: First, to develop measures to control nuclear materials in the nuclear fuel cycle. So far, IAEA safeguards have been concerned with the material balance in a facility or a Material Balance Area. It is useful to build new devices to control or trace the nuclear materials circulating around the whole nuclear fuel cycle. Second, the priority areas of safeguards application should be identified. For example, more weight might better be placed on the facilities using plutonium or highly enriched uranium. Third, safeguards devices should be incorporated into a facility at the design stage. As nuclear facilities in the future become more automated, safeguards elements must be integrated into the design of the facilities. Fourth, safeguards measures should make use of or rely on the process control and quality control of the facility operation. These four items indicate the direction in which more effort should be made to improve the national safeguards system.

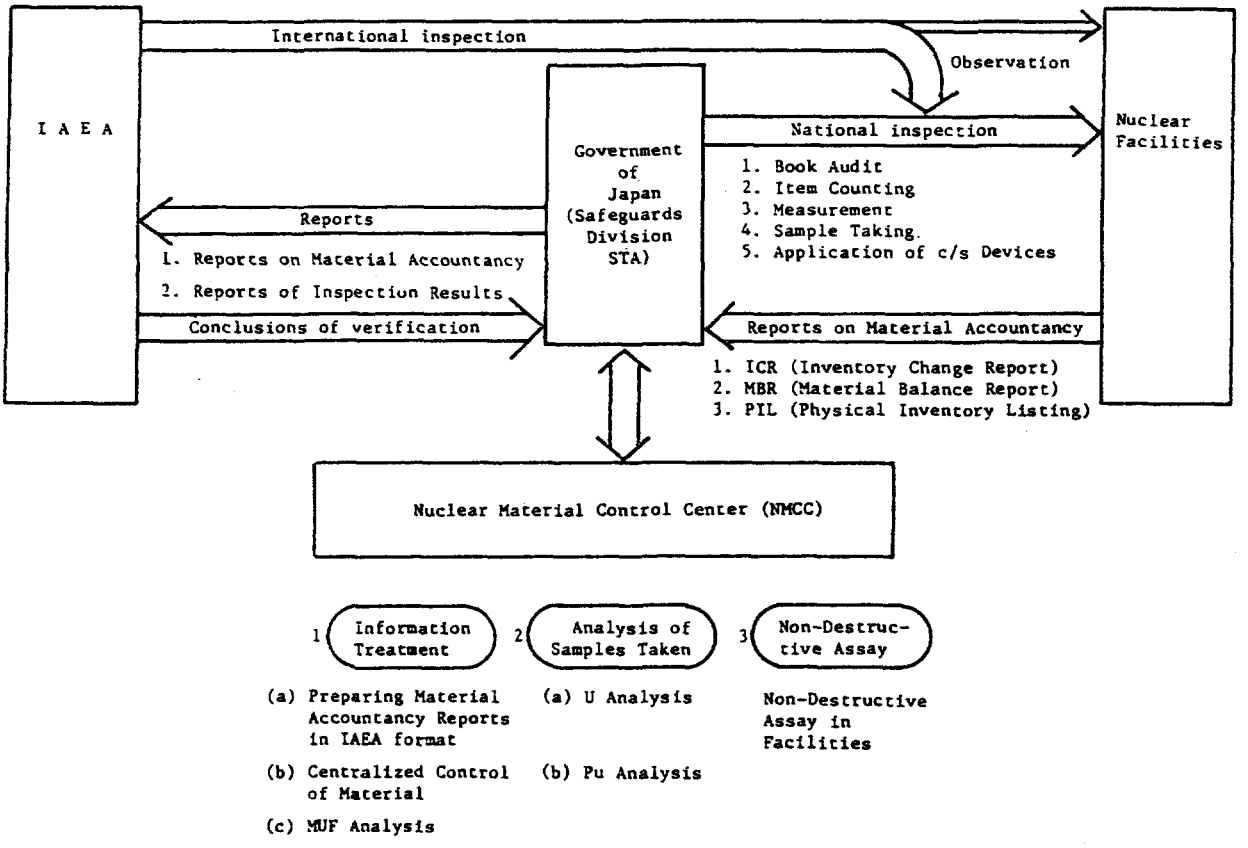
As the nuclear industry is intending to establish new commercial fuel cycle facilities in the 1980's, there is an urgent need to find out what are the best safeguards measures for an enrichment plant, a reprocessing plant, a MOX fuel fabrication plant, etc. Safeguards concepts on these plants, if they are to be incorporated at the design stage, must be formed well in advance of the operation of the plants. Moreover, that a particular safeguards concept for a facility is acceptable to Japan is not enough. The same safeguards concept has to be accepted as effective by other countries and the IAEA as well. The TASTEX project was the joint safeguards research and development project of Japan, the U.S., France and the IAEA to make safeguards on the Tokai reprocessing plant more effective. The Hexapartite project is a cooperative effort of Japan, the U.S., Urenco, Australia, the IAEA and Euratom to obtain a unified approach to safeguards on a centrifuge enrichment plant. JASPAS is the Japanese support project for IAEA safeguards. It is expected through the project that the research and development of safeguards in Japan will contribute to the improvement of IAEA safeguards.

CONCLUSION

One of the most important questions concerning IAEA safeguards is how to increase their effectiveness. In most cases, discussions on the effectiveness of safeguards are made from the viewpoint of those applying safeguards. However, in the discussion about international safeguards or IAEA safeguards, it is also necessary to look into the question from the viewpoint of those receiving safeguards. When we discuss this problem, it may also be necessary to distinguish between safeguards under NPT and safeguards not under NPT. Non-Nuclear Weapon States of NPT make commitments not to use nuclear energy for explosive purposes. For member states, safeguards under NPT is meant to demonstrate to the international community through IAEA that nuclear energy is not used for explosive devices in their countries. In this context, national safeguards system could become a useful device to increase the effectiveness of IAEA safeguards. The more the nuclear industry grows, the more complicated becomes the flow of nuclear materials. The national safeguards system is more suitable for grasping precisely the location and flow of nuclear materials through the nuclear fuel cycle. Japan, since the early 1960's, has cooperated with the IAEA for implementation of safeguards. The government of Japan spent 1,352 million yen for fiscal 1981-2 for implementation and development of safeguards. This excluded the cost of government inspectors and staff for safeguards, and corresponds to 0.5% of government expenditure for nuclear energy. One could ask why the government spends that amount for a national safeguards system to facilitate implementation of IAEA safeguards. The answer is that to make a national system more effective will lead to increasing effectiveness of the IAEA system, serve to demonstrate to the international community through IAEA safeguards the fact that nuclear energy in Japan is used only for peaceful purposes, contribute to an increase in mutual confidence in the international community and facilitate the free flow of nuclear materials and technological information in t e nuclear fuel cycle. IAEA safeguards are maintained effective when a recipient government cooperates with the IAEA. It is desirable to increase the number of countries which cooperate with the IAEA safeguards and to increase mutual confidence among these countries. The safeguards system in Japan is not regarded as the mechanism to absorb safeguards imposed from outside, but as the mechanism established by Japanese initiatives to demonstrate to the outside world through IAEA the fact the nuclear energy is used for peaceful purposes.

It is said that shaking hands was originally meant to show that the hand shakers have no weapons in their hands, but now shaking hands shows mutual friendship. I hope the international safeguards will be developed as something which increases our mutual confidence in promoting peaceful uses of nuclear energy.

Fig. 1 Safeguards Implementation System in Japan



THE PEACEFUL ATOM AND NATIONAL SECURITY

HERMAN E. ROSER
Assistant Secretary for Defense Programs
U.S. Department of Energy
Washington, D.C.

ABSTRACT

This presentation develops the relationship between the primary mission of the organization under DOE's Assistant Secretary for Defense Programs and the national and international safeguards programs. It discusses the reasons why DOE and Defense Programs are and will continue to be directly concerned with national and international safeguards, regardless of where the DOE's Defense Programs activities are located in the government. The Defense Programs organization is expected to remain essentially as it is now constituted. The presentation identifies and analyzes the differences and similarities among the domestic safeguards and security activities, the domestic accountability activities, and the international safeguards activities.

INTRODUCTION

I am very pleased to be here with you at this Institute of Nuclear Materials Management Annual Meeting to discuss why safeguards and security missions are under my jurisdiction and to share my thoughts on the relevant institutional arrangements for the immediate future.

As you know, my primary mission is to manage the Defense Programs activities of the DOE. These activities primarily embrace research, development, testing, production, and retirement of U.S. nuclear weapons. This program is budgeted at more than 4 billion dollars in FY 1982.

The Defense Programs' activities also include a number of corollary functions. These are:

I. The production of plutonium, tritium, and other isotopes for nuclear weapons, as well as for the DOE reactor programs and R&D programs for other government agencies and industry;

II. Defense waste management;

III. Research in inertial fusion (for applications to both nuclear weapons and power generation); and

IV. Three special security activities which directly support the Department's nuclear weapons and energy objectives, including nonproliferation. These are:

- Classification and declassification policies and procedures;
- International security affairs activities which include:
  - -- participation in arms control negotiations;
  - -- control of exports of both technical information and nuclear materials and hardware;
  - -- a continual intelligence evaluation activity to assure that all relevant factors are integrated into DOE's (particularly Defense Programs) policies and activities.
- Safeguards and security activities, which include the protection of DOE facilities, classified information, nuclear weapons, and nuclear materials in DOE's custody.

DP AND SAFEGUARDS AND SECURITY FUNCTIONS

It is a fact that the major portion of DOE classified activities and special nuclear materials are directly involved in the DOE nuclear weapons activities. Protecting nuclear weapons data, facilities and materials from any malevolence is an obvious responsibility of DP. In our domestic system of protection we include material control and accountability functions primarily to provide a backup detection capability to our security systems and to facilitate tracing any thefts which somehow might defeat our security systems.

The technology and the expertise we use in connection with protection of the weapons program are directly applicable to protection of other DOE nuclear activities and to international safeguards. Finally, the expertise

that exists in the nuclear weapons program is essential to evaluating the potential proliferation value of data, hardware and materials. Such evaluations are critical elements in international export and safeguards policies.

DOMESTIC PROTECTION AND INTERNATIONAL SAFEGUARDS

It is important to note, however, that there are some very substantial differences between the material control and accountability measures needed for domestic protection systems and those needed for international safeguards systems even though the technologies are the same. The differences begin with the systems' objectives.

Our domestic protection systems are aimed at preventing theft or sabotage while international safeguards are aimed at detecting diversion and thereby deterring same. The potential domestic system adversary is an impossible to quantify variable since it includes a mix of psychotics, political dissidents, disgruntled employees, etc. The assumed international safeguards adversary is a quantified constant, the state itself.

I commented earlier that the role of materials control and accountability is to backup the security system by providing for detecting any thefts that might somehow escape security systems detection. It also serves as a means of tracing and hopefully recovering stolen items. In the international systems, material control and accountability is the primary tool and it is used only for detecting possible diversion.

It is valuable at this point to reemphasize the role of international safeguards. I believe that the clearest way of doing this is the way Dr. Hans Blix, Director General of the IAEA, characterized it in his meeting with representatives of the media on December 11, 1981, shortly after assuming his new duties. Dr. Blix said:

> "It would be wrong to see these safeguards as any kind of control imposed from the outside. Rather, as I said, they are measures through which States, in the exercise of their sovereign will, rely upon an international organization to confirm through inspection that their actions conform to their stated intention not to acquire nuclear weapons. Since these States wish to convince the outside world of their continuing nonnuclear weapon status, it is in their proper interest that the safeguards should be effective.
>
> The safeguards they agree on may also make it possible for them to import nuclear material and equipment and acquire nuclear technology. This may certainly increase their readiness to accept safeguards.
>
> Essentially then safeguards are there to demonstrate that safeguarded material or equipment is not diverted or used for the production of nuclear weapons or for any other military purposes."

BASIC STEPS IN DEVELOPING SECURITY AND INTERNATIONAL SAFEGUARDS SYSTEMS

The basic steps in both a domestic protection system design and an international safeguards system design are the same, but the values are substantially different. They begin with the threats to be addressed. In the case of a domestic system, it is clear that the threat which the system must address is a variable and a function of the social environment. In the case of an international safeguards system, the threat is much simpler. The goal of the international system is to enable an independent international body to assure a State's neighbors that the first State is living up to its peaceful nuclear commitments. The threat that the system must assume, therefore, is the State itself. Thus, while both a domestic protection system and an international safeguards system must start with the threat, the domestic system potential adversaries are varied, while the international system assumed potential adversary is constant.

The next step for both systems is to identify the adversary sequence or diversion paths that might be used by the threat. Here again the domestic and international systems must go through the same steps. The domestic system needs to address the problem of some insider collaboration, while the international system must assume collaboration by all insiders. Notwithstanding, the basic process is, in fact, the same.

The next step, of course, is to design the system itself. In the case of the domestic system, we look for prompt detection and response. In the international system we look for early detection. The international system does not incorporate, for obvious reasons, any direct response to an adversary act in process, but rather relies on political sanctions after detection and report.

THE FORESEEABLE FUTURE

It is clear to me that the DOE's Defense Programs' organization will, in the near-term, continue to be actively involved in the development and improvement of both domestic protection systems for all nuclear activities and international safeguards systems. We must look as far into the future as possible to see how the coming developments in nuclear energy may pose different kinds of problems to the technological community, and may separate the technology for domestic protection from the technology for international safeguards. We need to continue thinking creatively. For example, in laser fusion we not only must be concerned with that

technology directly contributing to proliferation, but we must also be concerned with the technology providing a much more easily achievable source of high energy neutrons which themselves can be diverted to the production of special nuclear materials and, thereby, aggravate proliferation concerns. It is a challenge for all of us to remain alert to new problems and to continually examine the question we discussed a little earlier as to what institutional arrangement makes the most sense in a given set of circumstances.

Just one final word on the expected impact of possible DOE reorganization on the Defense Programs' activities in the safeguards and security arena. If the Defense Programs' activities are shifted to another cabinet department, what will happen to Safeguards and Security? The one element that has remained constant in all organizational plans considered to date is the integrity of the Defense Programs' institutional structure. I have every confidence that whatever happens to the DOE, there will be a DP organization with a strong domestic protection function. If DOE international safeguards responsibilities do not remain with DP, there will certainly be an arrangement to insure an appropriate role of DP program expertise. In any event, I wish to assure you that I will work toward adequate visibility and resources for the safeguards and security programs.

Thank you.

DOE'S SAFEGUARDS AND SECURITY PROGRAM PRIORITIES

RALPH E. CAUDLE
Director, Office of Safeguards and Security
U.S. Department of Energy
Washington, D.C.

ABSTRACT

This talk develops the relationship between the capabilities of key Department of Energy nuclear facilities to guard against successful adversary actions and the overall threat of adversary actions against those facilities. It recognizes the critical role of an independent inspection and enforcement program to help identify where the major vulnerabilities exist. It then addresses the high priority being afforded to the support role that the Office of Safeguards and Security plays in assisting the facilities with vulnerabilities to affect changes that will eliminate such vulnerabilities. These two important functions, namely, assessment and facility upgrade, are then discussed in the context of the overall safeguards and security program.

INTRODUCTION

Effective energy program safeguards and security is of vital importance to U.S. national security interests. My presentation recognizes that importance and discusses briefly the evolution of our most important energy program's safeguards and security policies. It also describes the major aspects of our current DOE institutional and programmatic approach to carrying out our safeguards and security mission.

Since the late 1960's when the AEC centralized its domestic and international safeguards functions, there have been concerted efforts to assure a graded domestic protection system which provides adequate and consistent protection. The early efforts reflected recognition of the need to integrate the elements of security with the elements of nuclear materials control and nuclear materials accountability in the domestic system, with the latter two elements also forming the focus for international safeguards. In 1974, AEC combined in one organization its Safeguards functions and its Security functions. This was a start towards integration of the functions.

When ERDA came into being in the mid-1970's, the attention of the Safeguards and Security staff was focused on the need to assess the domestic safeguards and security performance of field organizations, not so much in terms of compliance with requirements, but in terms of the system's effectiveness.

Those of you who were involved in these activities in the mid-1970's will also recall that this was the era in which considerable national attention was directed at acts of international terrorism which were on a clear path of escalation. As a consequence, our attention was oriented to deal with the awakened concern of the National Security community to violent transnational threats.

FOCUS OF PRESENT SAFEGUARDS AND SECURITY ORGANIZATION

In many respects I am most fortunate to have been handed the mantle of responsibility for Safeguards and Security at this time when our reaction to terrorism has matured and is no longer largely reactive. It is now possible to focus on the objective of effective and uniform graded safeguards without serious distraction. Let me hastily add that I do not, by any stretch of the imagination, suggest that the threats of international terrorism or other acts of violence have subsided. On the contrary, though I wish in the national interest that this were the case, I regrettably see no evidence to support such a happy conclusion. However, what I do see to be the case, is a more orderly reaction by the Executive and Legislative Branches of the government. We do have our brush fires to be sure, but they have approached a level of orderly sophistication, with considerably less "knee-jerk" reaction than was present in the past. This is very much to our national advantage since it enables us to be more deliberate and professional in dealing with the challenges we face.

SAFEGUARDS AND SECURITY INSTITUTIONAL FOCUS FOR THE 1980'S

As a result of the quieting of the waters so to speak -- the reorganization of the DOE's Safeguards and Security function (announced this past December) provides for a triad of major

elements which, in my judgment, will help us achieve the long-sought goal of an effective and graded protection system throughout the DOE complex.

The first element of our triad is a performance-oriented inspection and evaluation program reporting directly to me. This program will provide oversight review of the fields' Safeguards and Security programs. Within this program, we will carry out inspections of DOE Operations Offices and carry out evaluations which include analyses of problem areas to ensure that appropriate follow-up activities are taken. And here I would like to note that the fix can be in either the HQ-originated policy or in the implementation of that policy. We are also conducting special studies to provide an in-depth comprehensive review of the most significant Safeguards and Security issues we discover during our inspections and evaluations. Through these mechanisms we believe we can avoid the trap of developing ideal Safeguards and Security systems which have little, if any, practical or realistic application possibilities. In short, we are not going to let the "best" become the enemy of "good". Moreover, by essentially using the same experts in all of our assistance work and the same methods we can at least attain some degree of uniformity. This program is new but I can state that the early returns are encouraging.

The second element of our triad is a program to provide assistance to DOE field offices and their operating contractors in maintaing a continuing capability for application of current Safeguards and Security technology. This new focus on assisting field offices, in fact, provides us with two advantages. Not only do we have feedback from our inspection teams, but by putting our technical laboratory expertise to work in assisting field offices and their contractors, we are creating another common link to better understanding where our R&D focus needs to be, in the near- and long-term.

The third element of our triad is our Safeguards and Security Improvement Program. This is addressing existing DOE facilities which, in some cases, because they were built many years ago in an entirely different environment, are not ideally designed to facilitate the application of current, sophisticated Safeguards and Security systems. Early this year the Deputy Assistant Secretary for Defense Programs requested DP offices to identify critical Safeguards and Security needs. My office was assigned responsibility for coordinating the task with the field and program offices involved. We will assist in the evaluation of need, the establishment of priorities, and finally, with implementation. We are approaching our task on a dual track. We will first identify the "quick-fixes" for the major inadequacies, and concurrently we will look at the long-range, permanent improvements necessary. This activity will expand beyond the Defense Program area to ultimately include all DOE programs with security interests.

These are the three principal areas of focus of our reorganized approach to Safeguards and Security. As you can see, we have not created something entirely new. What we have done is to sharpen our focus. However, this will not be done at the expense of our other functions reflected in previous institutional arrangements. We are, for example, not only continuing our activities in the Nuclear Materials Management Safeguards System (NMMSS), but we have expanded the responsibilities of that group to include a focus for nuclear materials accountability responsibilities. We will continue to support all international safeguards responsibilities and the nonproliferation initiatives of the United States, and we are continuing to carry on (with a high level of management support) our international R&D and technology programs.

CLOSING REMARKS

My staff is very actively engaged, at this time, in what has proven to be a major exercise of delineating a long-range plan for our Safeguards and Security program. I am sure it will come as no surprise when I tell you that we are having considerable difficulty in producing such a comprehensive approach to our mission. I can promise you, however, that we will solve this problem and when we do, many of the questions that repeatedly occur on how, when, where, and why we do things, will be clearly answered.

In closing, let me assure you that we place a very high value on the feedback we receive from the field office and contractor officials, and we would welcome comments and suggestions in all areas of our Safeguards and Security activities. Please do not hesitate to provide me specific comments or suggestions related to my remarks today, or to any of the activities under my jurisdiction. We are trying to simplify the means by which you can communicate with the right members of our staff by setting up a series of ombudsmen, but if all else fails, I would be most pleased to receive direct communications, telephonically or otherwise, from one and all.

Thank you.

MAIN FEATURES OF THE EURATOM-IAEA SAFEGUARDS R AND D COOPERATION PROGRAMME

R. KLERSY[+], M. CUYPERS[+], B. LOVE[++]
Commission of the European Communities
+Joint Research Centre, Ispra, Italy
++Safeguards Directorate, Luxembourg

ABSTRACT

In the frame of a general cooperative programme between the European Atomic Energy Community and the International Atomic Energy Agency signed in 1975, an exchange of letters between the two organisations took place in May 1981, defining specific areas of safeguards R and D. These areas are related to containment and surveillance, measurement technology, information data treatment and evaluation, and training.

On the basis of the existing experience of safeguards implelentation by Euratom and related R and D work at the Joint Research Centre (JRC), a number of tasks have been defined, which are essentially orientated to the technical aspects of the international safeguards inspection activities. Emphasis is also put on the harmonisation and standardisation aspects, in particular, in the area of technical procedures, data output compatibility, data evaluation for measurements and material balance evaluation and procurement of reference materials for destructive and non destructive assay of fissile materials. Finally, some JRC developed techniques related to ultrasonic identification of seals or the applicability of a transportable mass spectrometer are specifically treated in this cooperation programme.

INTRODUCTION

The efforts of the International Atomic Energy Agency (IAEA) in developing and applying an effective safeguards system to the nuclear fuel cycle are well known and widely supported.

The European Atomic Energy Community shares the concern of the IAEA for improved standards of safeguards.

The Commission of the European Communities has the duty, by virtue of the EURATOM Treaty, of establishing and implementing the Community safeguards system in the EC countries. The Euratom safeguards system, while independent, contributes also to the application of safeguards as defined by the Non Proliferation Treaty. To assist in implementing its control responsibilities, the Commission has, since 1969, been carrying out a safeguards R and D programme executed in its Joint Research Centres.

A formal cooperative support programme between the IAEA and EURATOM has recently been signed by which the Commission proposes to exchange with the IAEA its continuing technical experience developed over many years, principally in the area of R and D and its practical implementation by inspectors in European nuclear facilities.

The exchange of letters of May 1981 between the Director General of the IAEA, S.Eklund, and the Commission's Vice President, W.Haferkamp, stated that the cooperation programme should result in technical assistance to the IAEA, in the harmonisation of techniques and procedures of potential use in safeguards implementation and in the evaluation of priorities of R and D as a function of the requirements of the application of safeguards in the EURATOM fuel cycle.

SCOPE OF THE COOPERATION PROGRAMME

The specific activities of the cooperative support programme are described in a technical annex comprising twenty seven tasks in the following main areas:

- containment and surveillance
- measurement technology
- training
- information, data treatment and evaluation

The main characteristics of the tasks are that they address technical problems of direct interest to international safeguards inspectors and are oriented to the development of practical tools (instruments and evaluation methods) and their test in field conditions. Much emphasis is put on standardisation and harmonisation aspects of measurement techniques, data generation and evaluation and preparation of reference materials. This should contribute substantially to the harmonisation of inspection procedures in joint inspection teams, where these are implemented.

The interaction with the IAEA is performed in different ways. Through several tasks, results of R and D work are provided in a timely manner to the IAEA, which would allow the inspectorate, as is already the case for EURATOM, to make valuable suggestions for improvements before the design of measurement systems or information systems is finalised.

In the frame of other tasks, equipment and information systems, mainly developed at JRC, are made directly available to the IAEA for test in field conditions or at headquarters. In other cases, participation of IAEA staff is arranged in experiments being performed by JRC staff in European facilities. In each case, the IAEA informs the JRC of its findings and suggestions, which become the basis for further improvement.

GENERAL DESCRIPTION OF TASKS AND PROGRESS

The complete list of tasks relating to the four areas of safeguards R and D mentioned above is summarised in Table 1. A general description is now made of the main features for each area.

A. Containment and Surveillance (C/S)

Eight different tasks have been defined for C/S.

They are principally related to the development or adaptation of ultrasonic testing techniques for the unique identity and integrity verifications of seals on a variety of materials. In particular, a seal has been developed for CANDU fuel storage casks (1). Several in-field tests have been conducted for under water identity taking of the seals in spent fuel storage pools. Improvements are under study in the seal marking and in the ultrasonic identification procedures for achieving higher identification reliability. The same ultrasonic principle is being studied for sealing fast reactor fuel bundles and MTR fuel assemblies.

A new type of general purpose seal has recently been designed.(2) It is based on the introduction of a low cost transducer inside of the seal, which greatly simplifies the identification procedure. A small industrial series of 200 seals is now under construction. Field tests of these seals by IAEA and EURATOM are foreseen during 1982.

The principle of the integrated transducer has also been applied for the unique identification and integrity test of six hundred U_3O_8 NDA reference materials for uranium 235 enrichment measurement, prepared by JRC Geel and US NBS in the frame of an ESARDA common project.(2) A final acceptance test of the standards and their identification by EURATOM and IAEA inspectors will be performed soon.

The above mentioned applications of ultrasonic techniques, together with the considerable effort invested in the frame of the Federal Republic of Germany support programme, and also in cooperation with SANDIA laboratories, for the sealing of LWR fuel bundles,(3) have the aim of demonstrating the applicability of one single sealing technique to a large variety of materials in the fuel cycle. This could introduce an important factor in the standardisation of procedures in the area of C/S.

In the area of surveillance techniques, a TV system (4), intended to achieve long term reliability in unattended operations, has been the subject of a development programme undertaken for the Safeguards Directorate.

This system has been offered to the IAEA for joint testing in field conditions.

B. Measurement Technology

Fifteen tasks have been defined and are related to destructive assay techniques and reference materials preparation, to non destructive assay techniques and to isotopic correlation techniques.

Concerning destructive assay techniques, a special emphasis is placed on the preparation and/or characterisation for the IAEA of reference materials or spike solutions for use in analytical assay of fissile materials. Furthermore, the procedures followed in the setting up and organisation of the interlaboratory exercises, incollaboration with ESARDA, on uranium determination in UO2 pellets and uranium isotopic determinations in UF6, will be illustrated to the IAEA, without specifying results of individual laboratories. For both exercises, the samples have been distributed to the participating laboratories and the results have been in part returned. The above activities are performed by the Geel establishment of the JRC.

In a study of the methods for independent calibration by inspectors of input accountancy tanks using spiking techniques (Mg, Lu), several experiments are planned at the EUREX reprocessing plant in Italy later this year with the presence of IAEA staff.

A special mention has to be made of the recent results obtained in the isotopic analysis of UF6 samples for low enriched uranium (up to 6%) with a transportable quadrupole mass spectrometer developed at the JRC, Ispra. (5) Two measurement campaigns have been performed in two enrichment facilities. One campaign was performed in the frame of the Hexapartite Safeguards Project and in collaboration with BNFL (Capenhurst). Very satisfactory results were obtained in field, generally within 0.05% of the plant operators measurements. In the worst case, the measurement differed by 0.3% relative to the declared figure and this was for depleted uranium.

In the field of isotopic correlation techniques, assistance was given by the Karlsruhe establishment of the JRC in the organisation of a data bank for inspection results from spent fuel reprocessing campaigns. Furthermore, as a follow up of an isotopic correlation experiment (ICE), performed at the WAK reprocessing facility (6), procedures for automatic data evaluation of reprocessing safeguards analyses are now being studied. This study is also closely coordinated with related tasks in the Federal Republic of Germany support programme.

For non destructive assay, further development is planned for the active interrogation Phonid instrument, which is based on the subthreshold neutron interrogation ($(Sb^{124}-Be)$ neutron source) and prompt fission neutron detection (with He^4 detectors).(7) This measurement system has been designed for the assay of bulk quantities of uranium (200g to 4Kg of uranium enriched up to 90%) and is currently used in inspection activities of EURATOM and IAEA in a European facility. The new study is related to the application of Phonid type instruments to bulk quantities of low enriched uranium in a fuel fabrication facility.

Special interest was expressed by the IAEA in making available to the inspectors a calibration laboratory for NDA equipment. Starting with the existing nuclear materials and basic detection equipment and handling facilities at the JRC, this laboratory will gradually be enlarged so as to meet the needs of both the IAEA and EURATOM inspectors.

Particular attention has to be paid to the task on NDA measurement data transfer. In this task, an approach to microprocessor based NDA instruments for data generation and evaluation is proposed.(8) A special standardised intelligent terminal, called IRIS, has been developed. The terminal assures the man-machine interaction through a keyboard, the display, the data output on a printer and the data storage on a magnetic cassette. The terminal is linked to the specialised host microcomputer of the measurement instrument. The same type of terminal is used for all automated NDA instrumentation. This assures a standard physical and logical data support and a standard format for the inspection, calibration, raw measurement and the in-field elaborated data. These complete sets of data, stored on a cassette tape, are brought back by the inspectors to the headquarters. This enables the validation at headquarters of the results obtained in field, and their further treatment. This principle has now been applied in practice to an active interrogation system and to a gamma-ray spectrometry-based uranium enrichment meter. A similar instrument is being built for plutonium isotopic ratio measurements in the frame of the Federal Republic of Germany support programme. It is the intention to equip all NDA instruments with the required hard and software to comply with this standard approach. These measurement systems will eventually be supplied to both the EURATOM and IAEA inspectorate.

Finally, an important task is related to the preparation of procurement schemas for NDA standards for a variety of finished products in the fuel cycle, such as fuel rods for LWR and fast reactor fuel, MTR fuel elements, fuel pebbles for THTR reactors. (9) These plant specific reference materials have to be prepared from production samples and independelty characterised, mostly by NDA in the plant and DA in a safeguards laboratory.

From the existing experience at the JRC and EURATOM Safeguards Directorate, this task proposes the preparation of general guidelines to be applied in the establishment of detailed proceduresfor the procurement, independent characterisation and certification by safeguards inspectorates of plant specific reference materials.

C. Training

The training of inspectors is foreseen mainly in three areas namely: use of non destructive and destructive techniques and of

ultrasonic identification of seals.

For non destructive assay, training is now organised for the application of neutron coincidence measurement systems. This programme is to be enlarged to include the use and evaluation of measurement data of instruments developed by JRC and used in European facilities by EURATOM and IAEA inspectors. In the near future, training of IAEA staff in the analytical laboratories of the JRC for the application of specific destructive assay technique is foreseen.

D. Information, Data Treatment and Evaluation

The JRC has developed in the past a nuclear material statistical accountancy system (NUMSAS) (10), for the evaluation of MUF for one material balance period, with the automatic interpretation of the declarations made by operators to the EURATOM Safeguards Directorate. Another feature of this system is the LEMUF evaluation, based on the detailed analysis and correct assignment of the measurement error sources, linked to the declaration of each batch of nuclear material.

This accountancy system has been applied or adapted by more than ten major bulk handling facilities in Europe and the EURATOM Safeguards Directorate. Recently, the NUMSAS code was installed on the IAEA computer and tested on a set of reference data.It is the intention to install in the near future at the IAEA also an extension of the NUMSAS system, but for the analyses of multibalance periods and/or multibalance areas, called ISADAM.(11) This system is implemented under the powerful data base management system ADABAS.

One task is to address more particularly the problems of how a near real time accountancy system, installed by an operator for management purposes, could be of efficient use for International Safeguards Authorities.

A pilot experiment of near real time accountancy is being executed now, and, after the approval of the plant operator, the general results of the study will be communicated to the IAEA. This type of study will also be performed in close cooperation with related tasks in the UK support programme.

Finally, the JRC and IAEA are cooperating in the design of a verification action plan for inspectors. One activity consists of the evaluation of the performances of two existing codes (INSPEC from Batelle North West and SASSET from JRC), (12). Another activity is the study of a system to be used in field. This field data processing system, to be installed on a portable microcomputer, is intended for the design of a sampling plan to be followed by an inspector, taking into account the real plant conditions (location of material, material description, measurement system available, personnel and time available to the inspectors, etc.). Some aspects of the Expert System technology will be implemented in this design.

CONCLUSIONS

In the general description of the cooperative R and D work with the IAEA, we have tried to show how, in the different tasks, the emphasis is put on the two main elements, namely, the development of inspection tools for immediate or future use and an approach to harmonisation and standardisation in the technical areas of safeguards.

It is also of great importance, in order to reach a high degree of standardisation, that the R and D effort, developed now in many countries, is well coordinated. In connection with the IAEA cooperation and support programme, the CEC is paying special attention to coordinating its own programme with support programmes of EC Member States, namely, the Federal Republic of Germany and the United Kingdom. The mutual exchange of information on the content and progress of the specific tasks in these programmes is in fact effected by the presence of observers from EURATOM Safeguards Directorate and JRC staff in the Joint Steering Committees with the IAEA for these programmes. Furthermore, the JRC informs the Member States of the European Community on the progress of its own IAEA cooperation programme through an Advisory Committee on Programme Management, covering all the safeguards R and D activities of the JRC.

We are aware of the substantial effort made by the Division of Development of the IAEA in coordinating the increasing number of support programmes to the IAEA. The special session organised by Mr.A.Von Baeckman, in this 23rd Annual Meeting of the INMM is an important means of establishing contacts and exchange of mutual information between concerned countries. From the Commission side, we wish to acknowledge the special attention paid by the IAEA project officers to inform us on R and D work performed in other countries and related to specific projects in our programme.

After approximately one year of active

cooperation with the IAEA, we consider that the mutual information on development activities within both organisations has greatly improved.

Also, as a consequence of the frequent interactions between project officers, the needs and requirements of the inspectors have been more clearly formulated, which should contribute to the development of more effective and more efficient tools for inspectors, leading to a more effective and more economic implementation of safeguards, not only in the EURATOM Community, but in all installations which are subject to IAEA inspection.

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Table 1

List of tasks of the Cooperative Support Programme between the Commission of the European Communities and the IAEA

Containment and Surveillance

- development of seals for CANDU spent fuel storage casks
- development of general purpose seals
- supply of ultrasonic identification equipment
- verification of containers of nuclear material
- fast reactor fuel assembly identification
- identification of MTR seals at the Savannah River reprocessing facility
- Multilock TV systems
- UF6 cylinder sealing by shrunk tubes

Training

Training for IAEA inspectors in NDA-DA and C/S methodologies.

Measurement Technology

- NDA measurement data transfer
- Pu isotopic ratio measurements by NDA
- application of Sb-Be interrogation device (PHONID)
- calibration laboratory for NDA equipment
- UF6 sampling instrument
- development of a transportable mass spectrometer for the assay of nuclear materials in enrichment plants

- information on measurement techniques applied at the input accountancy tanks of reprocessing plants
- calibration of input accountancy tanks using spiking techniques
- setting up of a data bank on ICT
- preparation and characterisation of spike RM's for IAEA-SAL
- characterisation of IAEA used RM's
- preparation of test samples for IAEA NWAL interlaboratory programmes
- interlaboratory measurement evaluation programme including preparation of test samples
- automatic data evaluation of reprocessing safeguards analysis
- implementation of NDA standards in facilities

Information, Data Treatment and Evaluation

- installation at IAEA of code for nuclear material statistical accountancy (NUMSAS).
- transfer to IAEA and adaptation of a safeguards data management system (ISADAM)
- near real time accountancy in fuel fabrication plants
- supply code (SASSET) for calculation of sample size and its evaluation. Comparison with the INSPECT code
- field data processing with portable microcomputers.

AUSTRALIA'S PROGRAM OF ASSISTANCE TO IAEA SAFEGUARDS

PAUL O'SULLIVAN
Australian Embassy
Washington, D.C.

INTRODUCTION - THE POLICY BACKGROUND

In announcing the Australian Government's nuclear safeguards policy on 24 May 1977, Prime Minister Fraser said, inter alia, that "... Australia would continue to attach major importance to the effective application of safeguards by the International Atomic Energy Agency. "We will," the Prime Minister added, "investigate whether there are specific areas in which Australia could usefully assist the Agency's capacity to apply increasingly effective safeguards."

IAEA safeguards are of central importance to Australia safeguards policy, which allows export of Australian uranium to selected countries as follows:

(a) To selected NNWS party to the NPT where because of these countries safeguards obligations under the NPT the entire civil nuclear industry is subject to effective safeguards applied by the IAEA to verify that nuclear material is not diverted from peaceful uses;

(b) To selected NWS which have assured Australia that uranium it supplies for peaceful purposes is not diverted to military or explosive purposes and accept that it be covered by IAEA safeguards.

Australia's support program for IAEA safeguards reflects their central importance to Australian safeguards policy as well as concepts and obligations outlined in the NPT, e.g.:

(a) NPT preambular paragraph 6 which expresses "... support for research development and other efforts to further the application, within the framework of the International Atomic Energy Agency safeguards system, of the principle of safeguarding effectively the flow of source and special fissionable materials by use of instruments and other techniques at certain strategic points."

(b) NPT Article III.1 which requires in part that "... each non-nuclear weapon state party to the treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfilment of its obligations assumed under this treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices...."

As a founder member of the IAEA, Australia of course had already fully endorsed the safeguards role of the IAEA as prescribed in its statute (e.g. at Article III.A.5) "... to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a state, to any of that state's activities in the field of atomic energy."

AUSTRALIAN SUPPORT PROGRAM: SCOPE AND ORGANISATION

Until 1980, Australia had assisted the Agency's safeguards activities on an "ad hoc" basis. At that time such ad hoc assistance was at a cost of approximately dollars Australia 90,000 per year and consisted of:

(a) provision for two years from 1978 of a cost-free expert for the IAEA information processing system with particular attention to safeguards information treatment;

(b) secondment of three professional officers to other safeguards-related areas of the IAEA Secretariat;

(c) participation by Australian officials in IAEA expert groups, studies and exercises in safeguards and related subjects;

(d) membership of IAEA Standing Advisory Group on Safeguards Implementation (SAGSI) since June 1979 by Director, Australian Safeguards Office.

While the support described in paragraph 5(b), (c) and (d) has continued, in June 1980 the Australian Government also approved the current support program which had been drawn up in consultation with the IAEA Secretariat and taking into account Australia's capacities and interests. The program consisted of:

(a) research projects on safeguards technology and methodology for enrichment plants;

(b) research into field equipment for inspectors; and

(c) a once-only financial contribution to the IAEA International Plutonium Storage Study.

The total cost of the current support program is dollars Australian 541,000 over three years.

The field of enrichment plant safeguards was selected for the research projects in view of the recognition by the International Nuclear Fuel Cycle Evaluation (INFCE) of the particular need for development of the Agency's safeguards capacity in relation to future commercial scale enrichment facilities (an area in which according to INFCE the Agency had had little experience). Also relevant was the possible future development of an Australian enrichment industry. A contribution under the support program to the development of an international plutonium storage scheme of dollars Australian 15,000 in late 1980 was made in response to the IAEA Director-General's appeal for voluntary contributions for this purpose. Such a contribution was consistent with Australia's nuclear safeguards policy which undertook to actively support multilateral efforts towards the control of reprocessing facilities and plutonium management.

Co-ordination of the implementation of the support program in Australia is managed by the Department of Foreign Affairs in consultation with the Department of Trade and Resources, which departments share responsibility for nuclear safeguards policy. Technical advice is co-ordinated by the Australian Safeguards Office (ASO); and ASO and the Australian Atomic Energy Commission (AAEC) are variously responsible for the technical implementation of the research projects.

The research projects on enrichment plant safeguards can briefly be described as follows:

(1) a systems analysis and assessment of techniques for safeguarding uranium enrichment plants, undertaken by the Australian Safeguards Office.

(2) development by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), under supervision of the Australian Safeguards Office, of a ruggedised assaymeter (portable multi-channel analyser) suitable for use by Agency inspectors in the field, and also for use in Australia.

(3) development by the Australian Atomic Energy Commission of non-destructive assay equipment for enriched uranium using active or passive interrogation.

AUSTRALIAN SUPPORT PROGRAM: DETAILED DESCRIPTION

Project 1: System Study on Safeguards for Enrichment Plants

The topics to be studied were worked out in consultations between the IAEA and the Australian Safeguards Office. After an initial identification of a number of topics with the potential for fruitful study, it became apparent that some of the topics - especially as they related to commercial enrichment plants of the centrifuge type - fell within the ambit of the hexapartite safeguards project which started work a few months later in November 1980. Discussions with the IAEA showed the desirability of work complementing that of the hexapartite safeguards project, but carried out in a more fundamental direction.

The systems study has the following guidelines in its five component parts:

(a) Diversion strategies: review various techniques for the production of highly enriched uranium. Provide an assessment of the technical complexity, timescale and changes to operational parameters associated with these diversion strategies.

(b) Safeguards value of access: provide information relating to the objectives of access strategies and the techniques necessary for their achievement. Identify where possible strategic points within cascade halls which will provide information necessary for the implementation of safeguards measures.

(c) Types of access: assess the effectiveness of varying degrees of access to a cascade hall in relation to parameters such as inspection activities, instrumentation requirements, frequency and duration of access and resources required.

(d) Implications of access: indicate the type of information which would be revealed by inspection activities within cascade halls and suggest techniques, where possible, for the protection of sensitive information. Provide a preliminary qualitative analysis of the effect on costs and inspector and operator effort of safeguards strategies involving varying degrees of access including the non-access strategy.

(e) Implications for safeguards approaches for research and development centrifuge facilities: make available to the IAEA relevant conclusions when any information generated during the course of the work is judged to have implications relevant to existing safeguards approaches for research and development facilities.

The systems study has been performed in relations to a reference centrifuge cascade designed by the Australian Safeguards Office on the basis of information published in the scientific literature and without access to classified information. Technical material has been submitted to the IAEA with a view to assisting its officers to make an appraisal of what diversion techniques are realistically feasible and what sort of measures it could seek to adopt in order to counter them.

Given developments in the Hexapartite Safeguards Project in relation to commercial enrichment plants, it is for consideration whether future work on the systems study should give emphasis to the safeguarding of research and development facilities for uranium enrichment by the centrifuge method.

Project 2: Development of a Portable Ruggedised Assay Meter (PRAM)

The objective of this project was to develop a portable multi-channel analyser system for non-destrictive assay work by IAEA inspectors in the field. A special feature of this particular system was that it was to use a microprocessor not only to process the raw data measured to give the desired result, but also to guide the inspector through the measurement procedure by prompting him at various points in the sequence. The project fell naturally into three stages:

Stage 1 - Construction of a bench working model using commercially available equipment, so as to demonstrate the features desired, and formulation of firm proposals and budgetary estimates for the next two stages.

Stage 2 - Construction and demonstration of a portable preprototype using purpose-built components where necessary.

Stage 3 - Construction of a production model instrument.

Stage 1 was completed by early 1982, and the equipment was demonstrated to the IAEA in Sydney on 8 March 1982. It was widely recognised at this stage that the outstanding feature of the equipment was its user-oriented software. However, in view of competing development by the USA of a similar system, which had reached the prototype testing stage, the Agency has advised that it would not be an effective use of Australian program resources to proceed to Stage 2. Nevertheless the Agency recognised that the project represented a carefully thought-out and effective man-machine interaction approach which had applicability beyond the specific multi-channel analyser project. To derive the maximum benefit from this the following actions have been taken:

(a) the computer programs written for the project have been transferred to the IAEA, both as listings and on tape, so that they can be run directly on similar computers in Vienna.

(b) exchanges of programs have taken place with the AAEC which is doing the work in connection with Project 3 (described in detail below).

(c) at the request of the IAEA, arrangements are in train for the CSIRO officer, who developed the software, to take up a position as a cost-free expert with the Agency in September for one year in order to assist in the development and implementation of procedures that will help to eliminate inspector error in operating measurement instruments.

Project 3: Development of Non-Destructive Assay Equipment - A Gas Phase Monitor

To achieve the goal of Project 3 the AAEC was asked to investigate the feasibility of developing non-destructive assay equipment which could be used by inspectors to measure the level of enrichment in centrifuge enrichment plants.

The first instrument developed by the Australian Atomic Energy Commission for this project is a gas phase monitor to measure the enrichment levels of UF6 gas samples from centrifuge enrichment plants.

Principle of Operation

The viability of the method used has been demonstrated previously by Greenwood-Smith (1971) (1) and Strittmatter et al. (1980)(2).

The principle of operation of this instrument is extremely simple and can be understood by reference to the schematic diagram of the system (Figure 1). A small sample of the quantity of UF6, whose enrichment is required, is taken from a storage cylinder or from any other appropriate sampling

position. It has been assumed that samples are taken under vacuum conditions by liquid nitrogen cryopumping. The minimum sample size required to achieve the design accuracy of 1 per cent for a UF6 sample, 3 per cent enriched in 235U, is 3 G. A larger sample is acceptable but does not improve the accuracy.

The UF6 sample bottle is connected to the enrichment monitor and the UF6 is allowed to evaporate into the previously evacuated volume of the measurement chamber. The total uranium content of the UF6 has within the measurement chamber is determined by measuring the attenuation of the 59.5 KEV gamma rays from a 241AM source placed beneath the chamber. The gamma rays must traverse the volume of the chamber to reach a 5 inches by 1 inch NAI detector placed directly above the chamber. For gamma ray energies of about 60 KEV, the absorption process of gamma rays in matter is almost entirely by the photo-electric process. Furthermore, the absorption cross-section has an effective Z4 dependence (3). Thus the uranium content of a UF6 sample is more than 3 orders of magnitude more effective in the absorption process than the total fluorine content. In addition, even large quantities of an HF impurity in the UF6 sample have no effect in the measurement process.

The principal gamma ray from the decay of 235U at 185.7 KEV has a 54 per cent branch probability. It is sufficiently separated in energy from other interfering gamma ray lines (such as those from the decay of 238U and its daughter products) that a measurement of its intensity with a NAI detector provides an accurate estimate of the total 234U content of the UF6 sample. Thus from a comparison of the two count rates in the same NAI detector, the enrichment of the UF6 sample can be determined. Of course, the system must be calibrated with standards previously measured by mass spectrometric methods.

With time there is a slow build-up of a uranium deposit (principally UF4) on the wall of the measurement chamber and thus it is necessary to subtract this background for each measurement. The magnitude of the background to be subtracted is determined by repeating the NAI count with the measurement chamber evacuated. This second measurement also serves to provide the unattenuated gamma ray count rate in the NAI detector from the 241 AM source.

The electronic system is shown in figure 2. The amplifier signals from the NAI detector are fed to a small portable pulse height analyser (Davidson Model 4106) which is serial interfaced to a Hewlett Packard HP85 computer. In operation the entire measurement procedure is directed by the program within the computer and the user of the instrument needs only follow its simple instructions. The vacuum gauges and the system's liquid nitrogen trap are also interfaced to the computer so that the operating system is aware of their status.

Analysis

A typical spectrum from the NAI detector is shown in figure 3. In this specific case the sample was of a nominal 3 per cent enrichment. The two large peaks at the lower end of the scale are from the 241AM source while the higher energy peak is from the 185.7 KEV gamma rays from the decay of 235U. In the analysis peak areas were obtained for the 185.6 KEV peak and the higher of the two americium gamma rays at 59.7 KEV. The background was assumed to linear beneath the peaks and was obtained by summing the 3 channels on each side of the specific peak. Thus for each sample four peak areas are obtained: C1, C2, C3 and C4. These are respectively:

C1 = Nett 235U (185.7 KEV) counts in the standard period of 1000 S.

C2 = Attenuated counts of 59.7 KEV gamma rays from 241AM with the sample in the chamber.

C3 = Background counts of 185.7 KEV gamma rays from uranium build-up on sample chamber walls.

C4 = Unattenuated 241AM counts with the chamber evacuated.

For each sample a factor called the enrichment factor (EF) can be obtained where -

$$EF = (C1 - C3)\ (1 - \frac{C2}{C4})^{-1}.10^{-4}$$

At the beginning of the development program for this instrument it was shown for samples with enrichments between 0.2 and 3 per cent that the enrichment factor obtained for a particular sample was independent of the UF6 gas pressure in the measurement chamber for gas pressures ranging from 30 TORR to 100 TORR.

Furthermore it was shown that the measured enrichment factors are linearly related to the enrichment of the sample. Figure 4 shows the variation of EF with enrichment determined by mass spectrometry for the first version of this enrichment monitor. Since the relationship is linear the system can be calibrated with two calibration standards of different enrichments and it is also a simple matter for the computer to solve the linear equation to obtain the enrichment of an unknown sample.

After considerable experience with the latest version of this instrument it has been shown that for measurements made at 60 TORR using 1000 S counting times the reproduceable accuracy of the instrument is:

0.8 per cent for 3 per cent enriched samples
1.6 per cent for natural uranium samples

A version of the instrument for the measurement of tails is being developed for which the estimated reproduceability is 1.3 per cent.

Operation of the System

The complete operation of the system is directed by the program within the HP85. Reference to the block diagram at figure 5 will assist in understanding this procedure.

Immediately after the operating program is loaded from the cassette, it initiates a check of the function of the computer itself and its accessories, such as the plotter/printer room, to ensure that all items are actually plugged into the system and working.

The first external interaction with the user of the system takes place with the identification subroutine. The user is requested to enter such relevant data as the date, time and his personal identification for subsequent recording with each measurement made and recorded.

Before the instrument can be used, the entire system must be set-up efficiently and safely. The initial set-up routine advises the user what the status of the instrument should be on his first confrontation with it and if the instrument is not in any of these present conditions, the program nominates the correcting procedure and any consequences that might have arisen because of unsatisfactory shutdown on the occasion of its previous use, or of any unauthorised tampering with the instrument in the intervening period. The next stage in the set-up procedure is to ensure that the vacuum pump is working satisfactorily and that the vacuum system itself has no leaks. To complete the set-up of the instrument, the user adjusts the gain of the gamma ray recording system under direction of the program. At this time the user can be sure that the system is ready for use.

The next stage in the operation of the instrument is the verification of the accuracy of its performance. This is achieved with a calibrated standard of UF6 whose enrichment has previously been measured using a mass spectrometer. The calibration of the instrument will have been made prior to installation and the derived calibration data are within the computer program. The function of the calibration source is simply to verify these calibration data. In the event that some change has occurred in the calibration of the instrument, the user has the help subroutine to advise him of his subsequent actions. The calibration subroutine directs the user on the correct procedure to transfer the UF6 sample to the measurement chamber and, at the completion of the measurement, on the procedure to return the sample to its sample bottle. These procedures are identical for the calibration standards and for all samples.

Before any values of enrichment for a calibration sample or an unknown sample can be obtained, it is necessary to measure the background. Thus a background measurement follows the calibration measurement. At the end of the background counting period, the computer has the required information to determine the enrichment of the calibration standard.

If the calibration of the instrument has been verified, sample measurements can be done accurately. For the first sample measurement, the preceding background measurement can be used. However, after the measurement of the first sample, the user of the instrument has the choice of either repeating the original calibration, performing a new background or proceeding to a new sample. In fact, the program will advise him of the optimum choice under normal conditions but allows him some freedom of action to respond to the details of his particular measurement regime.

When all sample measurements are completed, the user of the instrument is directed in the correct procedure to shutdown the instrument.

For each measurement, calibration, background or standard, the measured spectrum is correctly identified and written on the data cassette incorporated into the HP85. The user of the instrument will be able to see the spectrum displayed on the MCA during accumulation and, subsequent to output on the cassette, the spectrum is displayed in log form on the CRO display of the HP85 and then printed on its output printer. Figure 6 is the printout as the user will obtain it. Note the additional information printed with each output.

Present Status

The gas phase monitor was demonstrated to IAEA safeguards officials at the Australian Atomic Energy Commission's Lucas Heights Research Laboratories in March and April 1982. Modifications and developments have now proceeded to the point that the device is ready for field testing. It is expected that this will take place in the latter half of 1982. In the event that the Agency wishes tails measurements to be incorporated into the device this could be done following the field test when other modifications may also be effected.

FUTURE WORK

The following developments are planned for the remainder of the life of the current program.

Work in Project 1 is planned to go further into the details of the safeguarding of research and development centrifuge enrichment installations, continuing to use systems analysis techniques. It is expected that the software and logic aspects of Project 2, to be carried further within the IAEA, will make a useful contribution to non-destructive analysis carried out by the IAEA. Project 3 has good prospects for successful demonstration and establishment as a routine operating monitor. It is considered that the basis device also has potential for significant development and refinement, which will enhance its utility in the safeguards of enrichment plants.

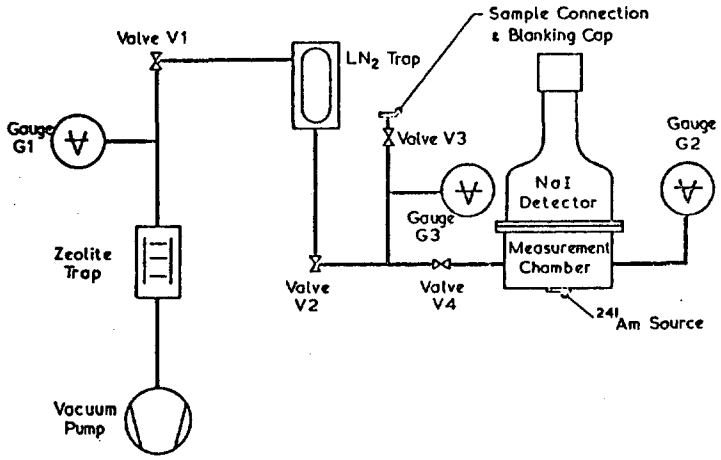

Figure 1. Schematic of the Instrument.

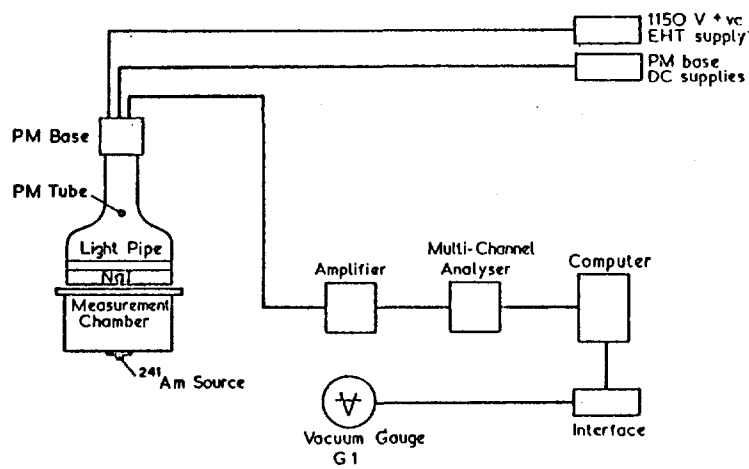

Figure 2. Block diagram of electronics.

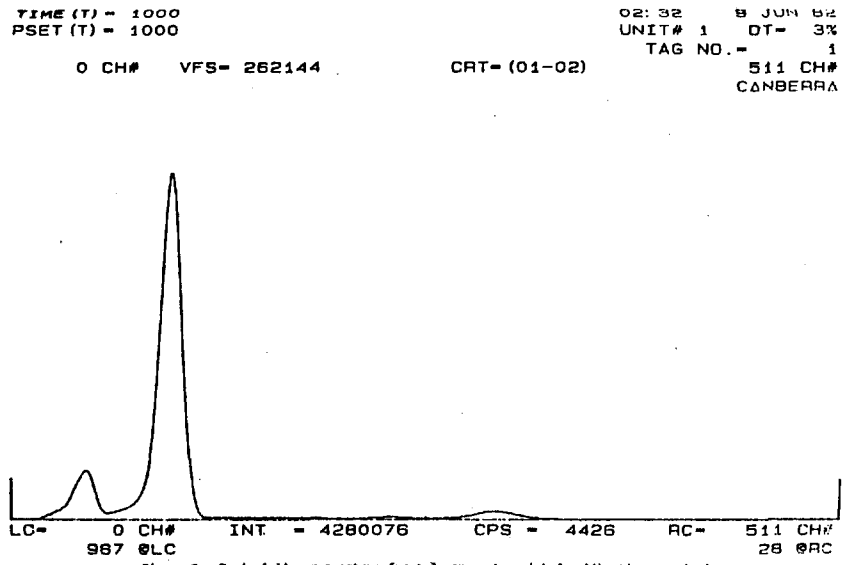

Figure 3 Typical linear spectrum for a 3 per cent enriched calibration standard.

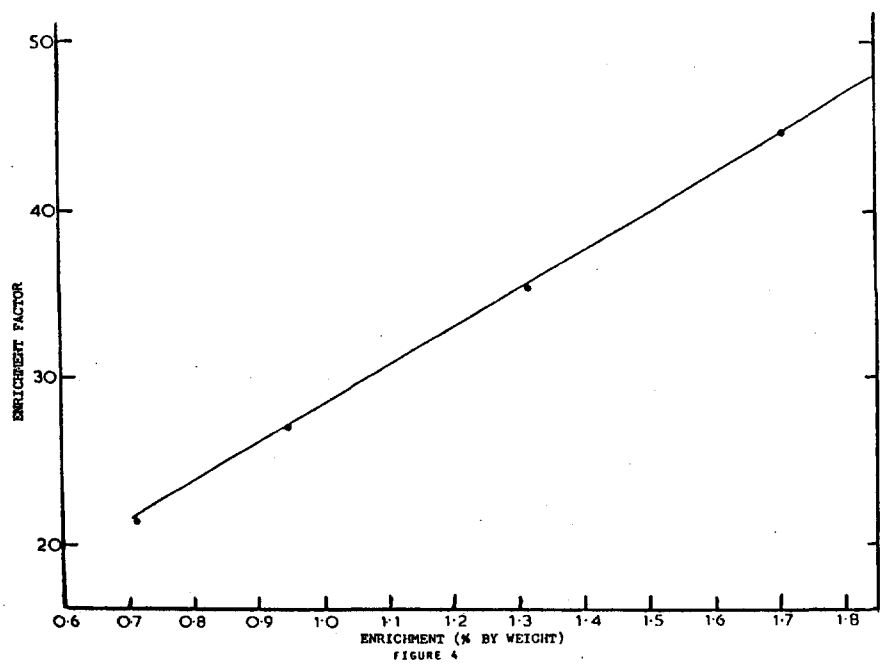

FIGURE 4

The Australian Government has recently agreed to participate in the Transport-By-Sea-Verification Project (TRANSEAVER) and dollars Australian 20,000 is being set aside under the program for that purpose in financial year 1982/83. The TRANSEAVER Project, which aims to enhance physical protection measures applied to shipments of nuclear material, is complementary to the remote control verification (RECOVER) Project. Australia is also a participant in the RECOVER Project.

Finally, the policy commitment of the Australia Government to "... investigate whether there are specific areas in which Australia could usefully assist the Agency's capacity to apply increasingly effective safeguards" should be reiterated. This investigation is a dynamic one. The Australian Government looks forward to continuing consultations with the IAEA, and countries with similar policy commitments, in order to ensure that the Australian support program continues to be relevant as well as economic in avoiding duplication of efforts.

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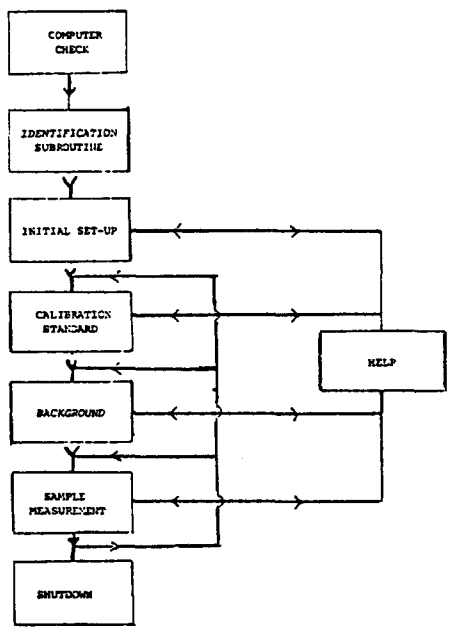

FIGURE 5. BLOCK DIAGRAM OF COMPUTER PROGRAM

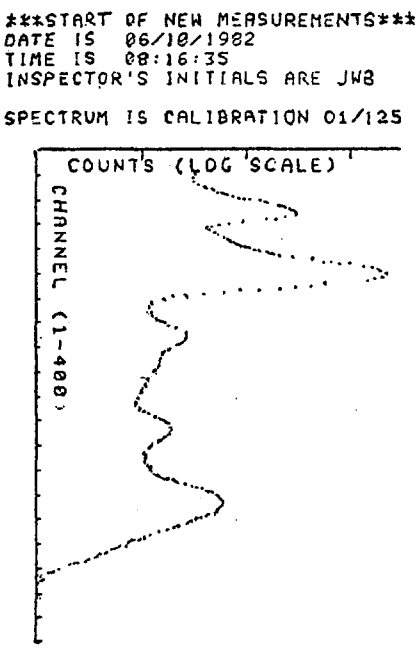

Figure 6 Typical printed output.

DEMONSTRATION OF AN AUTOMATED ELECTROMANOMETER FOR MEASUREMENT OF SOLUTION IN ACCOUNTABILITY VESSELS IN THE TOKAI REPROCESSING PLANT (PART II)

T. YAMONOUCHI, N. SUYAMA, M. HAYASHI, M. KOMATSU, T. UCHIDA AND Y. FUKUARI
Power Reactor and Nuclear Fuel Development Corporation (PNC)
Tokai-mura, Ibaraki-ken, Japan

S. SUDA AND B. KEISCH
Brookhaven National Laboratory
Upton, New York

Abstract

This report describes the results of an operational field test of the automated electromanometer system installed at the input accountability vessel (251V10) and the plutonium product accountability vessel (266V23) in the Tokai Reprocessing Plant. This system has been in use since September 1979 when it was installed in the PNC plant by BNL as part of Task-E, one of the thirteen tasks, in the Tokai Advanced Safeguards Technology Exercise (TASTEX) program. The first report on the progress of this task was published by S. Suda, et al., in the Proceedings of the INMM 22nd Annual Meeting. In this paper, further results of measurement and data analysis are shown. Also, the reliability and applicability of this instrument for accountability, safeguards, and process control purposes are investigated using the data of 106 batches for 251V10 and 40 batches for 266V23 obtained during two campaigns in 1981. The results are as follows:

(a) There were small but significant differences relative to the plant's measurements for both vessels of 251V10 and 266V23, however, the difference for 251V10 was slightly decreased in the latest vessel calibration.

(b) Initially, there were many spurious signals originating with the raw data caused by a software error in the system. However, almost normal conditions were obtained after corrections of the program were made.

In conclusion, it was demonstrated that this system could be used for the purposes of accountancy and process control. Approval for the use of these data for safeguards inspection purposes at a reprocessing plant is intended in the near future.

1. Purpose of the Task

The purpose of this task is to demonstrate the usefulness of an automated electromanometer system through actual campaigns at the Tokai Reprocessing Plant, thereby evaluating the applicability of the system together with the compatibility of its safeguardability with operator's purposes such as precise materials accountancy and process control.

This task has proceeded within the Japan Support Program for Agency Safeguards (JASPAS) since November 1981.

2. Description of the System

The liquid volumes in the input and plutonium product accountability vessels, which are named 251V10 and 266V23 respectively, were conventionally determined by water manometers with their own calibration equations and adjusted heights (Ha). The Ha is calculated by using the following formula:

$$Ha = H \cdot \frac{Dm}{Ds}$$

where H : height reading of the water manometer.

Dm: density of water in the water manometer at room temperature.

Ds: liquid density obtained from the analytical sample taken simultaneously from the vessel concerned.

This conventional method is inherently error prone, and is not compatible with rapid data processing. In contrast with these shortcomings of the water manometer, the electromanometer system is so designed as to measure automatically pneumatic signals, such as liquid levels and densities along with liquid temperatures, leading to almost instantaneous and accurate calculation of liquid volumes.

The outline of the electromanometer system is schematically shown in Fig. 1. Among the existing instrumentation systems for 251V10 and 266V23, the pneumatic signals from the dip tubes to level gauges and densitometers are branched at the input side to supply differential pressure signals -- at the pneumatic transmitter room (G565) for 251V10, and at the Plutonium Op-

eration Area (A324) for 266V23 --and connected to pneumatic scanners by using copper tubes. In order to make temperature corrections of liquid levels and densities, electrical signals from the existing thermocouple are branched at the input side of the receiver -- at the Control Room for both 251V10 and 266V23 -- and are input to a high-precision digital voltmeter. The instruments, such as the pneumatic scanner, electromanometer, and high-precision digital voltmeter, are installed in G565, and resultant digital signals are processed by a desktop computer in the Control Room.

In the electromanometer system, each datum is an average value of a 10-second, 100-point measurement, and measurements are carried out at intervals of three minutes. Measured values and the results of data processing are displayed on a CRT with simultaneous recording on magnetic disks. The magnetic disk has a 24-hr. recording capacity, and its daily changeover enables continuous measurement of liquid volumes. With regard to 251V10 and 266V23, the data recorded on the magnetic disk make it possible to prepare summary reports rapidly, in the forms of status display graphs and data reports, whenever operators require.

3. Outline of Campaigns in 1981

Two campaigns, the 81-1 campaign from February to June and the 81-2 campaign from September to November, were carried out in the Tokai Reprocessing Plant during 1981.

The amounts of spent fuels reprocessed in the 81-1 and 81-2 campaign were 26 tonne U and 14 tonne U, respectively. Then measurement for all batches of 251V10 and 266V23 were implemented by using the electromanometer and the water manometer. The numbers of batches for 251V10 in the 81-1 and 81-2 campaigns were 70 and 36, respectively, and those for 266V23 were 25 and 15, respectively.

Generally, the vessel calibration by water manometers for 251V10 and 266V23 is carried out once a year under the participation of the IAEA and national inspectors in parallel with that by the electromanometer system. In 1981, it was performed in July, and the latest derived calibration equations for both systems have been used since the 81-2 campaign.

4. Field Tests of the System

The demonstration measurements using the electromanometer system were performed during the campaigns from February to November 1981, and the playback of measured data was done at the time of the intercampaign. The values measured by the electromanometer system were then compared with those measured by the water manometer system. The examples of summary reports are shown in Figs. 2 to 5, and the measured source data with the results of the comparison are given in Tables 1 and 2.

4.1. Measurements in the Input Accountability Vessel (251V10)

In the 81-1 campaign conducted from February to July 1981, 70 batches were measured on a batch basis by using both the water manometer and electromanometer. All of the results indicated that the values measured by the electromanometer system were smaller than those measured by the water manometer, and a nearly constant difference was observed between them. The average value of the differences in 70 batches was approximately -13 L which corresponds to about -0.65% of the liquid volume when the tank was nearly full, (about 2,000 L), whereas the standard deviation of the differences was about 6 L corresponding to 0.30% of the liquid volume. The differences were about -1 L (-0.05%) when the tank was at heel volume, and it seems to be negligibly small.

Calibration of the input accountability vessel (251V10) was carried out after the 81-1 campaign, and so the results of calibration have been used to calculate liquid volumes since then. In the 81-2 campaign from September to December 1981, 36 batches were measured. The same trends as above were observed in this campaign. The values of the differences and standard deviation became significantly smaller than the previous ones. These are -7 L (-0.35%) and 4 L (0.20%), respectively. No significant differences were observed when the tank was at heel volume.

4.2. Measurements in the Plutonium Product Accountability Vessel (266V23)

Twenty-five batches of plutonium solution were measured in the 81-1 campaign, and comparison of the electromanometer system with the water manometer system was made on a batch basis as in the case of 251V10. The values obtained with the former were larger than those of the latter, and greater fluctuations were observed for the latter. The average value of the differences between the values measured by the electromanometer was very small. It was about 0.05 L which corresponds to 0.14% of the liquid volume at the time of measurement (about 35 L), and the standard deviation of the differences was about 0.14 L (0.40%). Further, when the accountability vessel was at heel volume the average value of the differences and the standard deviation were 0.03 L (0.09%) and 0.37 L (1.1%), respectively.

Calibration of the plutonium accountability vessel (266V23) was performed after the 81-1 campaign as in the case of 251V10, and liquid volumes have been calculated since then on the basis of the results of this calibration.

In the 81-2 campaign, 15 batches of plutonium product solution were measured, and the same comparison as in the case of the 81-1 campaign was made, indicating that the fluctuation in this campaign was almost the same as that in the previous campaign but with the differences

none in 266V23. These problems mostly resulted from spurious data, and were subsequently solved by modifying the computer program. Another cause was the omission of data on a disk when the program was stopped and restarted by using the automatic startup system. The program has been modified to overcome the problems.

(2) Hardware

The display panel of the high-precision voltmeter was out of order and returned to the manufacturer in August 1981 for repair. This repair took approximately 2 weeks.

8. Applicability as an In-Plant Instrument for Accountability

The electromanometer system was installed in the Tokai Reprocessing Plant in August 1979, and its applicability as an in-plant instrument for accountability has been evaluated by investigating the bias, as compared to the water manometer system, and the reliability of the instrument.

Although problems occurred in both software and hardware as shown in Table 6, most of these were quickly solved. Regarding the software, problems tended to occur when the system was expanded to include 266V23, but subsequent modification of the computer programs solved them, and no further problems are expected unless the program is greatly amended. Problems with the hardware could arise, however. In order to cope with them, a yearly maintenance contract has been concluded and a supply of spare parts has been purchased. Further, the maintenance of the electromanometer system requires more time than that of the water manometer system, resulting in a need to use the latter as a back-up while the former is under maintenance.

It seems that the difference between the value measured by the electromanometer and that measured by the water manometer stems from differences in the calibration equations. The same analytical method should be employed in the future in using the calibration equations for both systems. This should improve the situation.

Even though this system has been demonstrated as an accountability instrument, we hesitate to use this system immediately as the sole accountability measure for the Tokai Reprocessing Plant. However, it is convenient to use the system for safeguards purposes because of its merits such as automatic measurement, on-line processing of data, and rapid preparation of summary reports (rapid data output on demand).

9. Conclusions

The operation of the electromanometer system for the past few years has revealed that the system can be used for the materials accountancy for both the input accountability and the plutonium product accountability vessels of the Tokai Reprocessing Plant for the purpose of safeguards as well as of plant operation.

Some problems still remain to be solved with regard to software maintenance and differences compared to the water manometer system. This leads to the conclusion that it is still too early to use the electromanometer system as the sole accountability instrument. In addition, the maintenance of the electromanometer system may require a comparably long time, leading to the necessity of using the water manometer system while the electromanometer system is undergoing maintenance.

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Attachments

being greater. The average value of the differences and the standard deviation at the time of measurement were 0.12 L (0.34%) and 0.25 L (0.71%). When the vessel was at heel volume, these two values were -0.16 L (-0.46%) and 0.15 L (0.43%), respectively.

5. Vessel Calibration

During the intercampaign period in July 1981, calibration was performed for 251V10 and 266V23 by using demineralized water for the former and 3-N nitric acid for the latter. A given amount of the liquid was weighed by a platform scale, and fed into the vessel, followed by measurement of liquid levels with the water manometer and electromanometer. Calibration operations were repeated three times for each vessel. Regression analysis was applied to the collected data and used to derive the calibration equations.

The data collected by the electromanometer system were calculated using PNC computer programs. The vessel 251V10 was divided into four regions, and cubic or fourth-power calibration equations were used, whereas the vessel 266V23 was divided into two regions with cubic calibration equations.

The data measured by the water manometer system were calculated by the conventional method for analysis. The vessel 251V10 was divided into three regions with linear or quadratic calibration equations used, while the vessel 266V23 was divided into four regions with linear-or quadratic calibration equations. Each calibration equation for the electromanometer and water manometer was derived independently without attempting to be consistent between the break points of the region and the dimension of the equation. These vessel calibration equations for 251V10 and 266V23 are shown in Table 3.

6. Comparison of the Electromanometer with the Water Manometer

As Table 1 and 2 indicate, there exists slight differences between the values measured by the electromanometer and that by the water manometer, and the differences were investigated as described below.

6.1. Input Accountability Vessel (251V10)

With regard to liquid levels for both 2,000 L (operating volume) and 10 L (heel volume), several points were set up, and put into the calibration equations for the electromanometer and water manometer systems for comparison purposes. The results are given in Tables 4. The average difference between the calibration equations for the two systems were -5 L for the new equation and -13 L for the old one when the liquid volume was about 2,000 L. However, these values were 0 L for the new equation and -1.5 L for the old one at heel volume. These values are in good accord with the average difference in each campaign as shown in Table 2, suggesting that the differences between the calibration equations accounts for the differences in measured values. In the new equations, however, the difference has become half of the value obtained with the old equations. This value would not have resulted in a significant difference in material accountancy.

6.2. Plutonium Product Accountability Vessel (266V23)

With regard to liquid levels for both 35 L (operating volume) and 3 L (heel volume), several points were set up, and put into the calibration equations for the electromanometer and water manometer systems for comparison purposes. As shown in Table 5, the average difference between the calibration equations for the two systems were -0.03 L for the new equation and -0.11 L for the old one when the liquid volume was about 35 L. However, these values were -0.12 L for the new equation and -0.02 L for the old one at heel volume. Comparison of these values with the average difference in each campaign, as shown in Table 2, indicates good accord at heel volume. When the liquid volume was around 35 L, the average difference (-0.03 L) obtained by the new calibration equations was close to 0, but the average difference (0.12 L) in the measured values became greater. The cause is probably attributable to the calibration equations themselves, and therefore new small-difference equations will be derived from the coming vessel calibration by employing the following procedures:

a. Break points at which two adjacent calibration equations are joined should be the same for the water manometer and electromanometer.

b. Form of equations, e.g. linear, quadratic, etc. should be the same for the water manometer and electromanometer.

c. Calibration coefficients will not be the same for the water manometer and electromanometer because the two systems have unequal pneumatic lines and thus do not measure the pressure identically.

d. Temperature corrections and other data normalization algorithms should be uniformly applied to both the water manometer and electromanometer.

7. System Reliability

The electromanometer system has run fairly well for the past four years with only minor problems which are summarized in Table 6.

(1) Software

During the 81-1 campaign, data collection problems occurred two and four times in 251V10 and 266V23, respectively, whereas during the 81-2 campaign, the same kind of problems occurred eight times in 251V10 while there were

TABLE 1A

Volume Differences Between Electromanometer and Water Manometer Measurements: Vessel 251V10

81-1 Campaign						81-2 Campaign		
Batch #	Receipt (∿2000L)	Heel (∿10L)	Batch #	Receipt (∿2000L)	Heel (∿10L)	Batch #	Receipt (∿2000L)	Heel (∿10L)
FU1-061	-12	-1	HA1-034	-21	-1	GE1-015	-6	2
062	-7	-1	035	-25	-1	016	-5	0
063	-12	-1	036	-16	-1	017	-1	0
064	-15	-1	037	-15	-2	018	-17	1
065	-10	-1	038	-24	-1	019	-2	1
066	-11	-1	039	-12	-2	020	-17	-4
067	-12	-1	040	-12	-1	021	-5	1
068	-17	-1	041	-10	-1	022	-13	0
069	-5	-1	042	-17	-1	023	-8	1
070	-12	-1	043	*	*	024	-5	0
071	-8	-1	044	*	*	025	-9	1
072	-1	-1	045	-14	-2	026	-7	1
HA1-009	-16	-1	046	-14	-2	027	-14	2
010	-20	-1	047	-14	-1	028	-11	0
011	-16	-1	048	-17	-1	SH1-035	*	*
012	-15	-1	049	-16	-1	036	*	*
013	-10	-1	050	-26	-1	037	*	*
014	0	-1	051	-15	-1	038	*	*
015	-14	-1	FU2-001	-10	-1	039	*	*
016	-1	-1	002	-8	-2	040	*	*
017	-13	*	003	-10	-1	041	*	*
018	0	-1	004	-10	-1	042	-6	1
019	-11	-1	005	-13	-1	043	-2	1
020	-6	-1	006	-6	-1	044	-2	1
021	-10	-1	007	-8	-1	045	-5	1
022	-23	-1	008	-16	-1	046	-2	1
023	-11	0	009	-9	-1	047	-3	1
024	-19	-1	010	-8	-1	048	-3	1
025	-4	-1	011	-15	0	049	-4	1
026	-4	-2	012	-15	-1	050	-4	1
027	-14	-1	013	-14	0	051	-3	1
028	-20	-1	014	-27	-1	052	-8	1
029	-12	-1	015	-19	-1	053	*	*
030	-9	-1				054	-1	1
031	-25	0				055	-6	1
032	-14	-1				056	-6	1
033	-24	-2						

*missing data

TABLE 1B

Volume Differences Between Electromanometer and Water Manometer Measurements: Vessel 266V23

81-1 Campaign			81-2 Campaign		
Batch No.	Receipt (∿35L)	Heel (∿3L)	Batch No.	Receipt (∿35L)	Heel (∿3L)
PUA-071	0.29	0.32	PUA-096	0.72	-0.27
072	-0.27	0.87	097	0.26	-0.08
073	-0.01	0.15	098	0.21	-0.05
074	-0.04	-0.10	099	0	-0.08
075	*	*	100	0.17	-0.22
076	*	*	101	0.16	-0.10
077	*	*	102	0.30	-0.58
078	0.36	-0.09	103	-0.01	-0.26
079	0.11	-0.81	104	0.10	0.12
080	0.02	-0.10	105	0.08	-0.08
081	-0.04	-0.10	106	0.12	-0.15
082	0.06	1.17	107	0.10	-0.11
083	0.14	-0.10	108	-0.47	-0.18
084	0.09	0.05	109	0.17	-0.15
085	*	*	110	0.26	-0.14
086	0.03	-0.06			
087	-0.02	-0.06			
088	0.06	-0.02			
089	0.05	-0.10			
090	0.03	-0.02			
091	-0.05	-0.06			
092	0.34	-0.08			
093	0.15	0.03			
094	-0.03	-0.04			
095	0.04	-0.05			

*missing data

TABLE 2

Summary of Source Data

(1) Input Accountability Vessel (251V10)

			At nearly full volume (≈2,000L)				At heel (≈10L)	
Campaign	Input Batch	Number of Batches	Average of differences (L)		Standard deviation (L)		Average of differences (L)	Standard deviation (L)
81-1	FU1	12	-10	-13	4	6	-1	0
	HA1	43	-14		7		-1	0
	FU2	15	-13		5		-1	0
81-2	GE1	14	-9	-7	5	4	0	1
	SHI1	22	-4		2		1	0

(2) Plutonium Product Accountability Vessel (266V23)

	At nearly full volume (≈35L)		At heel (≈3L)	
Campaign	Average of differences (L)	Standard deviation (L)	Average of differences (L)	Standard deviation (L)
81-1	0.05	0.14	0.03	0.37
81-2	0.12	0.25	-0.16	0.15

TABLE 3

Vessel Calibration Equations for Each Accountability Vessel

(1) Input Accountability Vessel (251V10)

(A) Electromanometer

Region 1	0-97 mmH_2O	$V = -5.0844\times10^{-6}(Ha^3) + 7.6635\times10^{-3}(Ha^2) + 0.23538(Ha) + 4.43136$
Region 2	97-197 "	$V = -7.7229\times10^{-7}(Ha^3) + 6.7884\times10^{-3}(Ha^2) + 0.29687(Ha) + 2.80254$
Region 3	197-537 "	$V = 3.3004\times10^{-8}(Ha^4) - 5.5337\times10^{-5}(Ha^3) + 0.034332(Ha^2) - 5.26034(Ha) + 396.091$
Region 4	537 "	$V = -1.4078\times10^{-7}(Ha^3) + 3.7965\times10^{-4}(Ha^2) + 3.8002(Ha) - 481.578$

(B) Water Manometer

Region 1	0-277 mmH_2O	$V = 6.4085\times10^{-3}(Ha^2) + 0.38076(Ha) + 2.3590$
Region 2	277-597 "	$V = 4.0661(Ha) - 5.3025\times10^{2}$
Region 3	597 "	$V = 4.1268(Ha) - 5.6646\times10^{2}$

(2) Plutonium Product Accountability Vessel (266V23)

(A) Electromanometer

Region 1	0-100 mmH_2O	$V = -2.3861\times10^{-6}(Ha^3) + 6.0538\times10^{-4}(Ha^2) - 0.01408(Ha) + 1.28842$
Region 2	100 "	$V = 3.2898\times10^{-9}(Ha^3) - 5.4133\times10^{-6}(Ha^2) + 0.04850(Ha) - 1.20894$

(B) Water Manometer

Region 1	0-108 mmH_2O	$V = 1.2413\times10^{-4}(Ha^2) + 1.7276\times10^{-2}(Ha) + 0.75401$
Region 2	108-322 "	$V = 4.6621\times10^{-2}(Ha) - 0.95533$
Region 3	322-758 "	$V = 4.5564\times10^{-2}(Ha) - 0.67282$
Region 4	758 "	$V = 4.6386\times10^{-2}(Ha) - 1.2626$

TABLE 4

Comparison of Selected 251V10 Volumes

Pressure mmH_2O	New Equations			Old Equations		
(~2000L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)
600	1,905	1,910	-5	1,898	1,913	-15
605	1,925	1,930	-5	1,919	1,933	-14
610	1,946	1,951	-5	1,939	1,953	-14
615	1,966	1,971	-5	1,960	1,974	-14
620	1,987	1,992	-5	1,980	1,993	-13
625	2,007	2,013	-6	2,001	2,013	-12
630	2,028	2,033	-5	2,021	2,034	-13
635	2,049	2,054	-5	2,042	2,055	-13
640	2,069	2,075	-6	2,062	2,075	-13
645	2,090	2,095	-5	2,083	2,096	-13
650	2,110	2,116	-6	2,103	2,116	-13
Average			-5			-13

Pressure mmH_2O	New Equations			Old Equations		
(~10L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)
13	8.78	8.39	0.39	8.29	9.59	-1.30
14	9.21	8.95	0.26	8.75	10.12	-1.37
15	9.69	9.51	0.18	9.24	10.65	-1.14
16	10.14	10.09	0.05	9.73	11.20	-1.47
17	10.62	10.64	-0.02	10.24	11.77	-1.53
18	11.12	11.29	-0.17	10.76	12.34	-1.58
19	11.64	11.91	-0.27	11.30	12.93	-1.63
20	12.16	12.54	-0.38	11.84	13.53	-1.69
Average			0.0			-1.50

TABLE 5

Comparison of Selected 266V23 Volumes

Pressure mmH_2O	New Equations			Old Equations		
(~35L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)
750	33.51	33.50	-0.01	33.60	33.70	-0.10
760	33.97	33.99	-0.02	34.07	34.16	-0.09
770	34.43	34.45	-0.02	34.53	34.61	-0.08
780	34.89	34.92	-0.03	34.99	35.07	-0.08
790	35.35	35.38	-0.03	35.45	35.58	-0.13
800	35.81	35.85	-0.04	35.92	36.05	-0.13
810	36.27	36.31	-0.04	36.39	36.51	-0.12
820	36.74	36.77	-0.03	36.86	36.97	-0.11
830	37.20	37.24	-0.04	37.33	37.44	-0.11
840	37.66	37.70	-0.04	37.79	37.90	-0.11
850	38.13	38.17	-0.04	38.26	38.36	-0.10
Average			-0.03			-0.11

Pressure mmH_2O	New Equations			Old Equations		
(~3L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)	E.Mano.(L)	W.Mano.(L)	Dif.(L)
50	1.80	1.93	-0.13	1.90	1.93	-0.03
60	2.11	2.24	-0.13	2.20	2.25	-0.05
70	2.45	2.57	-0.12	2.57	2.59	-0.02
80	2.81	2.93	-0.12	2.93	2.95	-0.02
90	3.18	3.31	-0.13	3.33	3.33	0
100	3.62	3.74	-0.12	3.74	3.74	0
110	4.06	4.17	-0.11	4.19	4.20	-0.01
120	4.54	4.64	-0.10	4.66	4.66	0
130	5.01	5.10	-0.09	5.11	5.13	-0.02
Average			-0.12			-0.02

TABLE 6

Record of System Malfunctions and Instrument Failures
Operating Period: August 1979 through March 1982

Date	Description of Problem	Observed Effect	Downtime for Repair	Corrective Action
August 1979	Common carrier interface (CCI) failed (damaged in transit)	Loss of signal transmission between the computer and instruments	None	Computer was moved into operating aisle next to instrument rack for direct control while the unit was being repaired.
August 1979	Ruska thermostat control for heater on the Bourdon tube case failed	Zero drift	2 days	Replacement part, hand-carried by a U.S. visitor, was installed the following week.
September 1979	Ruska regulated power supply failed	Erratic zero behavior	None	By connecting 3 PNC laboratory test power supplies to the Ruska terminal strip, external power was provided until a replacement part arrived.
August 1980 through August 1981	Electronic scanner: intermittent, low probability, malfunction of the reed relays	Spurious data invalidates some measurement cycle results	None	Aug. '80 - When second vessel was added, error was made in existing software that tests for and reactivates closure of reed relay Aug. '81 - Software routine error discovered and corrected.
August 1981	Digital voltmeter failed	Blank display panel	2 weeks	Repaired by manufacturer
November 1981	Automatic restart routine failed	Loss of some data	None	Program modifications pending

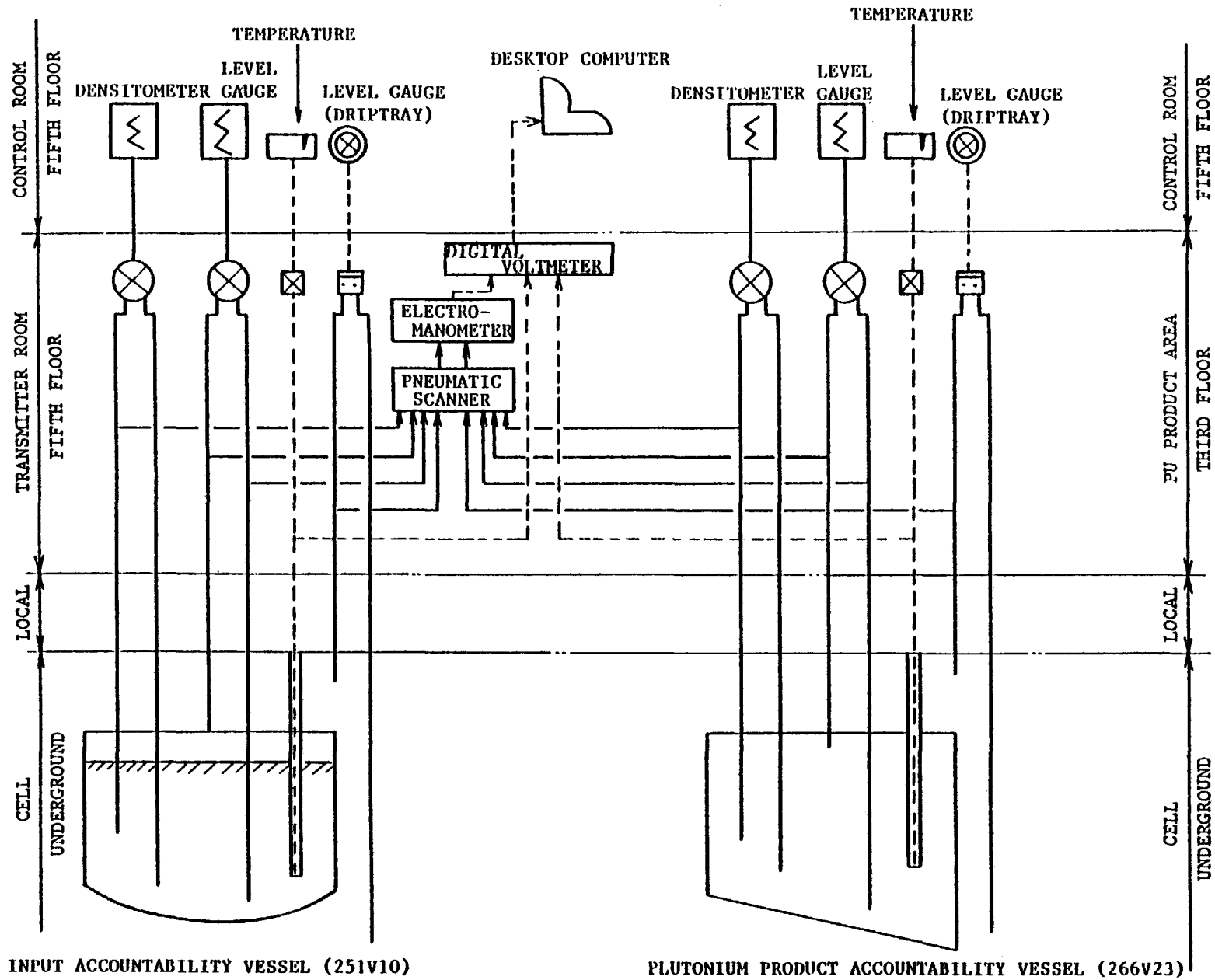

Fig.1 Electromanometer System

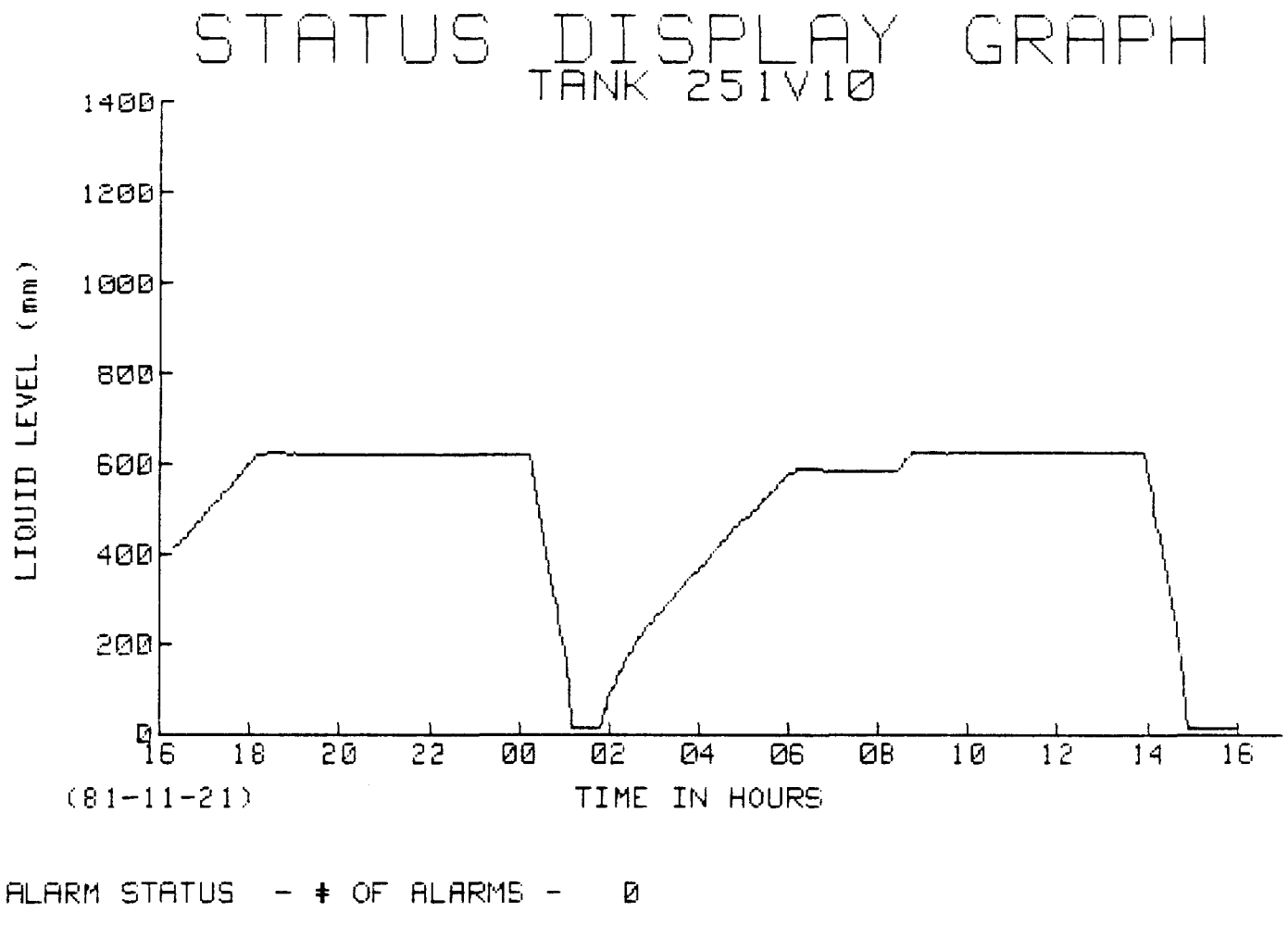

Fig.2 Input Accountability Vessel Status
Plot Liquid Level Monitoring

DATA SUMMARY REPORT (81 - 11 - 21) TANK 251V10

	POINT #1	POINT #2	POINT #3	POINT #4
TIME	19:58	22:01	23:07	00:01
TEMP (deg. C)	27.2	27.4	27.5	27.5
RUSKA 0 (mm)	.37	.39	.47	.46
VAPOR HEAD (mm)	-75.45	-73.78	-76.13	-76.24
LIQ. LEVEL 1 (mm)	289.56	290.06	289.96	289.74
LIQ. LEVEL 2 (mm)	831.60	831.56	831.67	831.73
LIQ. LEVEL 3 (mm)	848.22	848.32	848.44	848.38
LOAD CELL R'D AVG(v)	3.8227	3.7989	3.7887	3.7844
LOAD CELL R'D A (v)	4.3338	4.2919	4.2784	4.2771
LOAD CELL R'D B (v)	3.3353	3.3095	3.2985	3.2853
LOAD CELL R'D C (v)	3.2941	3.2915	3.2903	3.2818
LOAD CELL R'D D (v)	4.3404	4.3242	4.3173	4.3209
CALC'D DENS. (g/cc)	1.3546	1.3544	1.3544	1.3642
MEAS'D DENS. 1 (g/cc)	1.3663	1.3650	1.3655	1.3662
MEAS'D DENS. 2 (g/cc)	1.3669	1.3659	1.3664	1.3668
VOLUME (liters)	1990.520	1993.360	1992.750	1991.280
LOAD CELL MASS (kg)	2810.6	2786.2	2775.8	2771.4

DATA SUMMARY REPORT (81 - 11 - 22) TANK 251V10

	POINT #1	POINT #2	POINT #3	POINT #4
TIME	01:13	01:26	01:38	07:59
TEMP (deg. C)	27.5	27.4	27.3	29.4
RUSKA 0 (mm)	.44	.43	.45	.48
VAPOR HEAD (mm)	-76.44	-77.02	-76.99	-76.53
LIQ. LEVEL 1 (mm)	-1.00	-.99	-1.02	240.06
LIQ. LEVEL 2 (mm)	-1.00	-.99	-1.01	778.43
LIQ. LEVEL 3 (mm)	16.93	17.02	17.11	794.91
LOAD CELL R'D AVG(v)	1.1099	1.1080	1.1060	3.6275
LOAD CELL R'D A (v)	1.3828	1.3798	1.3774	4.1071
LOAD CELL R'D B (v)	.8717	.8731	.8742	3.1710
LOAD CELL R'D C (v)	.7734	.7760	.7780	3.1064
LOAD CELL R'D D (v)	1.3900	1.3868	1.3839	4.1087
CALC'D DENS. (g/cc)	1.3643	1.3643	1.3644	1.3628
MEAS'D DENS. 1 (g/cc)	0.0000	0.0000	0.0000	1.3570
MEAS'D DENS. 2 (g/cc)	0.0000	0.0000	0.0000	1.3575
VOLUME (liters)	8.523	8.553	8.581	1846.800
LOAD CELL MASS (kg)	31.9	29.9	27.9	2610.7

Fig.3 Pneumatic signals, Temperature, Density, Volume for Selected Point of Input Accountability Vessel (251V10)

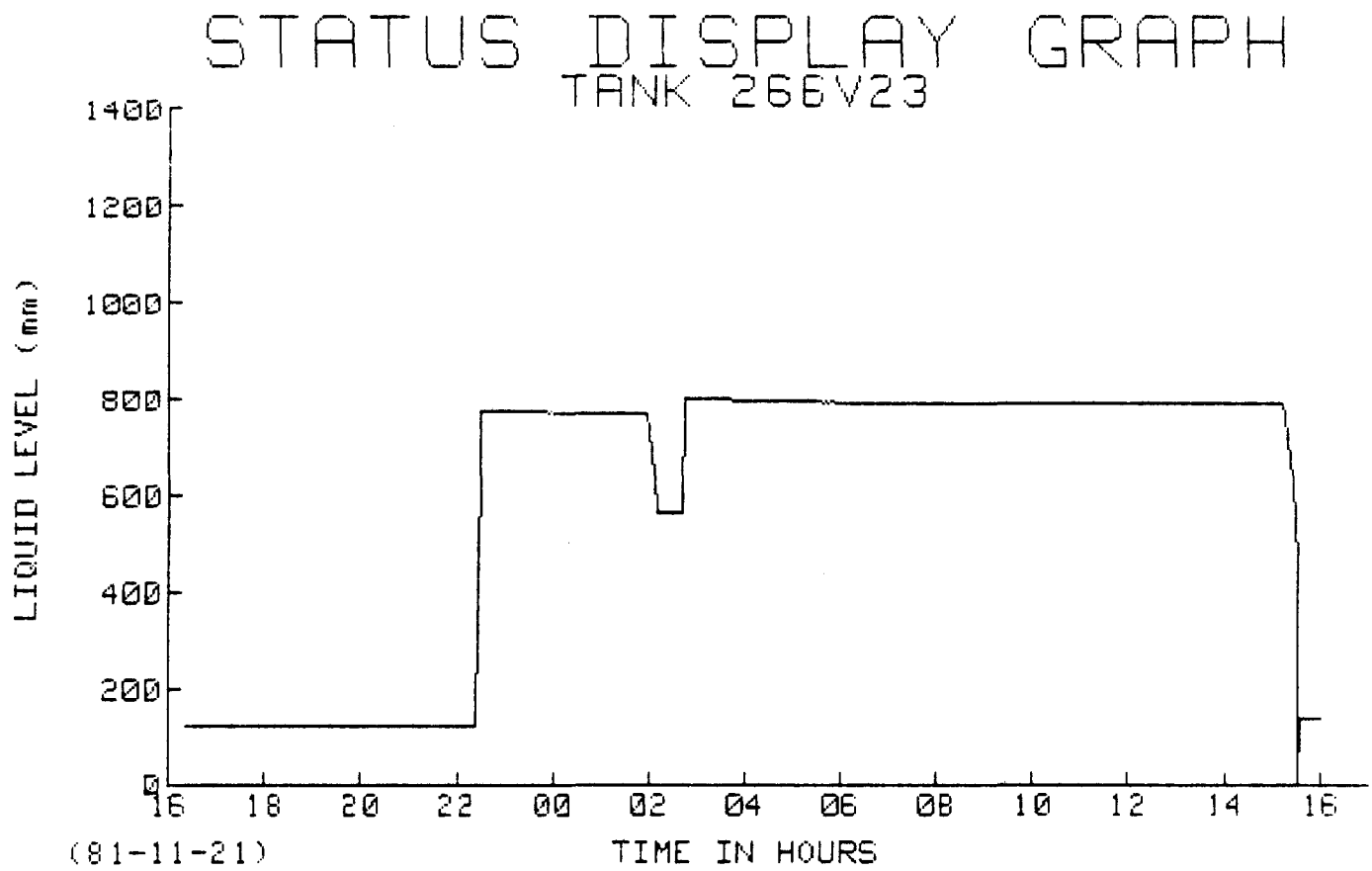

Fig.4 Plutonium Product Accountability Vessel Status Plot Liquid Level Monitoring

DATA SUMMARY REPORT (81 - 11 - 21) TANK 266V23

	POINT #1	POINT #2	POINT #3	POINT #4
TIME	16:59	20:58	00:01	04:00
TEMP (deg. C)	25.4	25.2	33.3	38.6
RUSKA 0 (mm)	.39	.43	.43	.40
VAPOR HEAD (mm)	-55.97	-54.45	-55.60	-51.17
LIQ. LEVEL 1 (mm)	-.96	-.92	408.29	435.54
LIQ. LEVEL 3 (mm)	181.55	183.87	1164.98	1176.06
LOAD CELL R'D AVG(v)	3.4868	3.4818	4.2844	4.3137
LOAD CELL R'D A (v)	8.1707	8.1689	8.1682	8.1683
LOAD CELL R'D B (v)	1.9528	1.9088	2.9772	3.1190
LOAD CELL R'D C (v)	1.7723	1.8057	2.6083	2.5784
LOAD CELL R'D D (v)	1.8479	1.8467	2.3971	2.5413
CALC'D DENS. (g/cc)	1.4927	1.4929	1.4826	1.4757
MEAS'D DENS. 1 (g/cc)	0.0000	0.0000	1.5082	1.4758
VOLUME (liters)	4.238	4.689	34.550	35.683
LOAD CELL MASS (kg)	90.4	90.1	135.4	137.1

DATA SUMMARY REPORT (81 - 11 - 22) TANK 266V23

	POINT #1	POINT #2	POINT #3	POINT #4
TIME	09:58	12:58	15:07	15:54
TEMP (deg. C)	30.4	29.3	29.0	28.0
RUSKA 0 (mm)	.44	.46	.39	.39
VAPOR HEAD (mm)	-54.74	-54.63	-54.83	-51.38
LIQ. LEVEL 1 (mm)	427.40	427.87	427.68	-.93
LIQ. LEVEL 3 (mm)	1172.65	1173.42	1173.86	204.54
LOAD CELL R'D AVG(v)	4.3579	4.3413	4.3341	3.5613
LOAD CELL R'D A (v)	8.1704	8.1701	8.1701	8.1699
LOAD CELL R'D B (v)	2.8465	2.7732	2.7471	2.0552
LOAD CELL R'D C (v)	2.8201	2.8495	2.8670	1.8426
LOAD CELL R'D D (v)	2.4121	2.4015	2.3959	1.8610
CALC'D DENS. (g/cc)	1.4863	1.4877	1.4891	1.4902
MEAS'D DENS. 1 (g/cc)	1.4854	1.4861	1.4874	0.0000
VOLUME (liters)	35.330	35.337	35.319	5.355
LOAD CELL MASS (kg)	139.6	138.6	138.2	94.6

Fig.5 Pneumatic signals, Temperature, Density, Volume for Selected Point of Plutonium Product Accountability Vessel (266V23)

QUALIFYING NONDESTRUCTIVE ASSAY FOR PLUTONIUM ACCOUNTANCY MEASUREMENTS

W.W. RODENBURG AND J.G. FLEISSNER
MRC-Mound
Miamisburg, Ohio

ABSTRACT

Reliable estimates of the precision and accuracy of nondestructive calorimetric assay have been made for a wide variety of plutonium-isotopic compositions and material forms. Material forms studied include oxides, metals, mixed-oxides and intermediate-process categories. Isotopic compositions range from 6 to 22% plutonium-240. Quantities ranged from 0.2 to 2000 g of plutonium. Estimates of accuracy and precision were based on comparison with traditional wet chemical assay techniques. Typically, the precisions and accuracies were 0.5% or better. These error estimates are in good agreement with internal uncertainties propagated from the calorimeter precision and the statistical uncertainties associated with the gamma-ray isotopic measurement. The measurement techniques can thus be applied to a wide variety of materials without performing similar experiments on every material category in the process.

An example is also given using this technique to calibrate another plutonium NDA method using the dynamic calibration approach.

INTRODUCTION

Despite the numerous advantages of NDA, most accountability measurements are based on sample weight multiplied by a factor. The factor usually is provided by chemical analysis or process experience. One of the primary reasons NDA has not been used more extensively is that its accuracy and precision have not been or cannot be demonstrated rigorously enough to satisfy accountability requirements. In this paper we will demonstrate how this has been done for plutonium using nondestructive calorimetric assay and how it can be extended to other NDA methods using the "Dynamic Calibration" technique.

Background

A measurement qualified for accountancy use consists of three essential ingredients: the measured value, and reliable estimates of the associated random and systematic errors. Lacking any one of these three components, the measurement is incomplete. Reliable estimates of error take into account effects due to all relevant sources of measurement variability. These include effects due to the instrument, the operator, the environment (e.g. temperature, humidity, line voltages, background radiation, etc.) and any other variable that can affect the measurement.

The Dynamic Calibration technique [1] takes these factors into account by calibrating the measurement with materials drawn from the process. A schematic representation of the dynamic calibration concept is given in Figure 1. First the process materials

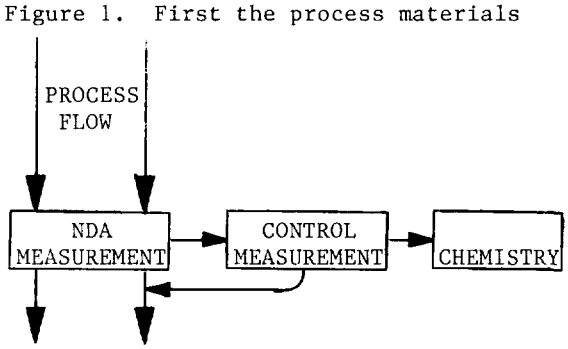

FIGURE 1 - A dynamic calibration system showing the relationship between measurements.

*MRC-Mound is operated by Monsanto Research Corporation for the U. S. Department of Energy under Contract No. DE-AC04-76-DP00053.

from a material category are measured by the NDA system to be calibrated. A representative portion of these materials is then measured by a control measurement of significantly better precision and accuracy than the NDA device. These measurements are used to provide an initial calibration as well as a continually updated or dynamic calibration that takes into account gradual changes in the measurement. The control measurement is also used to detect step-wise changes which require a new calibration be performed or which indicate an instrument malfunction.

Control Measurement

The key to making the dynamic calibration approach practical is the control measurement. Nondestructive calorimetric assay was selected for plutonium because it is accurate, precise, reliable, unaffected by most factors that NDA is subject to, directly traceable to national measurement standards, and cost effective.

Nondestructive calorimetric assay is a two-step process consisting of a power measurement (watts) by calorimetry and an isotopic determination by high resolution gamma-ray spectroscopy. For details of the procedure and the calculations involved, see ANSI N15.22 on calorimetric assay [2].

The calorimeters used for measuring the process samples were of Mound design with precisions and accuracies of 0.1% or better. For the small 0.2 to 4 g samples, a specially developed Mound analytical calorimeter was used [3]. This provided a direct link between the calorimeter measurements and traditional wet chemical assay techniques; e.g., controlled potential coulometry. The analytical calorimeter also made it possible to nondestructively estimate sampling errors and verify homogeneity [4].

Gamma-ray isotopic measurements were used to nondestructively determine the effective specific power, P_{eff}, of the material. P_{eff} is the analytical factor for converting watts to grams plutonium. It is calculated from the isotopic data as follows:

$$P_{eff} = \Sigma R_i P_i$$

where R_i = mass fraction (g isotope i/g plutonium)

P_i = watts/gram of isotope i

The isotopic determination method used employs two gamma-ray detectors and has been described elsewhere [5]. Basically, the method consists of two simultaneous spectral measurements over two energy regions, 120 to 400 keV and 300 to 700 keV. Absorbers are used to tailor the spectral response from the different energy regions. The two detectors used are matched to the spectroscopic requirements for each energy region. A small volume, planar Ge detector provides the high resolution needed for resolving the complex multiplets contained in the low energy region. A large volume, 70 cc Ge detector, provides the high efficiency required for the lower intensities of the gamma rays of Pu-239, Pu-240 and Am-241 in the high energy region.

Analyses of the spectra are performed on a PDP 11/34 computer. The analysis routine, GRPAUT, automatically performs the spectral reduction and obtains the isotopic composition of the sample [6,7]. This program is applicable to a variety of materials, including oxides, metals, ashes, fluorides, Pu/U mixed oxides and others. Reference materials of the same chemical or isotopic composition as the unknowns are not required. The program can be run by a technician and allows analysis of multiple spectra without continual operator intervention.

The wide applicability of GRPAUT is due in part to the intrinsic efficiency correction calculations performed by the program. GRPAUT determines the relative intensities of prominent gamma-ray peaks of Pu-239, Pu-241 and Am-241. It then calculates the efficiency response of the system using the known gamma branching intensities. This method not only corrects for detector efficiency, but also includes corrections for self-attenuation within the sample and in the container.

Traceability of Nondestructive Calorimetric Assay

One dram vials containing 0.2 to 4 g of plutonium were prepared using a variety of plutonium forms and isotopic compositions (see Table 1). The materials used include PuO_2 and mixed oxide from the SALE program and plutonium metal from the DOE plutonium Metal Exchange Program. The sample power of these vials was measured using the Mound analytical calorimeter. The isotopic composition of these samples was then determined by gamma-ray spectroscopy measurements. The plutonium content was calculated using the methods outlined in ANSI N 15.22 [2].

TABLE 1

SUMMARY OF RESULTS

Sample	A	B	C	D	E	F	G	H	I
Material Form	High Purity Metal	Low Purity Metal	Oxide	0.25 PuO_2 0.75 UO_2	Oxide	Oxide	Oxide	Dirty Oxide	Dirty Oxide
Sample Size (g)	4	4	1	0.2	4	2	1	4	1-2kg
Fissile Content (%)	94	94	88	88	88	76	73	94	94
P_{eff} (mW/g-Pu)	2.3	2.3	3.0	3.0	2.9	4.6	9.7	2.3	2.3
Ratio to Reference Value*	0.9994	0.9998	1.0014	1.0005	0.9989	1.0025	0.9926	1.0004	0.9984
RSD %	0.18	0.28	0.60	0.64	0.21	0.23	0.32	0.19	0.57
Propagated Error**%	0.34	0.34	0.59	0.66	0.37	0.42	0.51	0.22	0.28
F-ratio	3.56	1.47	0.97	1.06	3.10	3.33	2.54	1.34	0.24
F-critical 95% Confidence Level	3.79	3.79	3.79	3.79	5.05	5.05	5.05	1.85	1.85

*Reference Value for A & B was metal exchange mean, for C & D was SALE program reference values, E, F & G was average Mound and New Brunswick National Laboratory chemical assay, and H & I was Mound analytical.

**Error propagated from uncertainties in the calorimetry and gamma-ray isotopic measurements using method in ANSI N15.22.

The vial was then analyzed for plutonium on a "to contain" basis; that is, the entire content of the vial was dissolved and assayed. This approach eliminates many questions about sampling errors, transfer errors, weighing errors or changes in the weight due to absorption or desorption. The samples were also weighed initially so that comparisons could also be made with other laboratories participating in the SALE and Metal Exchange Program.

Typically, six or more samples were prepared of each material type. The ratio of the NDA value to the chemical assay value was calculated for each sample. The averages and standard deviations of these ratios were calculated for each material type. In addition, the random error of the nondestructive calorimetric assay was estimated from the random error of the calorimetry and gamma-ray isotopic measurements using the techniques in ANSI N15.22.

The F ratio of these two variances indicated that there is no significant difference in the two error estimates.

The larger random errors for the SALE materials were due primarily to the small quantities of material. Low count rates produced larger uncertainties for the gamma-ray measurement and the low powers increased the random error of the calorimeter.

For high fissile materials (88% or more) the biases were less than 0.2%, and generally not statistically significant. For the highest burnups, (material "G", Table 1) the Pu-238 contributed more than 70% of the decay heat. Even in this case, the bias from the reference value was still less than one percent.

Application of Nondestructive Calorimetric Assay to Process Materials

Materials H and I in Table 1 are from a "dirty oxide" category. Two samples a week were randomly selected for a

period of fifteen weeks. The material composition ranged from 81 to 86% plutonium and plutonium contents varied from 1600 to 2100 g. Several grab samples totaling 5 g were taken from each container. These were combined into a single sample and weighed. The remaining bulk material was also reweighed at the same time.

Both the gamma-ray isotopic measurements and the calorimetry power measurements demonstrated that the sampling was representative. First the effective specific powers determined by the gamma-ray measurements of the bulk sample were compared to those of the aliquots. There was no statistically significant difference between them. The ratio of the two measurements was 1.0014 with a relative standard deviation (RSD) of 0.44%. This also indicates that the gamma-ray measurement is independent of the quantity of material and does not affect the calorimetric assay technique. Next, the watts/gram of material for the bulk sample was compared to that of the aliquots. Here the ratio was 1.0006 with a relative standard deviation of 0.70%. Again, there was no significant difference between the means.

The aliquots were then dissolved and analyzed for total plutonium content as before. For the aliquots the ratio of the nondestructive calorimetric assay to the chemical assay was 1.0003 with a RSD of 0.28%. The same ratio for the bulk containers was 0.9984 with a RSD of 0.57%. We attribute the larger random error of this ratio to sampling error. This is consistent with the 0.7% random error observed for the W/g ratios discussed earlier. Thus, as observed with the well characterized material, the agreement with chemical analysis was excellent with no detectable bias for the high fissile materials.

Calibration of Other NDA Techniques

An example of using nondestructive calorimetric assay for the calibration of NDA is summarized in Table 2. In this case the NDA measurement was a transmission corrected gamma-ray measurement initially calibrated against synthetic standards.

Eight samples were selected over a period of several weeks from the category for which the NDA method was to be calibrated. The plutonium contents of the items selected all fell in a relatively narrow range between 340 and 420 g. For this reason no attempt was made to determine a new linear calibration. Instead, the results were treated as a point calibration of the present NDA measurement. As can be seen from Table 1, the NDA measurement is 7.8% lower than the control measurement. The standard deviation of the difference indicates that, except for the bias, this is a good NDA measurement.

TABLE 2

CALIBRATION OF NDA VERSUS NONDESTRUCTIVE CALORIMETRIC ASSAY

Sample	NDA Measurement	Control Measurement	Difference	
	Grams	Grams	Grams	Ratio
1	318	339	-21	.938
2	379	414	-35	.916
3	336	353	-17	.952
4	361	386	-25	.935
5	341	385	-44	.886
6	317	338	-21	.938
7	335	367	-32	.913
8	373	416	-43	.897
			Average	.922
			Std. Dev.	.023
			Std. Error of Mean	.008

The random error of the calorimetric assay propagated from the measurement errors is 0.8%. Overall, the random error of the difference between the two measurements is 2.3%. Using a method suggested by Jaech [8], the systematic error of the calibration was estimated from the equation:

$$S^2_{sys} = S^2_o + S^2_r/n \quad (1)$$

Where S^2_{sys} = systematic error variance

S^2_o = systematic error variance of control measurement

S^2_r/n = error variance of calibration measurements

Based on the earlier work done on high fissile plutonium, S_o was estimated to be 0.1% or less, and thus S_{sys} was estimated to be 0.8%.

Due to the high accuracy of nondestructive calorimetric assay, the second term of Equation 1 is the dominant source of systematic error. This error is usually dominated by the random error of the NDA measurement since the nondestructive calorimetric assay is much more precise. Thus, the magnitude of the systematic error can be reduced by making more calibration measurements.

Measurement Assurance

Another powerful aspect of the dynamic calibration approach is that by making continued control measurements the validity of the initial calibration can be verified or the need to recalibrate can be determined. For example, assuming no change in the random error, a shift of 2.6% in the calibration would be detectable at the 95% confidence level with eight more measurements.

Summary

The NDA of plutonium-bearing materials can be improved by further application of nondestructive calorimetric assay. This technique is accurate, precise, and reliable. It is not affected by most of the variables that can cause interference with other NDA techniques. Used as a control measurement, nondestructive calorimetric assay can provide more accurate calibration and valid estimates of the random and systematic errors of the measurement.

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PROBABILISTIC APPROACH TO NDA OF CONTAINER WITH NON-UNIFORM SNM DISTRIBUTION

Y. BEN-HAIM, E. ELIAS
Department of Nuclear Engineering
Technion, Haifa, Israel

T. GOZANI
Science Applications, Inc.
Palo Alto, California

One of the most important parameters influencing the accuracy of NDA techniques is the dependence of the measured quantities on the spatial distribution of the nuclear material inside its container. Equal quantities of SNM with different spatial distribution may give rise to different inferred amounts of SNM. This paper addresses the problem of non-uniformity in two levels. First, a statistical measure is developed which defines the degree of homogeneity obtained by randomly loading SNM into a container (e.g., 55 gallon). For a given measured activity, a statistical formulation is presented to calculate the conditional probability that a certain mass is present in the container. This probability distribution quantitatively defines the uncertainty of the measurement. A computation procedure is formulated which is applied to both passive and active NDA techniques.

INTRODUCTION

Highly accurate accounting methods for special nuclear materials (SNM) are necessary for mass balance control and to safeguard against material diversion. NDA techniques depend on measurement of the natural or induced activity of SNM. The activity measured for a particular container depends on the mass of SNM and also on its spatial distribution inside the container. Interpretation of the measured activity in terms of the contained mass is ambiguous unless the spatial distribution is known. Since such information is hardly ever available, it is often assumed that the SNM is uniformly distributed. In spite of extensive efforts made to reduce the dependence of the measured activity on spatial distribution, the non-homogeneity effect constitutes a major limitation on the accuracy of both active and passive NDA techniques, especially in medium to large containers.

Accounting for the inhomogeneity of the sample by a proper calibration procedure is generally difficult since little or no prior knowledge is available regarding the spatial distribution of the nuclear material in the sample. However, because of the method commonly employed to fill containers before assaying them, the spatial distribution of nuclear materials generally obeys simple statistical laws [1]. A statistical formulation of the problem has been recently developed [2,3] to quantitatively account for the effect of inhomogeneity on the response of NDA techniques. A statistical measure has been presented [2] which allows one to identify situations (types of samples and measuring systems) in which the assumption of spatial homogeneity is warranted. When such an assumption is not warranted, a probability value is calculated for each possible geometrical distribution. Further, since the determined mass of the nuclear material in the sample is a function of the spatial distribution, such a statistical approach enables one to determine a probability distribution for the mass instead of a single value based on a hypothetical distribution. In other words, the statistical approach enables one to calculate the conditional probability that a certain mass is contained for a given a measured response.

The present paper summarizes the basic concepts underlying the probabilistic approach to NDA of a container with non-uniform SNM distribution. A practical guide is outlined to the evaluation of the probability distribution of contained mass of SNM for a given measured activity or response. It is shown that this probability distribution quantitatively defines the uncertainty of the measurement. The shape of the calculated mass probability distribution for a specific NDA method is shown to depend on various design and operational parameters such as the measurement geometry, attenuation in the matrix material, and other variables related to the sample.

STATISTICAL ANALYSIS

To demonstrate the probabilistic approach, a practical system based on passive gamma detection is considered. The measured sample consists of a 55-gallon drum which is tightly packed with non-active matrix material, in which are embedded a certain number of small items, such as gloves, rags, or waste process material contaminated with

SNM. The basic assumption underlying the probabilistic approach is that the SNM items are randomly loaded into the non-active matrix, which, for now, will be considered as uniform. Further, we assume that interference or interaction between SNNM items or fragments is negligible because the quantity of SNM is small.

A common practice for analyzing the effect of SNM distribution on the performance of the NDA system is to perform preliminary measurements of the response profile in presence of the matrix material in the drum [4]. A fragment can be, for example, a small fuel particle or a fuel pellet. The response profile is the measured activity vs. position from a unit mass of SNM, or "fragment", embedded at different positions in the matrix-filled drum. It is typically a two-dimensional function, varying with the radial and vertical position of the fragment, but independent of the azimuthal position because usually the drum rotates on its symmetry axis during the measurement. The response profile is utilized here to define a statistical measure of the magnitude of spatial inhomogeneity of the SNM in the drum. It indicates how sensitive the measurement is to the position of the fragment. If the profile is perfectly flat, it is impossible to determine the position of the fragment by measuring its activity, i.e., the measured activity is independent of the SNM distribution. Alternatively, if the profile is steep over a certain range of positions, then the fragment can be well located by measuring its activity. The slope of the response profile at any point in the drum determines the degree of sensitivity of the measured activity to variation in the fragment position around that point. Even if the response profile is strongly non-uniform, the sensitivity to the fuel fragment position depends also on inaccuracy introduced by counting statistics. Combining these facts, one can estimate the smallest detectable movement around the point (r,z) in the drum in the radial direction r at fixed vertical position z as

$$D_r = \frac{[2F(r,z)]^{\frac{1}{2}}}{\left|\frac{\partial F(r,z)}{\partial z}\right|} \qquad (1)$$

where F is the response profile. Likewise, the smallest detectable vertical displacement is

$$D_z = \frac{[2F(r,z)]^{\frac{1}{2}}}{\left|\frac{\partial F(r,z)}{\partial z}\right|} \qquad (2)$$

The two parameters, D_r and D_z, basically define a "minimum detectable volume" (MDV), which is the largest volume element such that the measured total activity does not depend significantly on the exact position of the SNM fragments within this volume element. Generally, all practical efforts should be made to achieve a system in which the MDV is of the order of magnitude of the sample volume. Obviously, if such a design can be achieved, then the system response would be independent of material distribution and no further consideration should be given to the problem of inhomogeneity. However, in practice the MDV is smaller than the sample volume. The sample can then be divided into n bins of minimum detectable volume each. Note that the number n is defined entirely by the measured response function according to eqs. (1) and (2). Furthermore, since generally the sizes of the radial and axial dimensions of the bins, D_r and D_z, depend on the location within the sample, the bins do not have the same volume. A practical example of subdividing the sample will be considered later.

The quantitative definition of SNM homogeneity requires, in addition to the n bins defined above, information on the sample content. To simplify the analysis based, on previous experience with similar samples, we assume that each sample contains an average of w SNM fragments or units of identical mass μ. (Note that if the probability distribution of SNM fragments were available, it could be readily incorporated in the calculation.) With the help of this assumption, a measure for the deviation from homogeneity is given in Ref. [2].

$$\sigma = \left(\frac{n-1}{w}\right)^{\frac{1}{2}} \qquad (3)$$

Thus, for instance, if the sample is divided into 5 bins and the average number of SNM fragments is 100, then a deviation from homogeneity of 20% is expected ($\sigma = 0.2$).

When large deviation from homogeneity is expected, we have to estimate the error it induces in the measured SNM. A general model for determining that error has been developed in Ref. [3]. The model is used below to determine the expected error in a realistic, though reasonably simple, case, illuminating the capabilities and limitations of the method.

There are eight stages in the calculation as enumerated below.

Stage I — Using the system response profile, determine the number and boundaries of the bins with minimum-detectable-volume bins.

Stage II — Evaluate the response profile and fractional volume for each bin.

Stage III — Establish the probability g_w that a drum contains w SNM fragments.

Stage IV — Establish the empirical probability distribution of SNM fragment masses. In our case we assume all the fragments to be of the same mass.

Stage V — Define a multi-dimensional space whose dimension is one less than the number, n, of bins, and whose axes are the number of SNM fragments in each of the first n-1 spatial bins of the drum. Each integer lattice point defines a distinct spatial distribution of SNM fragments. Calculate curves in this space of constant measured activity for fixed number of SNM fragments. Repeat this calculation for each possible total number of SNM fragments in the drum.

Stage VI — Calculate the probability of each distinct spatial distribution of w SNM fragments. Employing the curves calculated in Stage V, compute the conditional probability $P(A_i \leq A < A_{i+1} \mid w)$ that the activity, A, falls in the interval $A_i \leq A < A_{i+1}$ when the number of SNM fragments in the drum is w.

Stage VII — Compute the bivariate probability distribution $(M_j < M < M_{j+1}, A_i \leq A < A_{i+1})$ that the total SNM mass is in the interval (M_j, M_{j+1}) and the activity is in the interval (A_i, A_{i+1}).

Stage VIII — Compute the conditional probability $P(M_j \leq M < M_{j+1} \mid A_1 \leq A < A_{i+1})$ that the total contained SNM mass is in the interval (M_j, M_{j+1}), given that the measured activity is in the interval (A_i, A_{i+1}). This conditional probability distribution is the final result which we seek. Its shape provides a measure of the error introduced by the SNM distribution in the sample.

We now proceed to a careful explanation of the execution of each stage.

SAMPLE CALCULATION

Stage I

The 55-gallon drums to be measured are cylindrical, so we shall define a cylindrical coordinate system centered on the symmetry axis of the drum at half the drum height. Let z be the vertical position above or below the origin, and r be the radial position. Likewise, H is the half-height of the drum and R is its radius. The empirical response profile chosen for this example is shown in Figure 1. A typical measured response

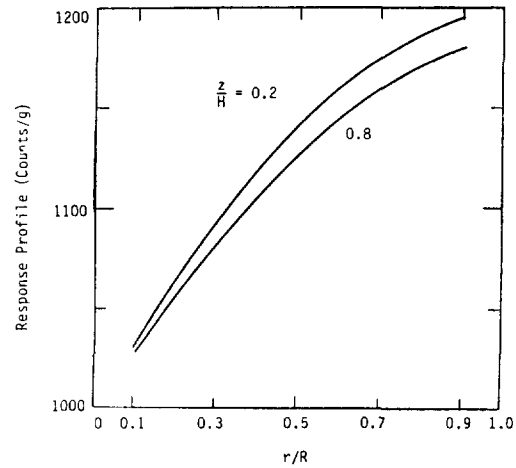

Figure 1. Response profile F (r,z) versus relative radial position (r/R) for various relative vertical positions (z/H). F has units of counts per gram of SNM.

in counts per gram (for fixed counting time) is plotted versus the reduced radial position. The two curves show the response profile at different vertical positions. Fitting of these curves is represented by

$$F(r,z) = \alpha\beta \sin\left(\frac{\pi r}{2R}\right) \cos\left(\frac{\pi z}{6H}\right) \qquad (4)$$

where α and β are constants that depend on the measuring time and count-rate used during the response profile measurement. In our example, $\alpha = 0.2$, $\beta = 1000$. The drum radius (R) and half-height (H) are 28 and 42.5 cm, respectively.

Using the fitting Eq. (4), we can readily calculate, using Eqs. (2) and (3), the minimum detectable radial and vertical displacements, D_r and D_z, as shown in Tables 1 and 2. Table 1 shows, for example, that at the vertical position z/H = 0.5 and the radial position r/R = 0.2, the activity measurement is not significantly sensitive to radial movement of the SNM over a distance of 4.5 cm. In other words, how the SNM fragments are distributed along a radial segment 4.5 cm long (at this location in the drum) will not significantly effect the overall measured activity.

Table 1 can be used to calculate the radial boundaries between the detectable volume bins at each vertical position. Similar computations are presented in Table 2 for the minimum detectable vertical displacements based on the response functions (Eq. (4)). The data in Tables 1 and 2 were used to calculate the vertical and radial boundaries of the bins as shown in Figure 2. Note that throughout most of the drum, the smallest detectable vertical displacement is larger than the height of the drum (85 cm). Where this holds, the response is not sensitive to the vertical distribution of the SNM fragments. Therefore, the drum was divided into 5 radial bins with no partitioning in the vertical direction.

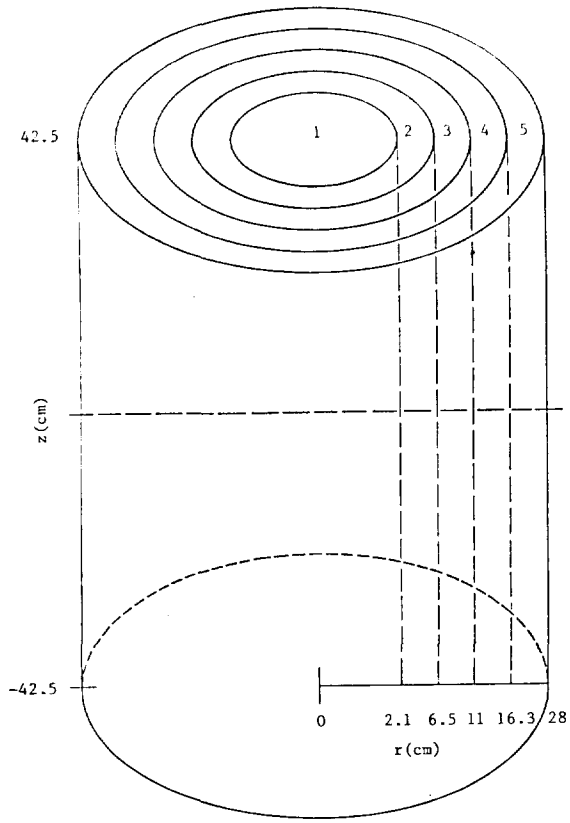

Figure 2. Final definition of the smallest-detectable-volume bins, showing a total of five bins in the drum.

Stage II

It is now our task to calculate the fractional volume and response profile for each bin. The fractional volume is readily calculated from the dimensions specified in Figure 2. Since the response profile does not vary significantly across a bin, it is sufficient to evaluate it at the center of each bin, using Eq. (4). The results are shown in Table 3.

Stage III

No accurate information is normally available on the number of SNM fragments in a drum. However, some statistical data can be accumulated if many similar samples are analyzed. In the present example we assume that each drum contains an average of 10 SNM particles. We also assume that the probability distribution, g_w, for the number of SNM fragments in the drum is Poisson. This predicts a finite probability that the drum contains any given number of fragments, no matter how many. This is given in Table 4. The second column shows the value of g_w for a specified number of fragments, w, while the third column shows cumulative sum of the g_w's. In practice, we are unable to consider all of the infinitely many possible number of SNM fragments contained in a drum. Furthermore, we know from size considerations that there must be an upper limit to the number of fragments contained. Table 4 shows that the upper limit to the number of contained SNM fragments may be chosen far less than the value that may be dictated by size limitations. Table 4 shows that the probability that the number of SNM fragments contained in a given drum is between 0 and 22 (inclusive) is 0.99972. That is, only 0.028% of drums examined will be likely to contain more than 22 fragments. This may be deemed a negligibly low probability, allowing us to limit consideration to 22 or fewer fragments contained in a drum.

Stage IV

It is certainly true that all the SNM fragments in the sample are not of the same mass. In order to account for this in our calculations, we require additional statistical information, as outlined in Reference [3]. However, since such detailed information is not likely to be available, we have assumed in this calculation that all the fragments are of the same mass: the average value, μ. This average, or typical, SNM fragment mass must be supplied as input data. In this example we use $\mu = 1$ gram.

Stage V

The drum has now been partitioned into five contiguous bins, and the response profile and fractional volume of each bin has been evaluated. Consider now a fixed number, w, of SNM fragments contained in a particular drum. Any particular spatial distribution of these fragments among the bins may be characterized by a string of four non-negative integers: the number of fragments in each of the first four bins. The number of fragments in the fifth bin is determined by subtraction. Let w_i represent the number of fragments in the i-th bin. Now let us consider a four-dimensional space whose axes are labeled w_1, w_2, w_3, and w_4. Any given spatial distribution fragments, represented by a string of integers $w_1,\ldots,w_4$, corresponds to an integer lattice point in our multi-dimensional space. Furthermore, to each spatial distribution of SNM fragments there is a unique value of measured activity, which we represent by $A(w_1,\ldots,w_4)$. This function can be evaluated for any values of $w_1,\ldots,w_4$, even for non-integer values. The aim of this stage of our calculation is to determine the equations of surfaces of constant activity in the multi-dimensional space. Moving on such a surface does not change the measured activity, although the total mass and distribution of the SNM in the sample changes.

Table 1

SMALLEST DETECTABLE RADIAL DISPLACEMENT (cm)

z/H \ r/R	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.2	4.1	4.3	4.7	5.2	6.1	7.3	9.6	14.1	28.2
0.5	4.2	4.5	4.8	5.4	6.2	7.5	9.8	14.5	29.8
0.8	4.5	4.7	5.1	5.7	6.6	8.0	10.4	15.3	30.3

Table 2

SMALLEST DETECTABLE VERTICAL DISPLACEMENTS (cm)

r/R \ z/H	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.2	1156	579	387	291	234	196	169	148	133
0.5	524	262	175	132	106	88.5	76.2	67.1	60.0
0.8	398	199	132	100	80.2	67.1	57.8	50.8	45.5

Table 3

RESPONSE PROFILE

Bin Number	Fractional Volume	Response Profile (Counts/g)
1	0.00563	1011.8
2	0.0483	1047.5
3	0.1004	1093.6
4	0.1846	1138.1
5	0.6612	1189.2

Table 4

PROBABILITY DISTRIBUTION FOR THE NUMBER OF SNM FRAGMENTS

w	g_w	$\sum_0^w g_i$
0	.000045	.000045
1	.000454	.000499
2	.00227	.00277
3	.00757	.0103
4	.0189	.0292
5	.0378	.0670
6	.0631	.1301
7	.0901	.2202
8	.1126	.333
9	.1251	.458
10	.1251	.583
11	.1137	.697
12	.0948	.792
13	.0729	.864
14	.0521	.917
15	.0347	.951
16	.0217	.973
17	.0128	.986
18	.00709	.9928
19	.00373	.9966
20	.00187	.9984
21	.000889	.99932
22	.000404	.99972

Before proceeding to describe how we do this, it is worthwhile to briefly discuss where we are heading in this and the following stage. Recall that we are considering a fixed total number, w, of contained SNM fragments. In the course of the present stage, we shall calculate the equations of surfaces, in the multi-dimensional space, of constant measured activity. We will find that as we move out from the origin of the space, we will pass surfaces of ever increasing activity. Now let us stand for a moment on one of these surfaces, and survey the integer latice points lying on or above our surface and below the next surface above us. Recall that each such lattice point corresponds to a distinct spatial distribution of the w SNM fragments. In the following stage, we will calculate the probability of each such distinct spatial distribution. By summing up the probabilities calculated for all the points on or above our surface and below the next surface above us, we are able to evaluate the conditional probability that the measured activity falls between the activity values of the two surfaces, given that w SNM fragments are contained in the drum. This conditional probability distribution is represented by $P(A_1 \leq A < A_{i+i} \quad w)$, where A_i is the activity of the surface on which we stand, and A_{i+1} is the activity of the next surface up. The final achievement of the following stage (VI) is to calculate this probability distribution.

We now proceed to develop the equations for surfaces of constant activity in the multi-dimensional space.

Consider a particular spatial distribution of w SNM fragments, with w_1 fragments in the first bin, w_2 in the second, etc. The activity of this distribution is

$$A(w_1,\ldots,w_5) = \sum_{i=1}^{5} \mu w_i f_i \qquad (5)$$

where f_i is the response profile (counts/gram) of the i-th bin (see Table 3) and is the mass of the fragments (in our case 1 gram). The total number of fragments is known and equals

$$w = \sum_{i=1}^{5} w_i \qquad (6)$$

Thus (5) can be re-written as

$$A(w_1,\ldots,w_4) = \sum_{i=1}^{4} \mu w_i (f_i - f_5) + \mu w f_5 \qquad (7)$$

This is a function in our four-dimensional space, and we seek surfaces for which $A(w_1,\ldots,w_4)$ = constant. Since the response profile is independent of the spatial distribution of SNM fragments, the quantities $f_1,\ldots f_5$ are simply numbers, independent of the w_i's. The analysis at this point would be more complicated if the response profile per bin were a function of the full spatial distribution of SNM, (e.g., due to self-shielding or multiplication). We do not consider this case in the present paper. The surfaces of constant A are planes, whose equations are

$$0 = \sum_{i=1}^{4} \mu (f_i - f_5) w_i + b \qquad (8)$$

The value of b is determined by the constant value, $\hat{A}$, of activity for the plane. Thus b is found to be

$$b = \mu w f_5 - \hat{A} \qquad (9)$$

Any values of $w_1,\ldots,w_4$ satisfying (8) and (9) will satisfy (7), where $A(w_1,\ldots,w_4) = \hat{A}$.

The lowest possible activity measurement, A_{min}, is zero, and occurs when no SNM fragments are contained in the drum. The greatest possible activity, A_{max}, occurs when w = 22 and all the fragments are in the bin with the highest response profile (bin #5). The resulting value of A_{max} is, (using Table 3),

$$A_{max} = w f_5 = 26162 \text{ counts.}$$

Nine intermediate values of activity conveniently divide this range into 10 equal intervals. The 11 delimiting values of activity are given by

$$A_i = \frac{i A_{max}}{10}, \quad i = 0,1,2,\ldots,10 \qquad (10)$$

Table 5 presents these 11 delimiting values of activity.

For each possible number, w, of SNM fragments, we will construct those planes of constant activity up to and just exceeding the greatest activity attainable for the given value of w. The resulting values of b are shown in Table 6.

Stage VI

For a fixed number of SNM fragments, the normalized probability of a particular spatial distribution w_1, $w_2,\ldots,w_5$ is given by

$$H(w_1,\ldots,w_5) = \frac{w!}{w_1!,\ldots,w_5!} p_1^{w_1} \cdot \ldots \cdot p_5^{w_5} \qquad (11)$$

where w_i is the number of SNM fragments in the i-th bin and p_i is the fractional volume of the i-th bin (see Table 3).

Our aim in this stage is to calculate the conditional probability $P(A_i \leq A < A_{i+1} \mid w)$ that the measured activity is in the interval

$$A_1 \leq A < A_{i+1} \qquad (12)$$

given that w SNM fragments are contained in the drum. A_i and A_{i+1} are the activities of two successive planes of constant activity in the multi-dimensional space introduced in the previous stage. To do this we must sum up the probabilities of all the spatial distributions represented by integer lattice points lying on or above the i-th plane and below the (i+1)-th plane. This process is repeated for each adjacent set of planes and for each value of w.

This process may be pursued in a routine manner. However, a word of caution should be added. The number of distinct spatial distributions which need to be located with respect to the planes of constant activity and for which Eq. (11) must be evaluated may be quite large. The number of distinct spatial distributions (not counting identical permutations) of w SNM fragments in n bins is

$$Q(w,n) = \frac{(w+n-1)!}{w!(n-1)!} \qquad (13)$$

This function is evaluated for several values of w and n, and presented in Table 7. In our case, 22

Table 5

DELIMITING VALUES OF MEASURED ACTIVITY (COUNTS)

i	0	1	2	3	4	5	6	7	8	9	10
A_i	0	2616	5232	7849	10465	13081	15697	18314	20930	23546	26162

Table 6

VALUES OF b

w	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}
0	0										
1	1189.2	-1426.8									
2	2378.4	-237.6									
3	3567.6	951.6	-1664								
4	4756.8	2140.8	-475.2								
5	5946.0	3330.0	714.0	-1903							
6	7135.2	4519.2	1903.2	-714							
7	8324.4	5708.4	3092	475.4	-2141						
8	9513.6	6897.6	4282	1665	-951.4						
9	10702.8	8086.8	5471	2854	237.8	-2378					
10	11892.0	9276.0	6660	4043	1427	-1189					
11	13081.2	10465.2	7849	5232	2616	0					
12	14270.4	11654.4	9038	6421	3805	1189	-1427				
13	15459.6	12843.6	10228	7611	4995	2379	-237.4				
14	16648.8	14032.8	11417	8800	6184	3568	951.8	-1665			
15	17838.0	15222.0	12606	9989	7373	4757	2141	-476.0			
16	19027.2	16411	13795	11178	8562	5946	3330	713.2	-1903		
17	20216.4	17600	14984	12367	9751	7135	4519	1902	-713.6		
18	21405.6	18790	16174	13557	10941	8325	5709	3092	475.6	-2140	
19	22594.8	19979	17363	14746	12130	9514	6898	4281	1665	-951.2	
20	23784.0	21168	18552	15935	13319	10703	8087	5470	2854	238.0	-2378
21	24973.2	22357	19741	17124	14508	11892	9276	6659	4043	1427	-1189
22	26162.4	23546	20930	18313	15697	13081	10465	7848	5232	2616	0
	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}

Table 7

NUMBER OF DISTINCT SPATIAL DISTRIBUTIONS

Number of Fragments	Number of Bins			
	5	10	20	40
1	1	10	20	40
5	126	2002	42504	1.09E6
10	1001	92378	2.00E7	8.22E9
22	14950	2.02E7	2.45E11	4.03E14

fragments may be distributed in 14,950 distinct ways among five bins. This is still a tractable number of calculations. However, were the drum divided into 10 bins, we would confront 2.02×10^7 distinct distributions, and the computation inivolved may be prohibitive. With 40 bins, the number of calculations becomes quite large, and some way of reducing the number of calculations must be developed.

Most of the assay devices are or can be designed so that a large number of bins (10 or more) will not often be encountered in practice. The incentive to avoid a large number of bins is not only the computational challenge. The greater the number of bins, the greater the uncertainty in the determination of the contained mass of SNM. The instrument designer hence strives to provide as flat a response profile as possible, thus limiting the number of bins to a small value. Nevertheless, in some cases the number of distinct distributions may be quite large, for instance, if the number of SNM fragments is large, and then special techniques must be employed to handle the computational difficulties.

Returning to our example, we present the calculated probabilities in Table 8. Each row contains a normalized probability distribution; each entry is the probability that the activity A falls in the inverval $A_1 \leq A < A_{i+1}$, given that w SNM fragments are contained in the drum. For instance, with nine fragments in the drum, the probability is 0.4707 that the activity will fall between the third and fourth activity surfaces. Reading the values of these delineating activities from Table 5, we have

$$P(7849 \leq A < 10465 \mid w=9) = 0.4707 .$$

Continuing in the same row of Table 8, the probability that the activity falls between the fourth and fifth surfaces is

$$P(10465 \leq A < 13081 \mid w=9) = 0.5293 .$$

Stage VII

In the previous stage we calculated the conditional probability $P(A_i \leq A < A_{i+1} \mid w)$ that the activity is in a certain interval, given that a fixed and known number of SNM fragments are in the drum. From Stage III we know the probability g_w that w SNM fragments are contained in a drum. From Stage IV we know that the mass of each SNM fragment is $\mu = 1$ gram. We will now combine the results of these stages to calculate the bivariate probability distribution $P(M_j \leq M < M_{j+1}, A_i \leq A < A_i + 1)$ that the total contained mass is in the interval

$$M_j \leq M < M_{j+1}$$

and that the measured activity is in the interval

$$A_i \leq A < A_{i+1}.$$

The activity intervals have already been defined (Table 5). The total mass of SNM fragments contained in any drum may range from 0 to 22 grams. Let us divide this range into 10 equal intervals. Thus the 11 delimiting values of mass are

$$M_j = \frac{22j\mu}{10} , \quad j = 0, 1, 2, \ldots, 10 . \qquad (14)$$

The values are shown in Table 9.

We shall start by calculating the probability that the total contained mass falls in the first mass interval and the measured activity falls in the first activity interval. The total contained mass M may fall in the first mass interval if 0, 1, or 2 SNM fragments are contained in the drum. The probabilities for these three events are, from Table 4,

$$g_0 = .000045$$

$$g_1 = .000454$$

$$g_2 = .00227$$

respectively. Turning now to Table 8, we find that the probability that the activity is in the first interval, given 0, 1, or 2 SNM fragments, is

$$P(A_0 \leq A < A_1 \mid 0) = 1.00$$

$$P(A_0 \leq A < A_1 \mid 1) = 1.00$$

$$P(A_0 \leq A < A_1 \mid 2) = 1.00$$

respectively. Combining these results we calculate the desired bivariate probability as

$$\begin{aligned} P(M_0 \leq M < M_1, A_0 \leq A < A_1) &= P(A_0 \leq A < A_1 \mid w=0)g_0 \\ &\quad + P(A_0 \leq A < A_1 \mid w=1)g_1 \\ &\quad + P(A_0 \leq A < A_1 \mid w=2)g_2 \\ &= (1.00)(0.000045) + (1.00)(.000454) \\ &\quad + (1.00)(.00227) \\ &= 0.00277 \end{aligned}$$

Now let us calculate the probability that the total mass is in the first interval and the measured activity is in the second interval. A

Table 8

CONDITIONAL PROBABILITY $P(A_i \leq A < A_{i+1} | w)$*

(Blanks are to be interpreted as zeros)

w \ i	0	1	2	3	4	5	6	7	8	9
0	1.00									
1	1.00									
2	1.00									
3		1.00								
4		1.00								
5			1.00							
6			1.00							
7			.00932	.99068						
8				1.00						
9				.4707	.5293					
10					1.00					
11					.9895	.0105				
12						1.00				
13						1.00				
14						.00054	.99946			
15							1.00			
16							.0439	.9561		
17								1.00		
18								.4513	.5487	
19									1.00	
20									.9552	.0448
21									.00003	.99997
22										1.00

*For the last interval (i = 9) the probability is to be interpreted as $P(A_9 \leq A \leq A_{10} | w)$.

Table 9

DELIMITING VALUES OF TOTAL CONTAINED MASS (GRAMS)

j	0	1	2	3	4	5	6	7	8	9	10
M_j	0	2.2	4.4	6.6	8.8	11.0	13.2	15.4	17.6	19.8	22.0

glance at Table 8 shows us that this probability is zero, since with less than 3 SNM fragments, the probability is zero of obtaining a measured activity in the second interval.

We proceed in this manner until we obtain all the results shown in Table 10. This bivariate distribution is normalized, so the sum of the entries of this table is unity.

Stage VIII

In this final stage, we calculate the conditional probability that the total contained mass is in a certain interval given that the activity has been measured and found to be in a known range. We represent this probability distribution as $P(M_j \leq M < M_{j+1} \mid A_1 \leq A < A_{i+1})$.

This result is readily obtained from Table 10. For example, suppose a drum has been measured and found to yield an activity reading between A_4 = 10465 and A_5 = 13081 counts. Referring to Table 10 we find that, in light of this measurement, the only mass intervals in which the total contained mass may fall are

$$M_4 \leq M < M_5$$

and

$$M_5 \leq M < M_6 .$$

Furthermore, the bivariate probabilities of these two cases are

$$P(M_4 \leq M < M_5,\ A_4 \leq A < A_5) = 0.19132$$

and

$$P(M_5 \leq M < M_6,\ A_4 \leq A < A_5) = 0.11251$$

respectively. The definition of conditional probability allows us to calculate the desired final results:

$$P(M_4 \leq M < M_5 \mid A_4 \leq A < A_5) = 0.62969$$

$$P(M_5 \leq M < M_6 \mid A_4 \leq A < A_5) = 0.37031 .$$

This process is repeated for each column of Table 10, and the results are shown in Table 11. Each column of this table is a normalized conditional probability distribution. These probability distributions are the final product of our efforts: they tell us the probability distribution of contained mass given measured limits of the activity.

The probability distributions, M, in Table 11 define the limits of error due to inhomogeneity of the SNM in the sample in our example. In a rather simplistic way one can define from M the maximum and minimum values of the total SNM mass, which can yield the same measured response. The results of Table 11 are plotted as error bars in Figure 3, as explained above. It is shown that for a low count rate of less than 5000 cps the errors due to inhomogeneity are negligible. This is because there is only one combination of SNM fragments in the sample which can yield such a low response.

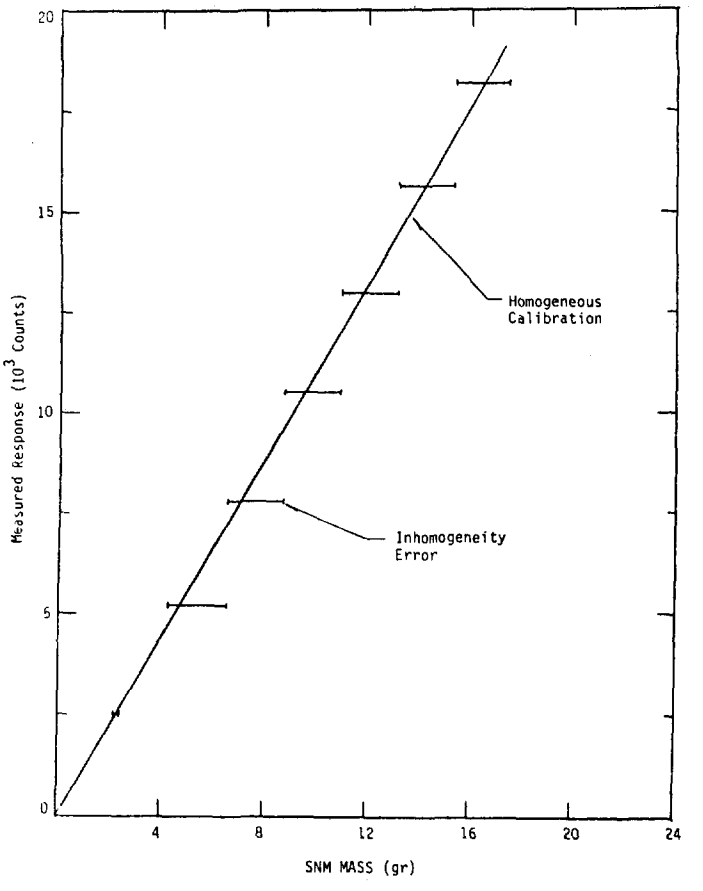

Figure 3. Error Due to Inhomogeneity of the SNM in the Sample

Table 10

BIVARIATE PROBABILITY DISTRIBUTION $P(M_j \leq M < M_{j+1} \mid A_i \leq A < A_{i+1})$*

(Blanks are to be interpreted as zeros)

j \ i	0	1	2	3	4	5	6	7	8	9
0	.00277									
1		.02647								
2			.1009							
3			.00084	.20186						
4				.05888	.19132					
5					.11251	.16889				
6						.00028	.08677			
7							.00095	.03355		
8								.00320	.00762	
9									.00179	.00138

*For the last interval (i = 9 or j = 9), the probability is to be interpreted as ($P(M_9 < M < M_{10}$, ---) or P(---, $A_9 < A < A_{10}$).

Table 11

CONDITIONAL PROBABILITY $P(M_j \leq M < M_{j+1} \mid A_i \leq A < A_{i+1})$*

(Blanks are to be interpreted as zeros)

j \ i	0	1	2	3	4	5	6	7	8	9
0	1.00									
1		1.00								
2			.99174							
3			.00826	.77418						
4				.22528	.62969					
5					.37031	.99834				
6						.00166	.98917			
7							.01083	.91293		
8								.08707	.80978	
9									.19022	1.00

*For the last interval (i = 9 or j = 9), the probability is to be interpreted as ($P(M_9 < M < M_{10}$, ---) or P(---, $A_9 < A < A_{10}$).

For simplicity, in this paper we have chosen only a few mass intervals and activities (10 for each). Hence, for activity (i.e., count-rate) above 5000 cps, only a combination of two mass distributions can generate each specific count-rate. Therefore, the error in the SNM is constant. Better definition of activity and mass may be obtained by dividing the full ranges of these quantities into finer intervals.

SUMMARY AND CONCLUSIONS

A statistical model has been applied to define the effect of SNM distribution on a NDA response. A specific example of passive gamma measurement has been chosen to demonstrate the concept. The methodology is, however, not limited to any particular NDA system.

The probabilistic approach enables a quantitative definition and assessments of the errors created by inhomogeneous distributions of the SNM in the sample. The proposed method can be generalized to include interactions between the SNM fragments, namely self shieldings and neutron multiplication. Also, effects of non-uniform matrix materials can be incorporated.

The knowledge of the above-mentioned errors along with other random and systematic errors will assure a proper assessment of the true accuracy of SNM assay measurements.

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SAFEGUARDS INSTRUMENTATION: PAST, PRESENT, FUTURE*

W.A. HIGINBOTHAM
Brookhaven National Laboratory
Upton, New York

Abstract

Instruments are essential for accounting, for surveillance and for protection of nuclear materials. The development and application of such instrumentation is reviewed, with special attention to international safeguards applications. Active and passive non-destructive assay techniques are some 25 years of age. The important advances have been in learning how to use them effectively for specific applications, accompanied by major advances in radiation detectors, electronics, and, more recently, in mini-computers. The progress in seals has been disappointingly slow. Surveillance cameras have been widely used for many applications other than safeguards. The revolution in TV technology will have important implications. More sophisticated containment/surveillance equipment is being developed but has yet to be exploited. On the basis of this history, some expectations for instrumentation in the near future will be presented.

It would seem to be worthwhile now and then, to take a look back at the safeguards activities in the past and to think about where we stand now and where we are going. Contrary to rumor, I was not involved at the start of safeguards or of the INMM. So my review of the early days is based on published documents.

As the title states, the subject is safeguards instrumentation, not safeguards as a whole. Also, the emphasis is on instruments for use by the IAEA, although most of the instruments also are useful for national safeguards applications. I am sure that this audience understands how instruments are, or should be used as tools for independent verification of material accounting and for containment and surveillance; and that the availability of suitable instruments, reliable instruments, and instruments that are easy to use are very important for the efficiency and credibility of IAEA safeguards.

How many of you have heard of Atomic Energy Commission contract AT (30-1)-2176, of 1959? The IAEA was then a couple of years old, but not yet actively engaged in safeguards. The nuclear test moratorium had started and there appeared to be some hope of halting the nuclear arms race. The Atomic Energy Commission requested Westinghouse Corporation to design an international safeguards system and to develop the necessary instrumentation. The contract was for one year.

Here is a summary of the instruments:

Chemical Analysis: Selection of methods, study of analysts' performance.

NDA: Passive gamma-ray scanner for MTR fuel plates.

Passive neutron assay of U-238, active assay of U-235 in PWR fuel assemblies

Annular nuclear core for criticality of PWR fuel assemblies.

Perimeter intrusion detector; motion detectors.

Access control techniques.

Portal monitor (gamma-ray, neutron, metal detectors)

Tamper indicating techniques; secure data links.

Data logging/processing computer.

On-line instruments: Liquid level, specific gravity, polarograph, alpha detectors, gamma-ray detectors and absorptimeters, neutrons, flowmeters.

Reactor power monitors (watts, thermal flow, n-flux).

Some instruments were purchased and evaluated. Gamma-ray and neutron instruments were constructed and demonstrated. Feasibility

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of some more elaborate NDA systems was established. 33 reports were written and distributed. All of this in one year, at a cost of 1.2 million dollars. By the end of the year the AEC had lost interest. No significant amount of safeguards R&D was sponsored until 1967, after the U.S., U.K. and U.S.S.R. had agreed on the terms of the NPT, and the Lumb Panel emphasized the critical importance of both domestic and international safeguards.

The IAEA, on the other hand, was becoming more active at this time, arranging for joint R&D projects with friendly member States. There were approximately 20 of these joint studies in the period 1959-1967. All of them had something to do with spent fuel: deducing burnup from gamma-ray spectra of the fission products, burnup calculations, reactor power monitors, and a device to photograph the serial numbers on fuel assemblies. The reason for this emphasis was that almost all of the facilities under safeguards at that time were reactors. The emphasis began to switch to fuel processing facilities when the NPT became a likely prospect in January 1967.

In 1968 I was invited to observe the ALKEM Exercise at the Karlsruhe Nuclear Center. At that time, the Karlsruhe safeguards group was doing very exciting things: systems studies, instrument development, and demonstration exercises. The ALKEM plutonium-uranium fuel fabrication plant, located nearby, fabricated about 200 kg of plutonium into fuel rods for testing in LWR's. The PuO_2, obtained from the U.S., was very carefully measured analytically. Pellets and rods were measured by gamma-ray spectrometry, and several rods were measured at-a-time in a giant calorimeter. Scrap and waste were also measured by NDA. Items were sealed, and there was a portal monitor. This was probably the first fully measured material balance for a fuel campaign.

The IAEA had begun to use seals in 1968. The Agency purchased the cheap cup or cap seals manufactured in the U.S. for the control of alcohol producers. Agency personnel conceived of the idea of marking the inside with random scratches, photographing this pattern, and optically verifying this pattern after a seal was returned. One of the first TSO tasks was to determine if the seal could be mechanically disassembled and reassembled without leaving obvious marks. C. Sastre and T. Gody found a way to do this and suggested a way to treat the seals to overcome this vulnerability.

Let me take NDA instruments according to application. The first reference in 1952 was to measuring the 186 KeV gamma-ray of U-235, in order to measure the U-235 in MTR fuel plates.[1] A NaI(Tl) scintillation detector was used. The first reference I find on employing this approach for enrichment is from G.E. Hanford, 1955.[2] There have been a great many papers on these applications since. Probably the largest application today, is for measuring the enrichment of UF_6 in cylidners, using an acoustic device to measure and correct for the thickness of the cylinder wall.

Of course, development of germanium detectors in the early 1960's opened up many new applications for high-resolution, gamma-ray spectrometry. Jim Cline used this technique to measure the plutonium contained in 10 liter bottles of Pu-nitrate in 1970.[3] At the same time, Ray Gunnink was developing very sophisticated gamma-ray spectroscopy systems and computer programs for measuring all sorts of radioactive samples. He remeasured the energies and branching ratios of the isotopes of special interest for safeguards and has continued to improve the sensitivity and efficiency of isotopic and elemental assay of plutonium samples.[4]

In 1968, the idea of using coincidence techniques to distinguish spontaneous fission events from alpha-n and background neutrons was rediscovered at the Naval Research Lab. and Los Alamos, simultaneously. I say rediscovered because Jacques Jacquesson of CEA, Paris, published this technique in 1963.[5] There have been many modified versions of the coincidence (autocorrelation would be a better word) circuit since then which have some advantages. Norbert Ensslin of Los Alamos has contributed much to our understanding of how these systems work and of how to assess and to correct for self multiplication of fission events in large samples.[6] Others who have contributed to this art include G. Birkhoff and L. Stanchi of Ispra, K. Boehnel of Karlsruhe, and K.P. Lambert of Harwell. What has also been important has been the large amount of experience in using these instruments, which has resulted in the design of special configurations for particular applications. High-resolution gamma-ray spectrometry, to measure isotopics, and passive neutron instruments are a very useful combination for the IAEA at plutonium handling facilities.

This brings us to active neutron or neutron interrogation instruments. The first that I remember were a neutron and a high energy photon activation sytem using pulsed accelerator sources. Los Alamos and General Atmics built vans with these machines which toured the U.S. in 1970. Like the Westinghouse sub-critical reactor of 1959, these seem, in retrospect, to have been overly ambitious. However the tours proved to be useful and there have been some important applications of pulsed neutron activation and delayed neutron counting.

The first active neturon instrument in the U.S. to use an isotopic neutron source, was the ISAS, designed by Tsahi Gozani at Rad Tech for United Nuclear Corp. The detector consisted of 3 plastic scintillators, sensitive to neutrons and to gamma-rays. Fission events were identified by requiring a coincidence of 2 or 3 of the scintillation detectors in response to the burst of prompt neutrons and gamma-rays from a fission. This was soon followed by the "random driver" of Los Alamos, which also had 3

detector slabs around the sample, but which responded only to neutrons. Each had its advantages and disadvantages and both are still manufactured and sold commercially.

Someone at Los Alamos deserves credit for combining the passive neutron coincidence system with a neutron source. The moderated, thermal neutron detectors of the former have high efficiency and the coincidence (autocorrelation) circuitry easily distinguishes induced fission events from the single neutron pulses due to the isotopic neutron source. From these have developed a great set of passive and active neutron NDA instruments, confused by such names as the "High-level neutron counter" (which in fact is quite inefficient), the "Active Well Coincidence Counter", (which can also be used passively, and all models are designed with a well), the "Neutron Coincidence Collar" (it is a "collar"), etc. In fact, all of this set of instruments use the same electronic circuits to count singles and coincident neutron pulses, the same calculator to reduce the data, and the same He-3 proportional counters. There are now a number of detector heads for specific uses (small samples to FBR fuel assemblies), and weak (and therefore safe) AmLi neutron sources are used for the active mode. This facilitates commercial production and simplicity of training, while offering instruments for a very wide range of materials.

Now for containment/surveillance (C/S). The IAEA performs surveillance, assuming that the walls of a UF_6 cylinder or of a reactor provide the containment. If the seals or locks or cameras are highly reliable, one has to worry about the containment; but that is another subject.

After seals, which I mentioned above, the IAEA began to use cameras for surveillance of sensitive areas for the considerable time between visits of inspectors. Someone else will have to record this history. The U.S. Government finally began to worry about physical protection of sensitive nuclear materials and facilities in 1973, after Ted Taylor and Mason Willrich warned of potential subnational threats. As a result of this the U.S. Government initiated R&D on physical protection instruments and techniques. Some of this has proved also to be of use to the IAEA. The camera systems used by the IAEA today have two Minolta 8mm, home-move cameras, adapted for time-lapse exposures, provided with a timer to take pictures at a chosen frequency, and enclosed in a tamper-indicating enclosure that is sealed by the inspectors after changing film cartridges. These are cheap systems. Over time, camera failures have been analyzed and largely corrected. There are still problems: The pictures are dim if the lights go dim (TV cameras have a much wider dynamic range). The film capacity is marginal, even using Kodak extra-thin B&W film. Even with two cameras, double failures do occur. Time is not recorded on the film. Some countries insist that the films be developed there - not sent to Vienna. If much activity is recorded on a film it may be very difficult to decide whether or not anything suspicious has happened.

Home movie cameras are about to disappear, being replaced by home TV cameras. This will offer an opportunity to replace film cameras with more effective and reliable TV's, in time. In the last few years Euratom and the U.S. have spent money developing TV systems. The Agency is now evaluating a U.S. model which has many attractive features. It works with high or low illumination, records time and date on each frame, has motion sensors to discard scenes with activities that are not of interest, records attempts to subvert it, and can replay the recorded pictures along with alarms to call attention to suspicious events. It is a very complex system and costs about $50,000 compared to about $1,000 for the two Minolta cameras in a tamper-indicating enclosure.

There are three instruments which I want to mention because they appear to be especially useful, and because they did not develop logically from the NDA and C/S programs above.

One is the Cerenkov viewer. The U.S. supplied a pool-type research reactor to the first Atoms for Peace Conference in Geneva, 1955. All of the delegates and many natives looked into the pool and admired the blue-green Cerenkov glow around the fuel elements. Night vision devices were developed during WW-II; snooper scopes we called them. These have been improved. Some genius at Los Alamos thought to find out if one could use these to see the Cerenkov glow of spent fuel assemblies that had been out of a reactor for several years. Lo, and behold, it worked. If you can persuade the reactor operator to dim the lights, you can see the glow, outlining the rods, looking down through the pool water at the top of fuel assemblies. Once a year, and whenever a surveillance camera fails, IAEA inspectors are supposed to reinventory the 1,000 or so spent assemblies in a reactor storage pool. Counting them may not be too time-consuming; but reading identity symbols under 20 feet of water is time-consuming and difficult. Besides, it would not be very difficult to replace spent fuel assemblies by dummies with authentic symbols. It is easier and more convincing to observe that all 1,000 assemblies are indeed in the pool, and glowing.

A serious problem for the IAEA, and even for U.S. agencies, is the shipment of radioactive safeguards samples to a central analytical laboratory for analysis. This is a vital operation. On their own initiative, a group of analytical chemists at Oak Ridge developed a clever technique for plutonium samples from a reprocessing plant. Highly radioactive solution samples from the input accountability vessel or less radioactive solutions downstream, are accurately measured and then spiked with accurately measured amounts of U-233 and Pu-244. Then small resin beads are

dropped into the solution to selectively absorb plutonium and a lesser amount of the more abundant uranium. A few beads are withdrawn, containing a micro-gram or so of plutonium, the radiation levels are so low that the beads can be legally shipped by air-mail to Vienna. The bead part worked well; but difficulties were encountered in preparing the samples and in performing the mass-spectrometer analysis at the Safeguards Analytical Lab. in Vienna. The Oak Ridge inventors have provided assistance to the analysts at the reprocessing plants and the spectroscopists in Vienna. The prospects look very good.

It has been my pleasure to have participated on a few IAEA expert groups. At one of these, I remember that Les Thorne, now head of the Far East Operations Section, complained about verifying weights. It was not too difficult to bring standard kilogram weights to calibrate the balances at a nuclear plant, but it was not feasible to bring tonne weights to calibrate the scales used at fuel fabrication plants to weight 2½ tonne cylinders of UF_6. Besides, in modern plants such scales are hitched to computers and the calibration could be changed at will.

Some friends at the National Bureau of Standards, whose business it is to keep up with weights, proposed a few years ago that commercially developed strain gauge devices, which are physically small, might be used by the Agency to independently weigh such heavy objects. Not only did this work, but the commercially available instruments have become less delicate and more accurate since then. Now, the IAEA can make its own measurements of the weight of UF_6 cylinders, PWR fuel assemblies, etc., if it can persuade the operators to hook this instrument between hoist and object when moving full containers, and also when removing the empty containers for tare weight. The technical problems are solved, though perhaps not the operational ones.

There are many more special instruments and applications, but these should be enough to support the following conclusions.

Some of the instrument developments came about directly as a result of continued R&D on safeguards instruments. The passive and active neutron instruments are of this class. In the case of gamma-ray instruments, the gamma-ray detectors, special amplifiers and multichannel analyzers were developed for other purposes, and adapted for safeguards uses. From here on, the important improvements in NDA instruments will be to make them easier to use, taking advantage, e.g., of micro-computers. For accuracy, calibration is vital. More effort is needed to develop NDA standards and to explain how the nature of fuel cycle items may affect the results. Few inspectors have a thorough understanding of the physical properties of nuclear materials. If possible, instruments should flash a warning if the spectrum is abnormal, or the dead-time losses excessive, etc.

The accurate variables measurements are usually based on the measurement of weight and the taking of samples to be sent to Vienna for chemical analysis. At bulk processing facilities for high enriched uranium or plutonium fuels, it would be desirable for inspectors to analyze samples at the facilities. There may be procedural problems. For example, the facility operator may insist that only his technicians handle the samples. Also, such equipment should not require years of training on the part of Agency analysts.

In the C/S area, I doubt that it will be economically feasible or technically credible to place great reliance on extended C/S, as was recently advocated by the International Working Group on Reprocessing Plant Safeguards. However, more extensive use of C/S, carefully integrated with accountancy, is surely needed. In some cases, I suspect that it will be useful to invest a considerable amount of money and effort in trying out techniques that may not, in the end, prove to be useful, but will lead to the better solutions. In this regard, the generous participation of the Japanese at the Tokai-Mura reprocessing plant and JAERI, has been invaluable in learning how to efficiently apply safeguards for reprocessing.

The $50,000 TV sets that the U.S. has provided the Agency, are another example of this. It would be very expensive to replace all of the Minolta twin cameras with these instruments. On the other hand, with all of the special features on these camera systems it will be possible to define the criteria for future cameras that will take advantage of the rapid changes now taking place in that field.

Sandia has developed and demonstrated a set of modules, various sensors and a tamper indicating data analysis and recording module, which should have a number of applications. For example, it could be used at a spent fuel storage pool to record the motions of the cranes which would be needed to remove spent fuel from the pool and would trigger the surveillance cameras only when suspicious activities were sensed.

By now we have solutions for almost all of the instrumentation problems we know of. What we need is closer cooperation between the developers and the users. I know that this is difficult to achieve. We have made a lot of progress in the last ten years. We just have to keep trying.

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AN OPERATOR'S EXPERIENCE AND LESSONS LEARNED IN IMPLEMENTATION OF IAEA SAFEGUARDS

ROY NILSON AND RICHARD A. SCHNEIDER
Exxon Nuclear Company, Inc.
Richland, Washington

ABSTRACT

After 18 months and seven IAEA inspections, considerable first-hand experience has been obtained in the implementation of IAEA safeguards in a U.S. bulk-handling facility. This paper reviews the experience in the Exxon Nuclear fuel fabrication plant and presents examples of lessons learned.

Two important conclusions can be made at this time. First, IAEA safeguards in a low-enriched fuel fabrication plant are not overly burdensome to the plant operator. Second, inventory verification by Agency inspectors can be made to an adequate degree of exactness with a minimum random sample size using largely state-of-the-art measurements.

Of high importance among the reasons for those above results is good communication between the inspectors and the operator. A cooperative, non-adversarial approach is found to offer the best chance of minimizing the burden and improving the efficiency. The inspectors have been willing to consider our needs and suggestions, and we have found the inspectors to be reasonable in their requests.

The unique window that the U.S. inspection effort provides should also assist materially in a better understanding in the U.S. of the IAEA's capabilities and the true burden of international safeguards. As the inspection effort shifts to other U.S. facilities, it is hoped that some of our experiences and learning can be helpful.

BACKGROUND

To encourage widespread adherence to the NPT by non-nuclear-weapons states, President Johnson in 1967 announced that the United States would permit the International Atomic Energy Agency (IAEA) to apply its safeguards to nuclear activities in this country. This policy was reaffirmed by each succeeding president. Early on, the offer enabled some cooperative experimental work at West Valley and Yankee Rowe for IAEA training purposes and to develop techniques and evaluate the burden of safeguards. However, it was not until the agreement between the United States and the International Atomic Energy Agency was ratified by the U.S. Senate on July 2, 1980 and entered into force on December 9, 1980 that the offer became implemented in its more typical form. On February 17, 1981, Exxon Nuclear's fuel fabrication plant was chosen as the first U.S. bulk-handling facility to come under the full safeguards agreement.

After approximately a year and a half of experience and seven inspections, what can one say about this activity? Some question, as may some of you in this audience today, why would the U.S., a weapons state, make such an offer in the first place. Second, why would the IAEA spend its scarce resources to implement it? The U.S. offer was a genuine one. On the one hand, it had a motive to encourage other nations to sign the NPT (which it did), and on the other hand, it was to show that the U.S. nuclear industry was willing to share the same burden being placed on non-weapons states signing the treaty.

Fifteen years after President Johnson's offer, we find ourselves finally entering into the implementation phase of the offer. Has the importance diminished over time? Is there still good to be gained? Is it still possible to benefit? Discussing these points, we should remember the basic conflict inherent in any inspector-operator arrangement. Can the IAEA's objective of effective verification be reconciled with the operator's desire of minimum burden? Is there an equitable middle ground which meets both of these opposing objectives?

Earlier papers[1,2,3] have discussed details of the inspection effort as the activity has unfolded over time. This paper is not intended to be as detailed an analysis as those and the reader is referred to the earlier papers. Instead, the primary purpose of this discussion is to review the experiences and lessons learned to date in the hope they will be useful to follow-on facilities under the implementation phase of the offer, and to give our preliminary conclusions on the cost and effectiveness of the inspection effort through the unique window which is now open for the first time.

EXPERIENCE

The seven inspections, occurring on the average of once every two months, have included two inventory verifications, each requiring four to six days and five shorter inspections involving various nondestructive measurements, observation of our measurements, selection of random samples and audit of our records and reports.

Verification of our inventory statement of nuclear materials is made by the inspectors using an attribute-variables sampling plan. This type of random sampling can detect with high probability the absence (or overstatement) of a quantity of nuclear material of safeguards importance from the plant's inventory. The inspector's attribute sample sizes for the inventory verifications were based on a goal quantity of 75 kg of U-235 contained and a sampling probability of 0.95 of including at least one gross defect in the sample. The variables sample sizes were approximately one fifth as large as the attribute sample size. The sampling method is further able to detect whether the goal quantity had been removed by taking a small number of whole items, by partially taking material from many items, or by taking a small amount of material from a number of items.

Enrichment of our starting material UF_6 is verified with a germanium detector[4]. An ultrasonic thickness gauge is used to measure the wall thicknesses of the steel UF_6 cylinders to correct for gamma ray attenuation.[5] Enrichment and uranium element composition of UF_6 are also verified from samples taken from the UF_6 line during processing.

The inspectors verify the weight of fuel pellets by witnessing our reweighing of them. Pellet samples are also selected for measurement of U and U-235 later at the IAEA laboratory.

For UO_2 powder verification, the inspectors use our SAM-2[5] enrichment meter as an attribute test. The selected buckets are first weighed and then machine tumbled to mix the material prior to the enrichment measurement. The tumbling insures that any substituted inert materials would be detected, since the SAM-2 as used only detects the gamma rays coming from the UO_2 in the bottom of the bucket. A fraction of buckets is sampled for U and U-235 analyses later at the IAEA laboratory. These samples serve as "independent" standards for the SAM-2 enrichment meter and also provide the data for the variables test. The independence of the sampling is preserved by completing the UO_2 enrichment measurements on all of the buckets selected for the attribute test before any buckets are identified for sampling for the later destructive analyses.

Fuel rods are randomly selected for verification and are measured for total fissile count with our active rod scanner[6]. Approximately 50 fuel rods need be scanned for a complete inventory verification. The rods are compared against full length "standard" rods selected from reject or excess rod inventories matching the rods tested. A few of the "standard" rods are downloaded in the presence of the inspectors and their fuel pellets are removed for weight verification and later destructive analysis at the IAEA. The majority of the rods are matched by standard rods and can be considered as measured by a variables method. A smaller number of rods ($\sim$ 20%) not matched with standard rods can still be considered verified from an attribute standpoint (to within $\pm$ 15%). The weights of pellets removed from the rods closely matched our stated weights of the fuel pellet columns originally loaded into the rods, and the enrichment verifications in the first inventory verification matched our values within a few tenths of a percent.

Two new instruments have been tested. One is a load cell[7] which fits on our crane attachment and allows the inspector to independently weigh UF_6 cylinders. The load cell has proved very useful to us as well, as it permits UF_6 cylinder weighing in situ, rather than having to move them to a central scale. The second device tested is the Los Alamos developed neutron coincidence collar[8] attachment for nondestructively verifying fuel assemblies.

The direct interaction with the Agency's inspectors has provided several opportunities to minimize the burden, and several of the measurements just described were innovations jointly evolved during the course of the inspections. However, unexpected benefits or spinoffs have also resulted which are important to both the operator and inspector. For example, the field testing of new instruments has demonstrated at least one new practical measurement method whose adoption by plant operators can increase their efficiency, e.g., the load cell weighing device for the crane.

LESSONS LEARNED

As stated earlier, the sharing between the operator and inspector of procedures, techniques and equipment have been mutual learning experiences which have reduced the effort and increased the effectiveness of the inspection. It is of interest to review some of the lessons learned.

It is important that the inspector be able to verify that all of the inventory items claimed by the operator are actually present. A 100% item count is not practicable, nor needed; the total number of items can be verified randomly. But this can only be done validly if the inspector is first given a list of the individual inventory items for selecting his samples.

It is also necessary that the inspector be assured that the operator's final inventory listing (after reconciliation) is the same as that provided earlier prior to verification. After the inspection, the operator knows which items the inspector has verified. If

later, in the final listing sent to the inspector, he alters the values of the items not verified by the inspector, the verification is meaningless. Of course, to counter this, the inspector could have recorded the values of all inventory items, but this would be time-consuming and is desired neither by the operator nor the inspector. A practical solution is to both provide the inspector the inventory list prior to his verification and a final inventory listing after reconciliation. The inspector can then make a one-to-one comparison between the two lists to assure that the final inventory listing is consistent with the initial list and that the inventory item values sum to the correct totals.

To carry out this procedure, the inspectors are provided with copies of our physical count sheets after we complete our physical inventory for each inventory location. These count sheets represent our provisional statements of the number of items present at each location, their individual identities, and their uranium and U-235 content.

The items on the physical count sheets are also arranged in numerical sequence by inventory sticker number and the stickers are applied by our inventory teams in order of physical location. This has made it easy to find the items selected for verification.

The inspectors have not yet been fully receptive to our two-list approach, but since U.S. regulations allow 30 days to close out an inventory and reconcile the books, there is no easy way to provide the inspectors with a final inventory list before they leave the plant; usually less than a week after the start of our inventory taking. We feel the solution described to this problem is fully equivalent and provides the necessary assurances against falsifications.

An alternative to this two-list approach (provisional and final) would be for us to complete our physical inventory, "freeze" it, and then reconcile and finalize the inventory before the start of the inspector's verification, so that a finalized list could be provided to the inspectors prior to their verification. But, this is impractical in our case, since it would require a one-to-two week "inventory freeze" and plant shutdown before the IAEA could start their verification.

No anomalies have been reported to us by the inspectors in either inventory verification. The inspectors have found minor discrepancies between our records and reports and the information received in Vienna via the U.S. Information System (NMMSS). We are in the process of resolving these discrepancies with the NRC and Oak Ridge NMMSS staffs.

Then of course, there have been the many effective mutually developed verification techniques using both Agency and operator measurement methods which have already been described.

COST-EFFECTIVENESS

The main burden experienced is the manpower for escorting inspectors, locating items for verification measurements, performing verification measurements, preparing accounting reports and inventory lists, and providing incidental services. Over the eighteen months to date, this manpower cost equates to less than 15 cents per kilogram of fuel produced in the plant, which is a small fraction of the total cost of producing fuel for LWR's.

We had early concern over the potential for lost production time while the inspectors completed their verification or having to slow or halt production in certain areas so that IAEA verification measurements can be made. This has also not proven to be a problem. In addition to the "two-list" approach already discussed, we have scheduled our inventory taking near a normal production break (e.g., a weekend), so that the inventory verification by the inspectors could be carried out during a normal production break. The IAEA inventory verifications have thus been able to be completed with only a few hours of lost production.

The technical and procedural innovations previously discussed have also proven useful in increasing the efficiency of the verification effort. We estimated that the use of our rod scanner saves approximately four man-days of inspector-operator time per inventory verification compared with a "manual" scan of fuel rods with a passive gamma counter. Likewise, the use of the SAM-2 enrichment meter for the attribute test has reduced the variables sample size by a factor of three from what it would have been if the variables method (weighing, sampling, and analysis) had been used in total. The load cell for weighing UF_6 cylinders has reduced considerably the time to verify UF_6 weights and is a practical device that may also be useful to us. The neutron collar for fuel assemblies enables for the first time the verification of final product, and from the test results to date, the neutron collar should be quite effective.

Our observations to date have shown that all available inventory items in a LWR fuel fabrication plant can be efficiently verified by independent measurement with an adequate level of exactness. Our values for the contents of sintering boats and trays of UO_2 fuel pellets and containers of uranium oxide powders are verifiable to a sufficient degree of quality by weighing, sampling, U-assay, and U-235 mass spectrometric measurements. Combined operator-inspector measurement uncertainties (one sigma level) can be held to 0.1 - 1.0 percent relative. The use of our rod scanner provides a verification uncertainty as small as 1-2 percent for fuel rods, and the independence needed can also be provided.

The enrichment of UF_6 in cylinders can be verified adequately by non-destructive means. Calibration of detectors using cylinders of known enrichments as standards can reduce verification uncertainties for enrichment to only a few percent (one sigma) relative.

An operator's SAM-2 enrichment meter is very valuable in providing the inspector a "gross defect" check for UO_2 containers. Opening a fraction of the containers for visual inspection and sampling for U-assay and U-235 by mass spectrometer provides "independent" standards, and the tumbling protects against material substitution.

The results of tests made on both BWR and PWR fuel assemblies with the coincidence neutron collar were good. The measured enrichment of fuel assemblies agreed with our values within a few percent. Details on how the collar will actually be used in a fuel fabrication plant has not been finally worked out.

One of the important benefits of the implementation of the U.S. offer is that for the first time full fledged IAEA inspections are occurring in the U.S. A window which has never been available before is now open.

SUMMARY AND CONCLUSIONS

It has been demonstrated that significant progress has been made in achieving efficient and cost-effective international safeguards inspections in a bulk-handling facility. Much of the success has been due to the desire on both the operator and inspector to cooperate with each other. Success has also been due to introduction of innovative approaches by both the operator and the inspector. Under such circumstances, the burden of safeguards can be acceptably low without sacrificing the Agency's objectives of adequate safeguards verification.

The operator can further control his burden by maximizing the "verifiability" of his inventory. Cooperative efforts between the inspector and operator in planning, scheduling, and coordinating the combined activities of inventory taking by the operator and inventory verification by the IAEA, are able to virtually eliminate lost production time. Non-destructive assay instruments also play an important role in the efficiency and effectiveness of IAEA verification.

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A NOTE ON THE ASSAY OF SPECIAL NUCLEAR MATERIALS IN SOLUTION BY X-RAY FLUORESCENCE

T.R. CANADA AND S.T. HSUE
Los Alamos National Laboratory
Los Alamos, New Mexico

X-ray fluorescence (XRF) techniques have been used for a number of years in the analytical chemistry laboratory to determine elemental concentrations in solution. The development of high-resolution, energy-dispersive technology and the use of radioisotopic exciting sources greatly simplified the associated hardware, adding a degree of flexibility required for chemical process, in-line application. This technology renews the interest in the application of XRF to special nuclear materials (SNM) assay for both process control and materials accounting purposes.

The traditional difficulty with XRF techniques--sample self-attenuation--has been addressed by several approaches, none of which are directly applicable to an in-line instrument. For a planar sample and a far-field geometry, the number of detected elemental x rays, N, is related to that element's concentration by

$$N = \rho\, K(\alpha) \quad , \tag{1}$$

where $K(\alpha)$ is a calibration function given by

$$K = C(1 - \alpha)/\ell n\alpha \quad .$$

C is a constant and $\alpha = \exp -(\mu_e + \mu_d)\rho x$, where ρx is the sample area concentration and μ_e and μ_d are the sample attenuation coefficients at the exciting and detected photon energies, E_e and E_d, respectively. For a wide range of α, $K(\alpha)$ may be approximated by $K = C\sqrt{\alpha}$.[1] $K(\alpha)$ is often determined in laboratory measurements by adding a standard concentration to the solution whose characteristic x-ray energy is approximately equal to that of the element of interest.

Recently, several authors[2,3] have adapted a variation of this "internal standard" approach to instrumentation that is designed to assay SNM in or at the process line. With this technique, the elemental x-ray peak intensity is normalized to the exciting source, incoherently scattered peak intensity. This normalization reduces or eliminates the measurement dependence upon exciting source intensity, count rate effects such as dead-time and pile-up losses and measurement geometry. However, empirical calibration curves, determined in a lengthy procedure, are dependent on the solution acid normality and the relative concentrations of SNM elements, for example, plutonium and uranium.

In this note, we present a formulation that allows these empirical results to be understood in a quantifiable manner and suggest an alternative measurement procedure that removes many of the technique's undesirable features while maintaining those that add to instrumental accuracy. The audience for this note is assumed to be familiar with XRF technology. A more detailed presentation, including proof-of-principle experimental results, will be presented in the future.

The number of detected incoherently scattered source photons (IC) may be expressed in an equation similar to Eq. (1);

$$IC = (\rho_m\sigma_m + \rho_s\sigma_s)K(\alpha_i) \quad , \tag{2}$$

where ρ_s and ρ_m are the SNM and matrix (everything else) concentrations and σ_s and σ_m are the respective incoherent scattering cross-sections. α_i is determined at E_i, the peak energy for incoherent scattering. If N_s is the number of detected SNM x rays, then it is straightforward to ratio Eqs. (1) and (2) to obtain

$$\frac{\rho_s}{\rho_m} = \frac{R\, K(\alpha_{is})\sigma_\mu}{1 - R\, K(\alpha_{is})\sigma_s} \quad , \tag{3}$$

where R is the ratio of detected x rays to incoherently scattered source photons, N_s/IC, and $K(\alpha_{is})$ is the ratio of calibration functions, $K(\alpha_i)/K(\alpha_s)$.

Equation (3) shows the inherent limitation of the simple ratio technique and gives the functional dependence for the additional parameters that must be determined if the expression is to be used. In the first place, this technique measures the relative SNM concentration. The total solution density must be measured to determine ρ_s; $\rho = \rho_s + \rho_m$. Secondly, the sample matrix constituents must be the same as those in the calibration standards. The matrix scattering cross section (σ_m) is a function of the effective

matrix atomic number. Excluding hydrogen, the incoherent scattering cross section varies ∿50% across the periodic table.[4] Finally, assuming that σ_m is a constant, $K(\alpha_{is})$, a function of ρ and the matrix and SNM mass absorption coefficients, must be determined.

The effective calibration function, $K(\alpha_{is})$, is given by

$$K(\alpha_{is}) = \exp -(\mu_i - \mu_s) \frac{\rho x}{2} \quad ,$$

where μ_i and μ_s are the sample mass absorption coefficients at E_i and E_s. If we assume the sample mass absorption coefficient to be a linear function of energy over the narrow range of interest, then $K(\alpha_{is})$ may be determined by measuring the ratio of two SNM x-ray peaks. From Eq. (1), this ratio is

$$\frac{N_\alpha}{N_\beta} = \delta \exp -(\mu_\alpha - \mu_\beta) \frac{\rho x}{2} \quad ,$$

where N_α and N_β are the elemental x-ray peak intensities at E_α and E_β and δ is a constant.

Equation (3) may then be written as a general calibration function

$$\frac{\rho_s}{\rho_m} = \frac{A\ N}{1 - B\ N} \qquad (4)$$

where

$$N = \left(\frac{N_s}{IC}\right)\left(\frac{N_\alpha}{N_\beta}\right)^{\left(E_i - E_s / E_\alpha - E_\beta\right)}$$

and A and B are calibration constants.

Equation (4) may be modified for mixed SNM solution assay. For example, with mixed plutonium-uranium solutions and assuming the uranium and plutonium incoherent scattering cross sections to be equal, the expression for the plutonium calibration curve becomes

$$\frac{\rho_p}{\rho_m} = \frac{A_p\ N_p}{1 - B_p\ N_p\ (1 + \rho_u/\rho_p)} \quad ,$$

where A_p and B_p are the calibration constants determined with pure plutonium solutions, and ρ_u/ρ_p is the ratio of uranium and plutonium concentrations. The latter may be determined, for the first iteration, from the ratio of observed characteristic x rays. Similarly the calibration curve for uranium is given by

$$\frac{\rho_u}{\rho_m} = \frac{A_u\ N_u}{(1 + C\ \rho_p) - B_u\ N_u (1 + \rho_p/\rho_u)} \quad .$$

Again, A_u and B_u may be determined with pure uranium standards. C is a constant that accounts for the enhanced fluorescence of uranium by the plutonium x rays.

Practical applications of this approach may be achieved with both K- and L-x-ray fluorescence. For example, consider the fluorescence of plutonium-bearing solutions with a ^{57}Co (122 keV gamma ray) source. In this case, the detected plutonium $K_{\alpha 1}$ x-ray intensity, N_s, at 103.6 keV, E_s, would be normalized to the 122 keV incoherent scattered peak intensity, IC, at 84.5 keV, E_i. The ratio N_α/N_β would be determined from the plutonium $K_{\alpha 1}$ and $K_{\beta 1}$ peak intensities at 103.6 and 117.1 keV E_α and E_β, respectively.

Similarly, the fluorescence of uranium-bearing solutions with a ^{109}Cd (22 keV x ray) source would allow the normalization of the uranium $L_{\beta 1}$ x-ray (17.2 keV) intensity to the incoherent scattered peak at 20.5 keV, and N_α/N_β would be determined by the ratio of the uranium L_α and $L_{\beta 2}$ peak intensities at 13.6 and 16.4 keV, respectively.

The formulation and alternative measurement procedure suggested above indicates that the "internal standard" approach may be improved by making measurements at one or more additional x-ray enegies of the element to be assayed. The effects of solution acidity variations and the relative concentrations of plutonium and uranium may be avoided. Because of the inherent stability of ratio techniques, little or no modification to this formulation is anticipated for cylindrical near-field geometries.

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UNIQUE AND REALISTIC TACTICAL TRAINING UTILIZING LASERS

ROBERT L. WILDE
Sandia National Laboratories
Albuquerque, New Mexico

ABSTRACT

This report describes the evolution of a simulated tactical engagement capability utilizing laser-equipped weapons and detector-equipped players which can be used for realistic tactical training and, to some extent, security system evaluation.

Introduction

Most modern security systems designed to protect SNM and other valuable assets against an overt attack consist of (1) detection systems--either technological or human to alert the system to the impending incident; (2) assessment systems--again involving both technology and humans to establish the seriousness of the threat; (3) communication systems--to alert responsible personnel of the situation; (4) access denial--physical barriers as deterrents or armed intervention to delay the intruders; and (5) response--on or off-site armed personnel to intervene and maintain control.

When examining system effectiveness, controlled testing is practical to determine the contribution of technology. Detection, assessment, and communications systems receive a meaningful evaluation because of their relationship with day-to-day usage. Special experiments to bound the parameters of these subsystems are also practical. The access denial contribution of physical barriers have also been evaluated. Times have been established for violent and nonviolent attacks against barriers. Still missing until recently, however, was some method of better preparing and, to some extent, measuring the contributions of the armed protective security force in either the denial or response role. A technique to examine these attributes and to improve protective force contributions with realistic engagement training is now becoming available. This activity is currently under development at SNL and is called Security Forces Experimentation and Evaluation (SFEE). It utilizes the basics of the Multiple Integrated Laser Engagement System (MILES) developed by Xerox Electro-Optical for the U.S. Army. The engagement simulation equipment consists of laser transmitter-equipped weapons and detector-equipped players and allows engagement gaming with substantial realism. Because of the differences between military and Department of Energy equipment usage, some changes have been made to the MILES.

Equipment Description

The engagement simulation system is a battery-powered laser transmitter and detector system designed around a family of weapons which allows realistic engagement simulation without the hazards of live ammunition. The laser transmitter attached to or part of the weapon (rifle, shotgun, machine gun, submachine gun, or handgun) includes an eye-safe, battery-operated gallium arsenide laser diode, which when actuated with the acoustic pulse and or flash of the weapon blank round emits pulses of coded infrared laser energy to simulate the effects of live ammunition. The pulsed laser beam becomes the laser "bullets." If the message contained in the pulsed laser beam is correctly received by sensors (IR detectors) worn by each participant on a harness and head array, an aural alarm is sounded indicating either a near miss or an incapacitation. An incapacitation or "kill" results in participant removal from the action.

The MILES is a Pulse-Code-Modulation (PCM) optical communication system. The system differs from conventional communication systems in that the interpretation of the transmitted message must, as closely as practical, simulate the weapon characteristics, such as round dispersion patterns and probability of kill as a function of range. A single tube laser transmitter scheme (Block Diagram in Figure 1) which sends both "kill" and "near-miss" messages is used for all weapons. With the initiation of blank fire, an 11-bit kill code message is transmitted four times. Upon completion of the four kill messages, an 11-bit, near-miss code is transmitted up to 128 times. The near-miss beam from the transmitter has a higher power than the kill beam and therefore

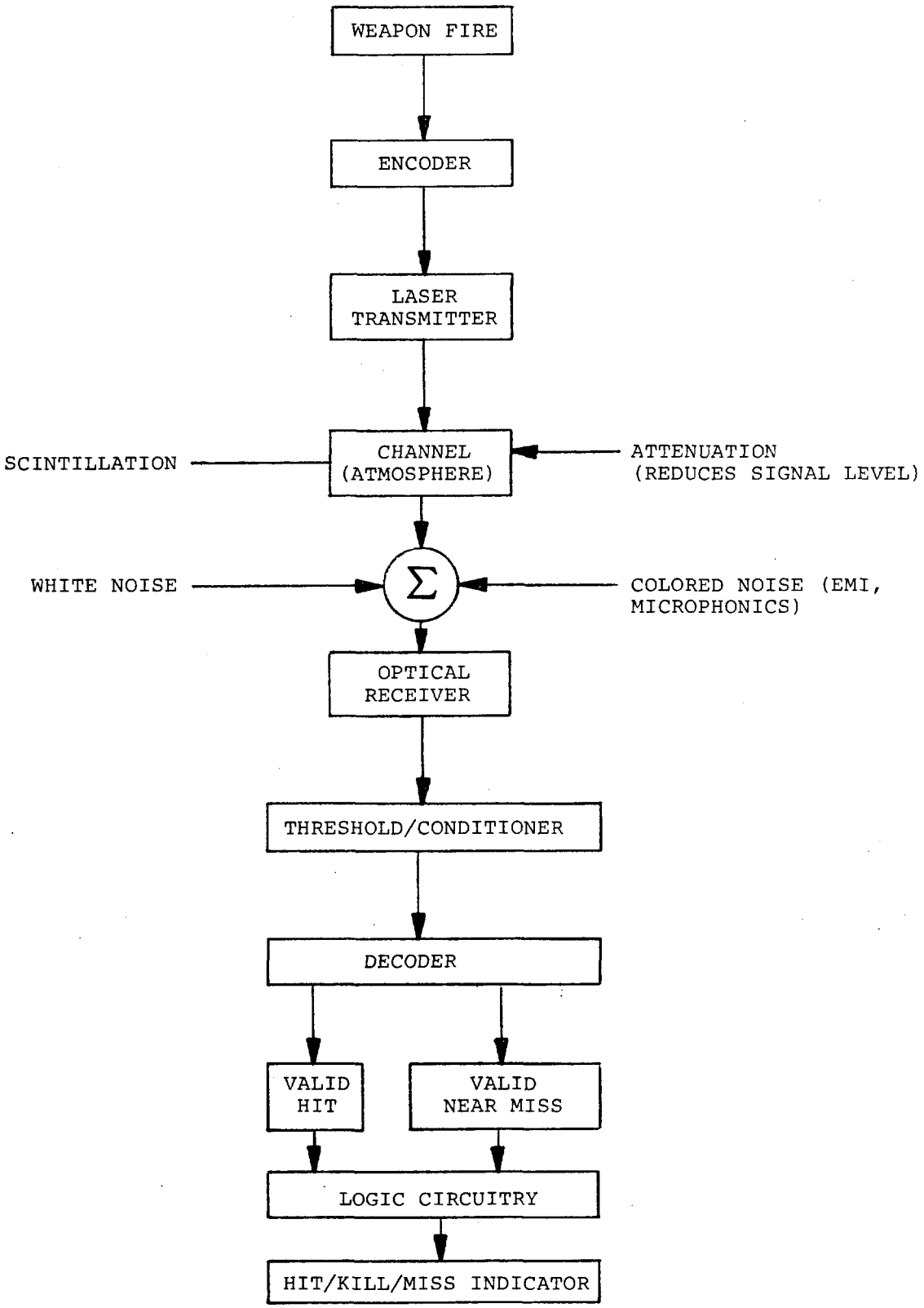
WEAPON FIRE
ENCODER
LASER TRANSMITTER
SCINTILLATION
CHANNEL (ATMOSPHERE)
ATTENUATION (REDUCES SIGNAL LEVEL)
WHITE NOISE
Σ
COLORED NOISE (EMI, MICROPHONICS)
OPTICAL RECEIVER
THRESHOLD/CONDITIONER
DECODER
VALID HIT
VALID NEAR MISS
LOGIC CIRCUITRY
HIT/KILL/MISS INDICATOR

Figure 1

produces a larger effective beam diameter over an extended range. This, plus the larger number of messages, greatly increases the probability of near-miss signal detection.

The optical receiver (detectors), as worn by the participant, is comprised of silicon solar cell photodiodes (detectors) and an amplifier. The photodiodes convert incident optical energy in the channel to electrical signals. Output of the optical receiver is analyzed by a threshold comparator which detects the presence of signals above a predetermined level. The output is conditioned for sampling by a decoder. The decoder continuously looks for a valid kill or near miss word pattern and, once finding such a pattern, the result is operated on by the appropriate logic and signals the user. An equipped player is shown in Figure 2.

The concept is being developed for a variety of typical weapons including handguns, shotguns and various automatic weapons; some have unique "word" patterns which allow the "target" detector electronics to recognize and react to the lethality of the particular weapon. The entire system is designed so that the probability of kill given a hit closely approximates the weapon firing live rounds. This allows the shooter's abilities to influence engagement outcome.

SFEE Objectives

The objective of the SFEE activity is to develop a system to primarily train armed personnel and/or evaluate (to some degree) the relative effectiveness of armed personnel contributions to transportation, facility or other security systems (and proposed changes to them) against various threats and scenarios in the small force engagement. This activity involves development of a system made up of dedicated and portable equipment which can be utilized at various locations. Key elements of the system are (1) laser-equipped weapons and body-worn detectors, (2) video instrumentation to record participant contribution, (3) communications, (4) vehicles to transport or facilities to store the equipment, and (5) a trained staff for technical and logistical support. Both a dedicated and portable range capability have been initially developed and are being utilized. For DOE security organizations, SNL has adopted a loaner program to provide them equipment on an annual 3-month loan basis. This allows them to accomplish training at the most convenient time, considering personnel availability; technical and logistical support is also provided as requested.

The SFEE capability can be employed either in training utilizing various scenarios and to some extent examine the effectiveness of partial or total security systems. Personnel, vehicles, guard towers, etc., can be instrumented so that realistic attacks can be staged. Detection systems and access denial can be simulated with reasonable realism. Strengths and weaknesses in supporting systems will often surface and some information about the total system effectiveness will result.

Experience

SNL has been applying the engagement simulation concept since 1978. Sixteen DOE facilities have utilized the equipment in familiarization, response and advanced training exercises. The equipment has been utilized at four NRC reactors during the development of a prototype tactical improvement package. Department of Defense organizations participating have included the Navy, Marines, Air Force, and various National Guard and Reserve units. Equipment support has been provided the Federal Bureau of Investigation, Department of State protective agents and several state and local law enforcement agencies. In all, some 7000 plus persons charged with security responsibilities have benefitted from the program.

SFEE Characteristics

The SFEE activity involves a man/machine system that permits engagements between adversaries with a realism not previously possible in small forces war gaming. Since human factors are most easily and accurately incorporated into a simulation by human involvement in roles as nearly identical to those assumed in actual combat, the SFEE approach allows ambushes of road convoys and attacks against facilities to be planned and carried out as they would be in real life, except the weapons effects are simulated. Experience with this capability strongly suggests that individual participant behavioral strengths and weaknesses quickly become evident.

Examples of apparent positive aspects of the SFEE activity are as follows:

- Marksmanship and Weapon Skills--The simulated probability-of-kill is sufficiently representative to reward the good marksman in a realistic manner. Additionally, problems with weapon reload, jams, handling, sighting, etc., are essentially identical to situations utilizing real bullets.

- Shooting Decisions--Simulated engagements force realistic participant decisions in acquiring, identifying, and neutralizing the correct target. In addition, behavior which increases the probability of neutralizing a target is balanced against the increased probability of defender detection by the adversary due to increased exposure, etc.

- Observation and Perception--Engagements expose participants to the need for alertness and an understanding of things happening around them.

Figure 2

- Communications--Proper and improper use and the importance of radios, hand signals, and voice communications are automatically emphasized.

- Cover and Concealment--The typical participant's desire to "live" forces strong emphasis in remaining under cover, while still contributing to the team effort.

- Tactics--The consequences of good and bad tactics are experienced by participation and the resulting outcome.

  Learning through the experience is believed to be an extremely effective process.

- Leadership--The effectiveness of appointed leaders becomes evident during the course of the engagement. Often, if the original leader is neutralized, a replacement leader surfaces from the surviving team members.

- Confidence and Morale--Participants seem to acquire a new confidence in their own and their colleagues' abilities. Often they accomplish tactical and physical tasks that they previously didn't believe within their capabilities. Thus far, an important boost in morale has been observed.

- Competition--The realism and challenge of the simulated engagements seem to instill a desire for each team to do better than previous teams. This healthy effect results in maximum participant motivation and contribution.

- Complementing Systems--SFEE realism allows the utilization of other security system elements such as access denial, alarms, towers, and vehicles in a realistic manner.

The SFEE activity is still undergoing development. As with any simulation of this type, inadequacies in simulating the hardware and differences in human behavior in gaming and real engagement situations cause deficiencies to be present. Some which have been identified are:

- Marksmanship--The laser pulses travel at the speed of light without "bullet drop" and, consequently, the required sight picture for a kill (hold dead on) is not representative of the real rifle/bullet requirement for long range or moving targets. Additionally, for some target postures (such as standing broadside with all detectors showing), a participant is easier to kill than with a real bullet.

- Realism--Although apparently the most realistic of engagement concepts, participants may be performing differently than if real bullets were present. Inquiries of participants some times indicate they would be more conservative in a real engagement. This conforms with available literature on suppressive effects during combat.

- Morale--On occasion, when realistic scenarios are employed, the outcome can be discouraging to participants if the security system of which they are a part fails overwhelmingly. Training officers should be alert to this possible outcome when selecting scenarios.

Equipment Upgrades

The capability to simulate small force engagements is in its infancy. Nevertheless, enormous possibilities now exist with the availability of the laser-equipped weapon. A significant R&D effort is anticipated to improve and expand system realism and improve participant instrumentation for better data collection.

The MILES was designed for training emphasizing military tactics. Within the Department of Energy (DOE), tactics are being developed for small force engagements. Consequently, several modifications have been made to the MILES to better support DOE training approaches. Among the changes are (1) the addition of a mylar transmitter insert to improve close-in (< 30 ft.) kill characteristics, (2) an adjustable 5-detector soft cap head array in lieu of a military helmet array, (3) additional resistance to RF interference, (4) an ability to remotely reset a participant with a controller gun, and (5) player-key power turn off.

Among the identified future upgrades are (1) better man-worn detector arrays to acknowledge wounds and provide more complete body coverage, (2) a capability to simulate area fire weapons such as the 40 mm grenade, (3) probability-of-kill more in line with the best available data, (4) a capability for more expedient weapon bore sight, (5) a no-key system, (6) body worn instrumentation to include recording player position location, player pairings when firing, timing, human factors (e.g. stress), and (7) a real-time readout of player status to aid in exercise administration.

DOE facility training personnel report that current force-on-force training is not always practical because it requires reasonably large numbers of people, often involves overtime pay, and sometimes does not involve all participants. Consequently, an additional upgrade to the

system involves radio-controlled, laser sensitive pop-up targets as shown in Figure 3.

Typically, six targets would be placed so that different shooting situations are confronted as the participant progresses through the course. The targets would automatically rise by sensing the proximity of the participant. The participant must then identify if the erected target is friend or foe. If a friend, a no-shoot decision is appropriate. If a foe, the participant must either neutralize the target or take cover since after an adjustable delay, the target will "shoot back" at the participant with a wide-beam, on-board transmitter until the target is neutralized. This approach will allow individualized or small group training under stress similar to engagement simulation yet be more practical to employ.

Conclusion

The SFEE activity provides, perhaps for the first time, realistic force-on-force combat simulation. These simulations emphasize security personnel strengths and weaknesses in (1) employing tactics, (2) communications, (3) physical abilities, (4) morale, (5) leadership, (6) motivation and (7) marksmanship. Training can be conducted at any location to deal with its unique situation and problems. With proper coordination, exercises can be conducted during working hours, in and around potential high risk targets. Tactical response to a hostile situation can be evaluated to demonstrate and improve capabilities and define areas which need additional emphasis.

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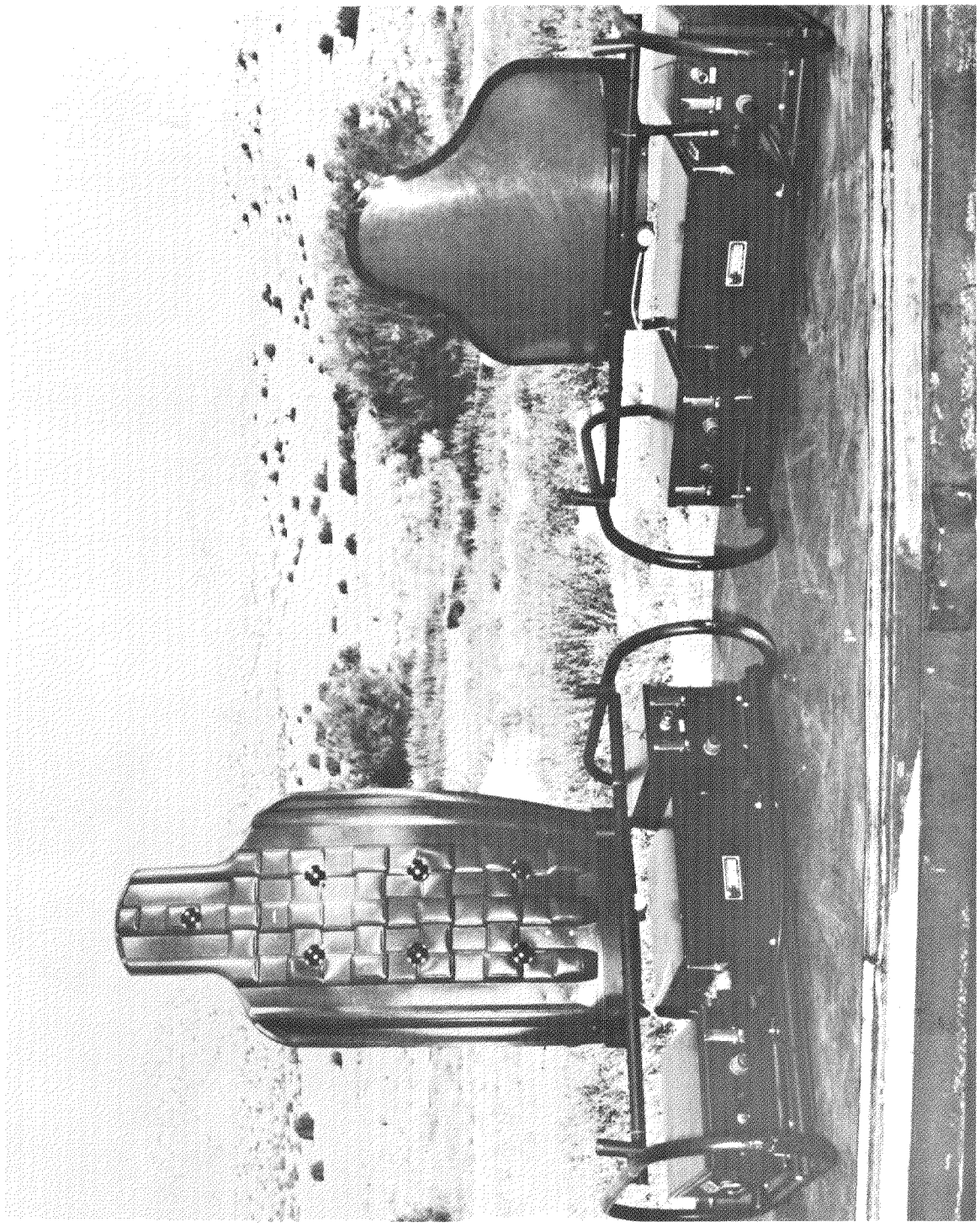

Figure 3