VOLUME X, NUMBER 3/FALL 1981

NUCLEAR MATERIALS MANAGEMENT

Journal of the
INSTITUTE
OF
NUCLEAR
MATERIALS
MANAGEMENT

FEATURE ARTICLES

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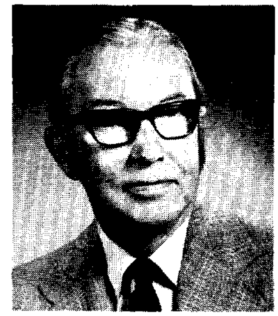
INMM EDITORIAL

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



First of all, I would like to express my appreciation of the erstwhile Executive Secretariat, in particular of Jerry and Ed Johnson, of E.R. Johnson Associates, who took over managing of the Journal from Tom Gerdis in 1980 and kept it operating while the INMM Executive Committee was searching for a more permanent replacement. It was no easy job to take over from Tom, on short notice. It has been a pleasure to work with such pleasant and energetic people.

This issue will introduce you to John Messervey, the new Executive Director of the Institute, who is now responsible for managing and getting-out the Journal, among other things. There have been unavoidable delays, since Tom moved on to different, if not greener, pastures. John and I hope to get back on schedule soon. For that, we need more technical contributions.

Next, I feel compelled to comment on two incidents, which must be of great concern to members of The Institute, since they may affect the credibility of international safeguards. One is the destruction of the almost completed 40 megawatt research reactor in Iraq by Israeli warplanes. Israeli representatives have since stated a number of reasons why they did not trust the Nuclear Non-Proliferation Treaty and IAEA inspection. The IAEA view was well presented by Dr. Hans Gruemm at the annual meeting in July, which appears in the Proceedings issue. Since the NPT and the IAEA were intended to forestall just such conflicts, one might have hoped that the Israeli government would have joined up and worked to make the international system more effective.

Another disturbing incident was the announcement by some U.S. Government officials that the U.S. was giving consideration to extracting plutonium from spent power reactor fuel for use in nuclear weapons. Nuclear News, the monthly news and comment journal of The American Nuclear Society, said in October, "If the Administration has leaked this as a trial balloon to gauge response to the idea, then anyone who has toiled for peaceful nuclear applications should act quickly and decisively to deflate the balloon." On November 4, the U.S. Senate sent "an urgently needed signal to the Department of Energy and the rest of the world," according to Senator Gary Hart, by adopting an amendment to the energy and water appropriations bill that would prevent the Department of Energy from buying spent power reactor fuel for military uses. The balloon seems to have been deflated.

It will continue to be most important to maintain a clear distinction between the peaceful and military applications of nuclear energy. This will only be possible if the nuclear weapon states halt their mad race to produce more and more nuclear warheads, and all of the non-nuclear weapon states support the NPT and IAEA safeguards, and assist in extending the scope of such international undertakings.

Finally, I would like to welcome a new safeguards publication, the ESARDA Bulletin, published by the European Safeguards Research and Development Association, which has sponsored the very valuable annual ESARDA Safeguards Symposia for the last three years. Issue Number 1, October 1981, contains reviews of work of the several technical working groups, of the third annual symposium, and of the ESARDA seminar on containment and surveillance that was held at Ispra in September 1980. The ESARDA symposia and the new Bulletin complement the similar activities of the Institute of Nuclear Materials Management, and are positive evidence that most of the nations of the world are dedicated to making international safeguards more credible and effective.

NUCLEAR MATERIALS MANAGEMENT is published five times a year, four regular issues and a proceedings of the annual meeting of the Institute of Nuclear Materials Management, Inc.

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CONSTITUTION AND BYLAWS CHANGES APPROVED

Balloting on the proposed amendments to the Constitution and Bylaws was held open until Stepember 18, to accommodate the Canadian members whose ballots were mailed late because of the Canadian mail strike.

The results of the balloting were as follows:

Total Ballots Returned	238
For Amendments to the Constitution	216
Against Amendments to the Constitution	22
For Amendments to the Bylaws	198
Against Amendments to the Bylaws	40

Changes were the most extensive to have been presented to the membership since the INMM was chartered. The major purpose was to establish graded membership, but the Committee also included some clarification of procedure.

It was suggested that future changes should be published in the Journal for comment by the membership before the final ballot is mailed. The Committee agrees with this proposal and has so recommended to the Executive Committee.

CHAIRMAN'S COLUMN

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

Predictably, 1981 has been a very active year for the Institute. Thanks to the diligent efforts of my predecessors and those who actively supported their fine leadership, the Institute is beginning to move into a level of maturity and sophistication never before realized. We are becoming more professional, both in our technical stature and in the way we go about our business. We are making progress but we still have a lot to learn. We still make mistakes that could be avoided and we still are not meeting the needs and desires of all of our membership. Our goal is to continue to improve in all of these areas.

As 1981 draws to a close, let me review some of the significant milestones that were met during this past year. In 1981, we formally launched our Certification Program. While the program, admittedly, is struggling to stay afloat, the Executive Committee is committed to making it a workable and worthwhile program.

Through the restructuring of our Safeguards Committee, we have been able to become an effective force in the formulation of the technical aspects of government policy for both domestic and foreign safeguards issues. Dialogue with the appropriate government agencies has been established and a framework for both formal and informal input is in place and working well.

Our Education Committee has broadened its horizons and offered numerous technical courses in diverse locations across the U.S. in order to better meet the needs of our changing and growing membership. The committee continues to make every effort it can to provide the best training programs utilizing the resources and expertise of the Institute and its members.

The Physical Protection Technical Workshop Group has been instrumental in developing a mechanism for the discussion of and transfer of the technology associated with the important and technical issues in the design and operation of physical protection systems. The several workshops sponsored by this group have benefited both members and non-members, as well as served as an excellent vehicle for promoting and establishing the credentials of the Institute in this very important aspect of safeguards.

We have new standards activity this year. The Institute is now the secretariat for the ANSI N-14 Committee, "Packaging and Transportation of Radioactive Materials". A major factor in ANSI requesting the Institute to take this secretariat was our fine record as secretariat for N-15.

So, as you can see, there has been much progress made during the year due to the fine and diligent efforts of many of you. You are to be congratulated for a job well done, for without you, the job could not be done at all. Thank you all for your support and may God bless you in the next year. Happy Holidays!

INMM 1980-81 ANNUAL FINANCIAL REPORT

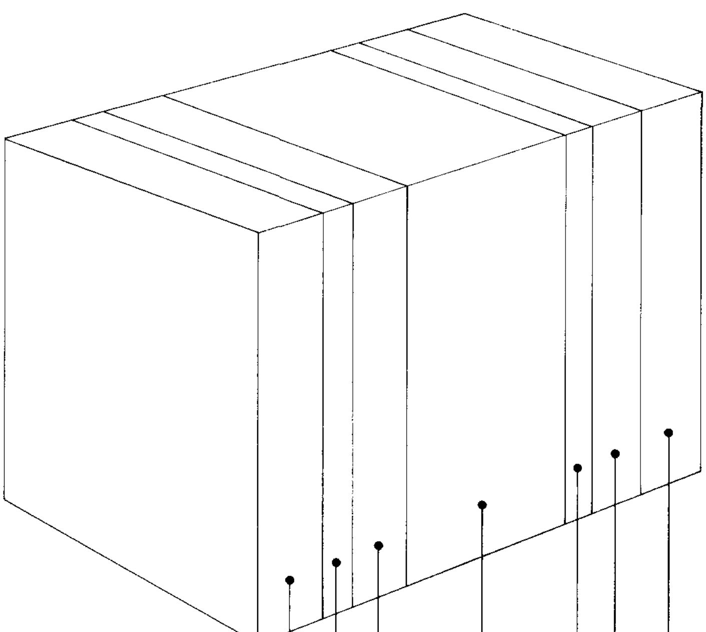
EDWARD OWINGS
Treasurer
Oak Ridge Y-12 Plant
Oak Ridge, Tennessee

During the past year, the Institute continued to finance a wide range of educational and technical services for our members. Despite rising expenses, we have been able to maintain annual dues at $30.00. During the fiscal year ending September 30, 1981, INMM received $149,324. Principal sources of income included the annual meeting, educational courses, workshops and technical working groups, and page charges to support the publication of the quarterly *Journal* and annual meeting *Proceedings.*

During this same period, INMM expended $135,813. The largest area of expense was for the annual meeting and the printing of the quarterly Journal and annual Proceedings. Other expenses included the Secretariat and support of the many Institute committees and five regional chapters.

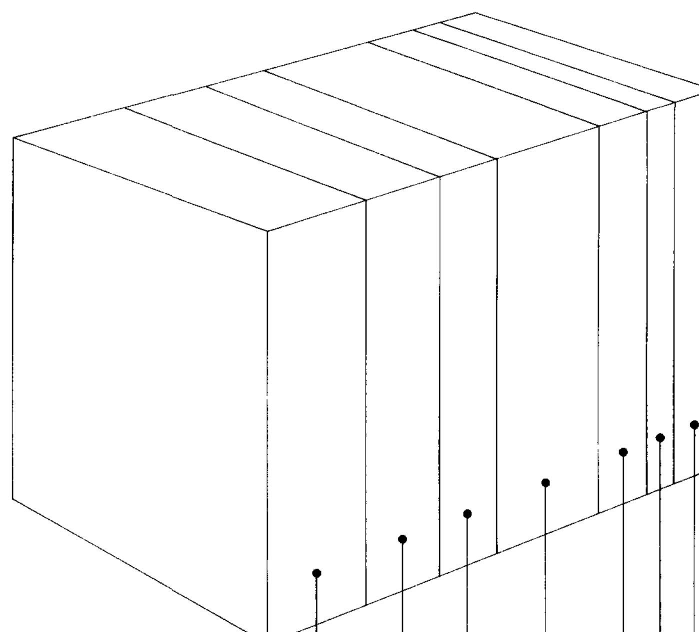
The surplus funds for the year have been invested in secured certificates of deposit. Income from these investments builds new programs for our members. The INMM bank account was also converted to a NOW account in January, 1981. INMM operates as a tax-exempt corporation under IRS Section 501(c)6 not-for-profit organization. Questions regarding this report should be directed to me at (615)574-2580, FTS 624-2580.

INCOME



15%	Dues
7%	Proceedings
12%	Education
36%	Annual Meeting
6%	Interest
11%	Workshops/Technical Working Groups
13%	Journal
100%	

EXPENSE



22%	Secretariat
17%	Proceedings
13%	Journal
23%	Annual Meeting
11%	Committees & miscellaneous
6%	Workshops/Technical Working Groups
8%	Education
100%	

INMM HEADQUARTERS REPORT

JOHN E. MESSERVEY
EXECUTIVE DIRECTOR

Chairman Gary Molen (left) and Secretary Vince DeVito reviewed membership growth at the October executive committee meeting.

A brief summary of items of interest to our members.

This issue of NUCLEAR MATERIALS MANAGEMENT is the result of many individual efforts, notably, Willy Higinbotham, Gene Weinstock, the editorial review committee and, of course, the authors. Now our mission will be to get the Journal back on schedule. The winter edition should be completed by February 15. *The spring edition will follow the Journal's original schedule.*

Excitement is building toward next year's annual meeting in Washington, D.C. Invited Papers Chairman Joe Indusi has three highly regarded speakers for our opening session. Contributed Papers Chairman John Lemming has issued a Call for Papers to all INMM members. Special annual meeting articles from Yvonne Ferris, Tom Sellers and Mark Elliott appear in this issue. John and the staff are working on completing the Proceedings *before* the annual meeting. Please note the contributed papers deadline of June 15, 1982.

Our operating guide, the INMM Policy and Procedures Manual, is under thorough revision by Vice Chairman John Jaech. Revisions reflect new responsibilities by the INMM headquarters staff, several revisions in operating policy, and new tasks undertaken for ANSI N-14 and N-15.

The executive committee met in Columbus, Ohio, October 20-21, 1981. The Hyatt Regency Columbus was unanimously selected as the site of the 1984 annual meeting. This meeting will mark the 25th anniversary of the Institute. The 1983 meeting will be held July 10-13 at the Denver Marriott City Center.

Special thanks to Ed and Jerry Johnson for their enormous contribution during the transition from Reston, Virginia, to our headquarters in Chicago. E.R. Johnson Associates kept INMM records in exceptional order and the smooth transition reflected their care.

INMM EXECUTIVE COMMITTEE
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VICE CHAIRMAN John L. Jaech
SECRETARY Vincent J. DeVito
TREASURER Edward Owings
MEMBERS AT LARGE
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Roy B. Crouch
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Charles M. Vaughan

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Safeguards	Bob Sorenson
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Constitution & Bylaws	Roy Cardwell
N-15 Standards	Ralph Jones
Awards	Willy Higinbotham
Education	Harley Toy
Annual Meeting Program	Yvonne Ferris
Annual Meeting Arrangements	Tom Sellers
Site Selection	Ray Lang
Physical Protection TWG	Jim Williams
Statistics TWG	Carl Bennett
Chapters/Membership	John Barry

INMM CHAPTER CHAIRMEN

Japan	Yoshio Kawashima
Vienna	Djali Ahimsa
Central	Harvey Austin
Southeast	Mary Dodgen
Northwest	Bob Sorenson

INMM CALENDAR OF EVENTS

JANUARY 11-15, 1982
Introductory Statistics with Applications to Special Nuclear Material Control
The INET Corporation
Palo Alto, California

FEBRUARY, 1982
INMM Executive Committee Meeting
Denver Marriott City Center
Denver, Colorado

MARCH 16-19, 1982
Technical Workshop on Physical Security
Marriott's Tan-Tar-A Resort
Osage Beach, Missouri

JULY 18-21, 1982
INMM 23rd Annual Meeting
Hyatt Regency Washington
Washington, D.C.

OCTOBER 6-8, 1982
Physical Protection Workshop
Sheraton Old Town
Albuquerque, New Mexico

TWENTY-THIRD ANNUAL MEETING SLATED FOR WASHINGTON, D.C.

JULY 18-21, 1982
HYATT ON CAPITOL HILL

Washington, D.C.! The nation's capital! Site of the 1982 Annual INMM Meeting! Washington, D.C., more than any other city belongs to us all, and whether you are coming for the first time or for the twentieth, there is much to see and do.

Washington is one of the world's most beautiful cities with its magnificent museums and monuments which are either situated along the banks of the scenic Potomac River or surrounded by seasonal flowers. The monuments are often lit for evening display. Some highlights include the White House, the Capitol, the Washington Monument, the Lincoln Memorial, the Jefferson Memorial, the Kennedy Center, the Smithsonian Museums on "the Mall", and the Arlington National Cemetery. The site of our meeting, the Hyatt Regency Hotel, is just a stone's throw from the Capitol, and Hugo's Restaurant, atop the hotel, gives an unmatched view of Capitol Hill and its historic buildings.

You'll find that D.C. is an easy place to get around thanks to the Metro subway and bus system. They go to just about any place you would care to visit. Taxis are reasonable if you stick to the downtown area because fares are based on a zone system.

A good place to begin your sightseeing is at the White House, but get there early, because July is a popular month for visitors to Washington. A short walk over to the Mall to catch the Tourmobile enables you (for the price of a ticket) to ride to 18 landmarks in the city, with free re-boarding privileges. Two of the newest and most popular stops on the Mall are the East Wing of the National Gallery of Art and the National Air and Space Museum. Be sure to visit the gift shops at the various museums for some of the best shopping in Washington. Lunch may be purchased either from an outdoor cafe or from one of the many cafeterias inside the Museum buildings. Continuing up the Mall you will come to the Capitol. Tours of this impressive building leave every few minutes from the Rotunda. You can even take the Tourmobile across the Potomac to Arlington National Cemetery where you can see the changing of the guards at the Tomb of the Unknown Soldier, President Kennedy's grave, and the Lee Mansion.

The White House, Washington, D.C.—This striking building, modeled after an Irish castle, has been the home of every President but George Washington. The White House ranks among the top ten attractions in the nation's capital. Photo courtesy of Washington Convention and Visitors Association.

Georgetown is the city's most fashionable and historic district with its distinctive shops of every description and elegant 18th and 19th century homes. Be sure to visit the Georgetown Park shopping complex, a new and unique place for both shopping and dining. Located a short walk up Wisconsin Avenue is the famous Dunbarton Oaks, with its museum and fabulous garden.

For children, no trip to Washington would be complete without a trip to the National Zoo, to say hello to the pandas. The National Air and Space Museum is also a required stop. A relatively new attraction for young visitors to our city is the Children's Museum with its "please, touch" policy.

Your biggest daily decision may be where to dine. Washington offers a limitless choice of cuisines with an equally wide range of prices. Lion d'Or and Germaines, French and Vietnamese cuisines respectively, are nationally recognized for their excellence.

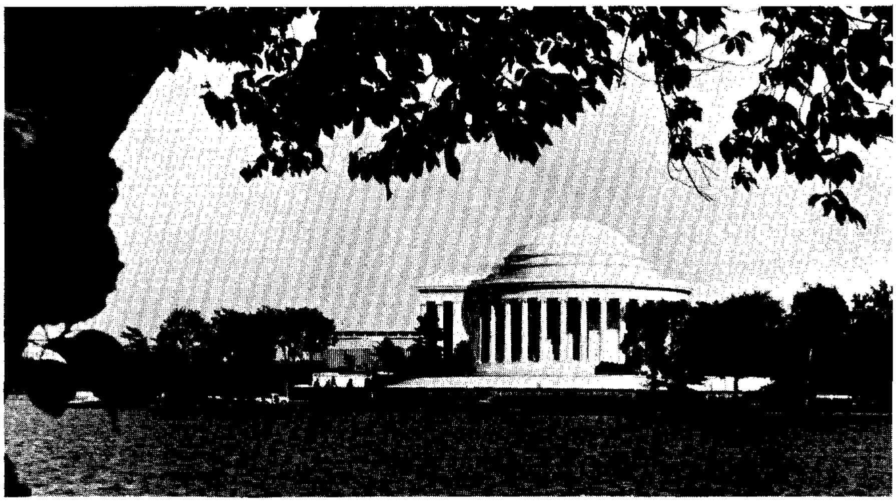
A new arrival on the Washington Scene is "ticketplace". Everyday from noon to five, you can purchase for ½ price any unsold tickets to that evening's performances at the Kennedy Center or any other Washington theatre. If you prefer refreshments with your entertainment, then the night scene in either Georgetown or Capitol Hill may be your preference.

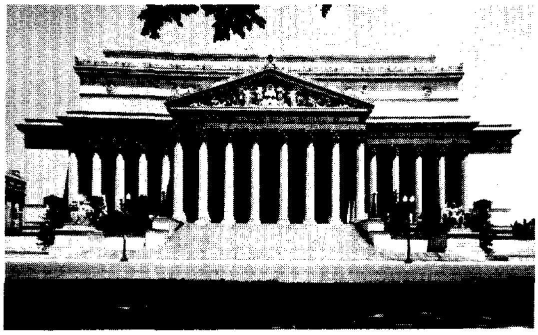
A short drive from Washington there are many other historic sites. Less than an hour away is Annapolis, with its quaint streets and restored homes as well as the U.S. Naval Academy. Slightly longer drives can take you to Baltimore, with its exciting Harbour Place, restored Williamsburg, or historic Gettysburg.

We, Mark Elliott, Mary Clark, and Joe Tinney, your local arrangements committee, are working to mark your visit to our capital a memorable and exciting stay. Do plan on bringing your family and consider staying a few extra days.

U.S. Capitol, Washington, D.C.—Perhaps the most famous building in the United States (and the most photographed) the U.S. Capitol is the home of the legislative branch of the U.S. government. It is here, in the House and Senate chambers, that Federal laws are enacted. Visitors to the nation's capital can watch this exciting process by obtaining a free pass from their Senator or Congressman. Photo courtesy of Washington Convention and Visitors Association.

Jefferson Memorial, Washington, D.C.—Considered by many to be the most beautiful structure in the nation's capital, the Jefferson Memorial is situated on the Tidal Basin. In springtime the memorial is surrounded by a blaze of cherry blossoms. Photo courtesy of Washington Convention and Visitors Association.





National Archives, Washington, D.C.—The Archives is a "must" for the visitor to the Nation's Capital. This imposing building is the storehouse of the national records. The three most important documents of the land—the Declaration of Independence, the Constitution and the Bill of Rights—are displayed daily in the main hall.

1982 ANNUAL MEETING PROGRAM

YVONNE M. FERRIS
Program Chairman
Rockwell International, Rocky Flats Plant
Golden, Colorado

The theme for next year's program will be "Nuclear Safeguards Today." If that sounds practical, down-to-earth, and utilitarian, then you have clearly understood the intent of the Program Committee. We want the program to reflect what each one of you is doing NOW to advance or implement safeguards. In otherwords, if it works, flaunt it!

Please read the Call for Papers carefully and if you see a place where you and your facility can contribute a paper, get started right now. Sharing measurement, statistical, physical security, and accounting techniques which work successfully will profit everyone.

Poster sessions were well received at the 1981 meeting in San Francisco and will be a part of the 1982 program. The horizon has been broadened a bit, too, by including sessions on safeguards in transporting nuclear material and safeguards in waste management.

The Program Committee is working hard to plan interesting, worthwhile, and even controversial sessions. Please make their job a little easier by preparing your contribution today.

Copies of the Printed Proceedings of the Annual Meetings of the **INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT**

The proceedings (1960–1981) are in bound volumes.

		Domestic Rates			Domestic Rates
1st Columbus, OH	1960	$35.00	12th West Palm Beach, FL Volumes I and II	1971	$100.00 /set
2nd Denver, CO	1961	$35.00	13th Boston, MA	1972	$50.00
3rd St. Louis, MO	1962	$35.00	14th San Diego, CA	1973	$60.00
4th Buffalo, NY	1963	$35.00	15th Atlanta, GA	1974	$55.00
5th Pittsburgh, PA	1964	$35.00	16th New Orleans, LA	1975	$75.00
6th Cincinnati, OH	1965	$35.00	17th Seattle, WA	1976	$35.00
7th Columbus, OH	1966	$35.00	18th Washington, D.C.	1977	$35.00
8th Washington, D.C.	1967	$35.00	19th Cincinnati, OH	1978	$60.00
9th Chicago, IL	1968	$35.00	20th Albuquerque, NM	1979	$35.00
10th Las Vegas, NV	1969	$35.00	21st Palm Beach, FL,	1980	$25.00
11th Gatlinburg, TN	1970	$35.00	22nd San Francisco, CA	1981	$25.00

These prices are applicable only in the United States. All other countries must be charged for the cost of air mail postage.

PROCEEDINGS
INMM Headquarters
2400 East Devon Avenue
Des Plaines, IL 60018
312/635-7700

TECHNICAL WORKING GROUP ON PHYSICAL PROTECTION REPORT

JAMES D. WILLIAMS
Chairman
INMM Technical Group on Physical Protecton
Sandia National Laboratories
Albuquerque, New Mexico

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

- Physical Security Equipment — March 16-19, 1982
- Physical Protection Review—Getting the Most for Your Money — October 6-8, 1982
- Central Control and Information Display Systems — Late January 1983 (tentative)
- Security Personnel Training (formerly Guard Training) — Summer 1983 (tentative)

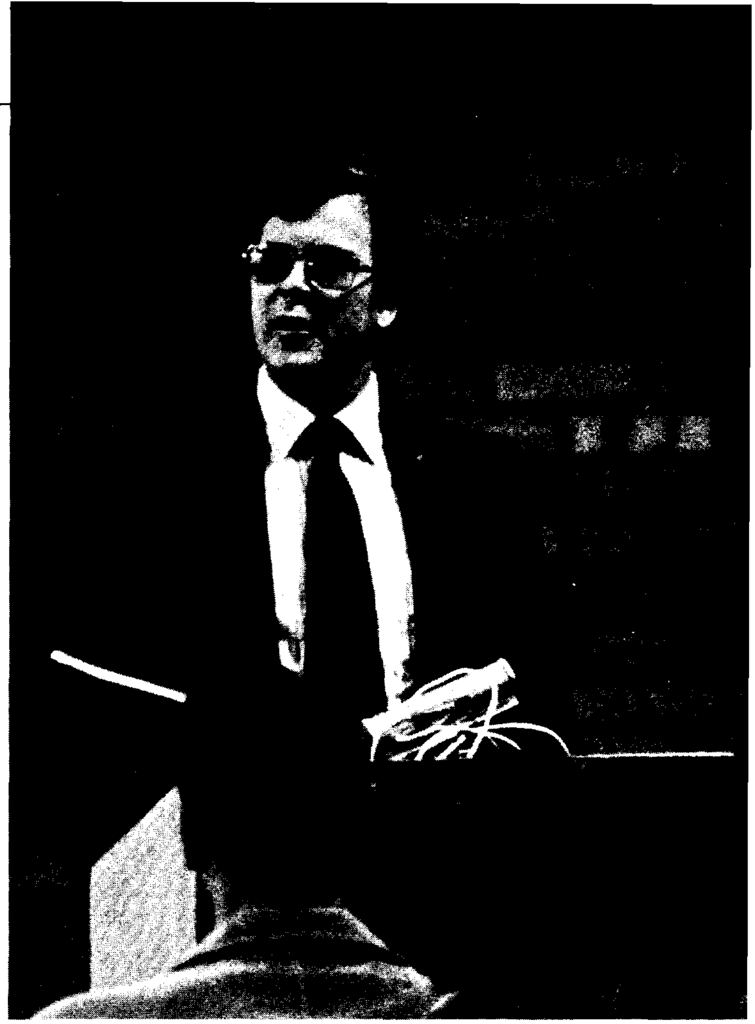
Workshops on other subjects of interest to physical protection personnel will be considered if enough interest is expressed. Additional details about the group activities and plans are given below.

General
The Second Guard Training Workshop was held at St. Charles, Illinois, October 16-18, 1981. This was a very successful workshop and is discussed in detail by Dr. Paul Robertson, Workshop Chairman, in the second part of this report.

Physical Security Workshop
The Third Physical Security Workshop (with major emphasis on intrusion detection and entry control systems) will be held at Marriott's Tan-Tar-A Resort, Osage Beach, Missouri on March 16-19, 1982.

Tan-Tar-A Resort is on the beautiful Lake of the Ozarks. The resort operates all seasons, has outstanding conference facilities, and abundant indoor and outdoor recreational facilities (handball, tennis, swimming, bowling, billiards, sauna, exercise room, etc., plus outdoor miniature and regular golf, boating, fishing, and even a small ski run). The resort has agreed to allow workshop attendees to stay up to two days before and two days after the workshop at the special conference rate. The resort is located 180 miles southeast of Kansas City and 180 miles southwest of St. Louis. Air service to the Lake Ozark Airport is provided by Air Illinois and TransMissouri Airlines. If enough interest is expressed, participants can be picked up at the St. Louis Airport by the Airport Marriott and assembled for a late afternoon trip to the resort by chartered bus. The three and one-half hour ride through the Southern Missouri countryside in the spring in a bus stocked with refreshments should initiate the interpersonal communication which has been characteristic of previous workshops. Additional details about the workshop will be contained in the Winter Issue of this Journal.

Physical Protection Review
A new workshop entitled, "Physical Protection Review—Getting the Most for Your Money," will be held at the Sheraton Inn, Old Town, Albuquerque, New Mexico, October 6-8, 1982. These dates occur during the International Hot Air Balloon Festival. More than 500 balloon crews will be participating and large numbers of observers make late hotel/motel reservations difficult to obtain.



Mr. Bill Knauf, Department of Energy, Office of Safeguards and Security, addressing attendees of the INMM Workshop on Guard Training, Pheasant Run Hotel, St. Charles, IL, October 14, 1981.

In order to ensure the proper number of rooms, the Sheraton has requested that firm reservations be made in early July. This workshop is intended to attract approximately equal numbers of people from the Department of Energy and their contractors, the Department of Defense and their contractors, the Nuclear Regulatory Commission and their licensees, and high security commercial industries. The purpose is to have a series of workshops in which ideas can be shared, hopefully to save the entire community the cost of redundant activities and result in more effective physical protection systems. Additional details of this workshop will be continued to be announced in future issues of this Journal.

Central Control and Information Display Systems
A Workshop on Central Control and Information Display Systems is being tentatively planned for late January 1983. It will deal with topics related to controlling and displaying security, fire, safety, and other information and how to integrate such systems into a facility operation plan. Larry Barnes, Allied General Nuclear Services, P.O. Box 847, Barnwell, SC 29812, telephone (803) 259-1711, has agreed to be the Workshop Chairman. Please contact Larry to express your interest in this workshop and possible discussion topics. The meeting will probably be held in the Atlanta area.

Security Personnel Training
The third workshop concerned with the training of security personnel is tentatively being planned for the summer of 1983. Additional details will be announced as they become available.

INMM TECHNICAL WORKSHOP ON GUARD TRAINING

L. PAUL ROBERTSON
Workshop Chairman
Sandia National Laboratories
Albuquerque, New Mexico

Sixty-seven persons attended the second INMM Technical Workshop on Guard Training held at the Pheasant Run Hotel in St. Charles, Illinois, on October 14-16, 1981. Special thanks go to the moderators of the smallgroup sessions who did an outstanding job in making the workshop a success. Our thanks also go to Mrs. Doris Mortenson, Sandia National Laboratories, Albuquerque, for her registrar and arrangements activities.

The evening of October 14 was spent registering and attending a get-acquainted cocktail party. The workshop had an international flavor with attendees present from Canada and France. Approximately one-half of the attendees were oriented toward NRC and the other half toward DOE policies and procedures. A wide range of organizations were represented including private utilities, commercial security organizations, engineering and consulting firms, governmental agencies, and military units.

The opening session followed the breakfast for moderators on October 15. The workshop was opened by J.D. Williams, Chairman of the INMM Technical Group on Physical Protection. The workshop's keynote speaker was Mr. Robert F. Burnett, Director of the Division of Safeguards of the Nuclear Regulatory Commission. Mr. Burnett identified some of the major problems in nuclear security including: Poor corporate attitude; Deficient security management and organization; Poor personnel selection and training; low morale; and inadequate equipment forcing excessive dependency upon human-intensive measures. He also stressed the need for professionalism among nuclear security officers and expressed the opinion that standards and certification assuring a more professional officer would perhaps be better administered from within the security organizations rather than from governmental agencies. To improve the security officer's self-image, Mr. Burnett suggested the use of the terms "security officer" and "security inspector" rather than such terms as "watchman" or "guard." The opening address was followed by an active question and answer period. Assisting Mr. Burnett in fielding the questions and responding was Mr. Bill Knauf, last year's keynote speaker, representing DOE/OSS.

Prior to the workshop each attendee had selected three smallgroup sessions that he desired to attend. In most cases each attendee was able to participate in the topics chosen. The smallgroup sessions were held, four at a time, on Thursday morning, Thursday afternoon, and on Friday morning with from 10 to 18 participants in each session. The moderators of these sessions gave summaries of the major topics discussed during the closing meeting on Friday.

The smallgroup topics and the moderators were:

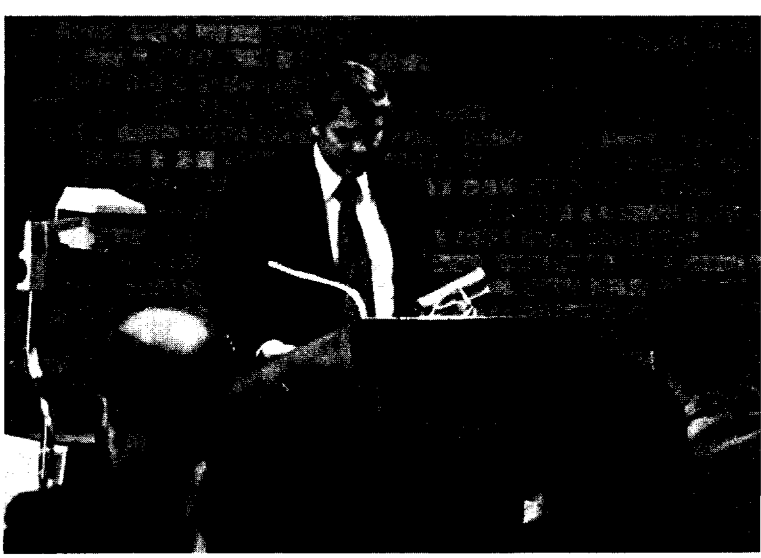
1. Legal Constraints and Obligations. Jerry J. Cadwell, Brookhaven National Laboratory, Upton, NY
2. Command Post/Control Room Operations. J.S. Hinson, Sandia National Laboratories, Albuquerque, NM
3. Government Requirements Relating to Guard Training. Laura B. Thomas, NUSAC Inc., McLean, VA
4. Tactical Training Techniques. Don B. Priestley, Burns International, Pittsburgh, PA
5. Psychological Screening/Testing of Security Personnel. Kristina Z. Markulis, USNRC, Rockville, MD
6. Overcoming Guard Complacency. Robert C. Bohlman, Nuclear Security Forces Inc., Stamford, CT
7. Systems Approach to Planning of Training. Fred L. Crane, International Energy Assoc., Washington, DC
8. Special Guard Equipment. Sam L. Thompson, Detroit-Edison Company, Detroit, MI
9. Contingency Planning. Janice V. McGee, Duquesne Light Company, Shippingport, PA
10. Dedicated Response Force Organization and Planning. Larry Musselwhite, Allied General Nuclear Services, Barnwell, SC
11. Physical/Medical Standards for Security Personnel. W.D. Telfair, C.R.C. Inc., Columbia, MD
12. Special Situations Training. Elgin J. Arave, DOE-Dayton Area Office, Miamisburg, OH

Mr. John Messervey, INMM Executive Director addressed the workshop participants at the banquet on Thursday evening, October 15. He outlined the functions and objectives of INMM primarily for the non-members in attendance.

Proceedings of the workshop will include the keynote speech, and the summaries of each of the smallgroup sessions. Copies of the proceedings will be mailed automatically to each workshop participant. Additional copies may be obtained by contacting:

L. Paul Robertson—1716
Sandia National Laboratories
Albuquerque, New Mexico 87111
(505)844-7706

The evaluation sheets completed by the attendees indicated that the workshop was a complete success. The majority of attendees suggested that another workshop using the same format be conducted in approximately one year. Perhaps the title should be changed from "guard training" to "security personnel training".



Mr. R.F. Burnett, Director of Safeguards Division, NRC, addressing the 67 attendees of the Technical Workshop on Guard Training at the Pheasant Run Hotel, St. Charles, IL, October 14, 1981.

LARGE CLASS FOR ACCOUNTING AND AUDIT COURSE

Twenty-three participants from the U.S. and Canada attended the recent short course in Accounting and Auditing for Nuclear Materials presented in Oak Ridge, Tennessee, October 26 through the 29th. The course was sponsored by INMM and hosted by Union Carbide Nuclear Division and the Central Region INMM Chapter.

The instructors for the course were Sheldon Kops, former Chief, Materials Management and Safeguards Branch of the Chicago Operations and Regional Office; and Paul A. Korstad of Battelle, Pacific Northwest Laboratory's Accounting Department. Mr. Roy Cardwell of UCND was host and special coordinator.

The presentation and discussion of accounting systems for nuclear material control included accounting records and procedures, internal controls, reports, and manual and electronic data processing systems. Audit programs as applied to internal audit and independent inspection, as well as audit techniques specific to nuclear materials were also included along with working paper techniques, use and design. The course also included report writing and a review of accounting material with an eye towards the INMM Certification Examination.

Attendees of the course included Barbara Andres, Atomic Energy of Canada Ltd.; Karen Canody, Babcock and Wilcox Company—CNFP; Stacia Herndon, EG&G Idaho, Inc.; G.J. Healey, Atomic Energy Control Board of Canada; Vic Hubbard, Rockwell Hanford Operation; E.A.G. Larson, Atomic Energy of Canada Limited Research Company; Charles Lower, NLO, Inc.; Jack Mertes, Battelle, Pacific Northwest Laboratory; Michele Pennington, E.I. duPont—SRP; Russell Pierre, Goodyear Atomic Corporation; Edna M. Arwood, ORNL; R.L. Cline, ORNL; Steven W. Combs, Y-12; Alice B. Downing, Y-12; Connie P. Hall, Y-12; Gary G. Hilton, CSD; Penny P. Jessen, Y-12; William S. Kiser, CSD; Cathy D. Mattice, Y-12; Peggy H. Scott, CSD; John S. Stephens, CSD; Edgar Darden, Jr., Bill G. Roach, Union Carbide Corporation, Oak Ridge Associated Universities, Nuclear Division.

It is anticipated that the course will be again offered in Columbus, Ohio, during the spring of 1982.

First row: Darden, Lower, Cline, Scott, Hall, Andres, Downing, Arwood, Pennington, Herndon, Jessen, Mattice, Canody, Combs, Korstad. Second row: Kops, Larson, Hubbard, Hilton, Pierre, Mertes, Healey, Roach, Kiser, Stephens.

CERTIFICATION BOARD ACTIVITIES

DR. FRED TINGEY
University of Idaho
Idaho Falls, Idaho

Congratulations are in order for Ron Hawkins of NUSAC who has successfully completed all the requirements for certification as a Safeguards Specialist. Ron completed the requirements while attending the annual meeting of the Institute in San Francisco.

In order to stimulate interest in the program and indicate to the applicant the level of expertise that can be anticipated by the examination, typical examination questions will appear in this column from time to time. The first set is as follows:

1. The IAEA is a United Nations organization.
   a) True b) False
2. Only data generated within the accountability period should be used in constructing material balances and associated uncertainties.
   a) True b) False
3. If a measurement $Z = \frac{X}{Y}$ and Var (X), Var (Y), and Cov (X,Y) be sample estimates of the *relative* variances and covariance in X and Y then the *relative* variance of Z is approximately:
   a) $\mathrm{Var}(X) + \mathrm{Var}(Y) + 2\,\mathrm{Cov}(X,Y)$
   b) $\bar{X}^2\,\mathrm{Var}(Y) + \bar{Y}^2\,\mathrm{Var}(X) + 2\,\bar{X}\,\bar{Y}\,\mathrm{Cov}(X,Y)$
   c) $(\bar{X}/\bar{Y})^2\,\mathrm{Var}(X)/\bar{X}^2 + \mathrm{Var}(Y)/\bar{Y}^2$
   d) $\mathrm{Var}(X) + \mathrm{Var}(Y) + \mathrm{Var}(X)\,\mathrm{Var}(Y)$
   e) $\mathrm{Var}(X) + \mathrm{Var}(Y) - 2\,\mathrm{Cov}(X,Y)$
4. A record showing an inventory difference in red or in brackets indicates an increase or a gain in the account.
   a) True b) False
5. A double entry system of accounting is:
   a) two sets of records
   b) a system of bookkeeping where each transaction involves a two-way self balancing entry posted to a record
   c) a journal, a ledger, a subsidiary ledger and a general ledger
   d) none of the above
6. Overstating inventoried shipments affect ID as follows:
   a) A loss in the shipping MBA and a gain in the receiving MBA
   b) A gain in the shipping MBA and a loss in the receiving MBA
   c) An overstated Book Inventory at the end of the month in the shipping MBA
   d) An understated Book Inventory at the end of the month in the receiving MBA
7. Which limit of error could be considered typical for a bulk weight measurement on UO_2 in the 10 kilogram range?
   a) 10% b) 1%
   c) .1% d) .01%
8. Which of the following methods need not be complied with for a personnel screening program?
   a) Privacy considerations
   b) Providing a satisfactory appeal procedure
   c) The Freedom of Information Act
   d) Equal Employment Opportunity Commission guidelines
   e) NRC regulations

SAFEGUARDS COMMITTEE REPORT

ROBERT J. SORENSON
Chairman, Safeguards Committee
Battelle Pacific Northwest Laboratory
Richland, Washington

The Safeguards Committee met at the Sheraton Palace Hotel in San Francisco, on both Sunday, July 12, and Thursday, July 16. In attendance at one or both meetings were: Charles Vaughan, Dick Duda, Cookie Ong, Ralph Lumb, Jim de Montmollin, Paul Persiani, Brian Smith, Wally Hendry, Ken Sanders, Mark Killinger, Marty Messinger, Bill Powers, John Jaech, Fred Tingey, and Bob Sorenson. We were pleased to see the renewed interest in the Committee's activities as indicated by the increased attendance.

The purpose of the Sunday meeting was to discuss some of the recommended changes in safeguards requirements for low enriched uranium facilities. While the Committee is in essentially complete agreement regarding recommending the reduction in some of the requirements for low enriched uranium, the question of requiring the current limit of error calculation is still up in the air. It was discussed at great length with Fred Tingey and John Jaech. At the conclusion of our meeting we decided that we would try to have a specific recommendation on the low enriched uranium question ready for our next meeting with the NRC.

The Subcommittee for Government Liaison, chaired by Dick Duda, has been very active. The Subcommittee characterizes its basic work objective as making available technical, operational, and commercial inputs to those in the U.S. government who deal with international nuclear safeguards issues and policies. The Subcommittee would like to provide informational feedback that will be useful in considering the relevant technological, commercial, and cost-benefit implications of policy decisions. Dick has held several meetings in Washington, D.C. to discuss the International Plutonium Storage (IPS) and plutonium buffer storage issues. Just this month Dick Schneider of Exxon Nuclear is representing the Subcommittee at a meeting in Vienna.

The Safeguards Committee held its second meeting with the NRC on August 26. This was another productive meeting between our professional society and the NRC. We are very pleased that Mr. Robert F. Burnett, Director of the Division of Safeguards, has agreed to continue with these dialog meetings on a quarterly basis.

The following was the agenda for the meeting:

- Method of disseminating "lessons learned" from safeguards incidents soon after they occur.
- Status of the proposed MC&A Reform Amendments (Category I).
- Update/status of possible LEU amendments.
- Proposal on decision criteria to replace current usage of LEID.
- Discussions regarding the need for NRC to investigate sampling errors associated with UF_6.
- Impact of the NRC's reduced financial support to NBS and its effect on the supply of standards.
- Discussion on the proposed General Statement of Policy and Procedure for Enforcement Actions (Re: 10 CFR Part 2) as it pertains to LEU.
- Information from the NRC regarding any new rules being developed or under consideration for modification.

continued on page 14

continued from page 13
The ad hoc committee of LEU fuel fabricators met on October 6 to review and comment on the most recent proposed changes to the LEU regulations. They are now circulating their comments within the group and we should be ready to send our final comments to the NRC before the end of October. We are anticipating a significant change in the regulations for LEU as a result of this mutual effort.

The Safeguards Committee is conducting two one-day meetings concerning the recent advance notice of rule making entitled, "Material Control and Accounting Requirements for Facilities Processing Formula Quantities of SSNM," (*Federal Register,* September 10, 1981, page 45144). The purpose of the meetings will be to provide a better understanding of the intent of the advance notice and to receive informal comments from those affected. In other words, it will allow the NRC a chance to explain more fully the objectives and the options to achieve those objectives. In addition, those licensees affected will be able to informally provide input regarding any areas of concern with the implementation of the advance notice. The Committee is providing the forum for this exchange and will facilitate the discussion. For the convenience of those having to travel, we plan to hold two separate meetings, one on the East Coast and one on the West Coast. Each meeting will be based on the same agenda.

The activities of the Safeguards Committee continue to be diverse and interesting. Over the past year the members of the Committee have amazed me with their energy, zeal, and dedication. Their accomplishments over the past months have been significant.

MEMBERSHIP COMMITTEE REPORT

J.E. BARRY
Chairman
Gulf States Utilities
Beaumont, Texas

WELCOMING YOSHIO KAWASHIMA AND COMMENTS ON NUCLEAR POWER POLICY CONTINUITY

I appreciatively welcome Yoshio Kawashima to the INMM Membership Committee. Mr. Kawashima, Executive Director of the Nuclear Material Control Center in Japan, has presided as its Chairman over the extraordinary growth of the Japan Chapter. We look forward to his contributions to this committee's activities.

Here in the United States on October 3rd, President Reagan issued his long-awaited policy statement supporting nuclear power. As a result, overt licensing activities for the Clinch River Breeder Reactor will recommence. Additionally, he removed the federal ban on commercial reprocessing as established four and one-half years ago by President Carter and ordered a study of ways in which the government can facilitate its development. Unfortunately the nuclear industry, domestically and internationally, no longer counts on continuity in United States nuclear power policy for more than four years at a time. We have three years until the next Presidential election to energetically alter this attitude with irreversible actions and accomplishments. Internationally, as well as nationally, nuclear power's future role must be assured as has been exemplarily demonstrated so far by France during its recent democratic transfer of political power.

The following fifty-five individuals have been accepted during the period July 1, 1981 to September 30, 1981. To each, the INMM Executive Committee extends its welcome and congratulations. New members not mentioned in this issue will be listed in the Winter 1981 (Volume X, No. 4) issue.

Ronald H. Augustson, Senior Officer, International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria, 2360 1856

Olan Gene Bates, Senior Officer, International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria

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Maria Julia Carvalho, Scientific Officer, Gabinete de Proteccao E. Seguranca Nuclear, Rua Nunes Claro, 9, 1000 Lisboa, Portugal, 769753

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Robert Schaer, Dipl. Physicist, International Atomic Energy Agency, Wagramerstr. 5, P.O. Box 200, A-1400 Vienna, Austria 222/2360/2072

Kurt Schaerf, Safeguard Inspector, International Atomic Energy Agency, Vic, 1400 Vienna, Austria

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Houng Yiu Soo, Nuclear Research Officer, U.S. Army (Corps of Engineers), Washington, DC, 20305, (202) 325-7026

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Kazuo Tanaka, Radiation Hygiene Section, Mitsurbishi Atomic Power Industries, Inc., 1297 Kitabukuro-Cho, Omiya-City, Saitama, Japan, 0486-42-4411

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Samual L. Thompson, Training Coordinator—Security, Detroit Edison, 2000 Second Ave., Room 600 SB, Detroit, Michigan 48226, (313) 237-9293

Isabel Pacheco Torres, Director, Division Nuclear Fuels and Reactors, Department of Nuclear Energy, Av. Republica, 45-5., 1000 Lisboa, Portugal, 76 97 53

Amado Arthur Trujillo, Member of Technical Staff, Sandia National Labs, Albuquerque, NM 87185, (505) 844-5360

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Tadashi Yamamoto, Senior Scientist, Japan Atomic Energy Res. Inst., Tokai-mura, Naka-gun, Ibaraki-ken, 319-11, Japan, (02928)-2-5531

Albert Keith Yancey, Superintendent of Plant Protection, Union Carbide Corp., Nuclear Div., P.O. Box 1410, Paducah, Kentucky 42001, (502) 444-6311, Ext. 246

EDUCATION COMMITTEE REVIEWS FORMAL COURSE PRESENTATIONS

H.L. TOY
Chairman, Education Committee
Battelle Memorial Institute
Columbus, Ohio

John Jaech presented the Selected Topics Statistics Course during the week of September 14, 1981, at Battelle-Columbus. The course was well received by 12 attendees.

The Accounting and Auditing Course was presented at Oak Ridge during the week of October 26, 1981. Roy Cardwell served as course coordinator and Shelly Kops and Paul Korstad at Battelle-Northwest served as formal instructors. Ed Owings also assisted in the presentation of the course.

Each member has received word of the Introductory Statistics Course to be held January 11-15, 1982, at the INET Corporaton in Palo Alto, California. Dr. Gregg Dixon of INET will be the course instructor. The course will prepare participants for the advanced level INMM course "Selected Topics in Statistical Methods for Special Nuclear Material Control".

Dean Scott of Battelle-Northwest has agreed to serve as a member of the education committee. Dean will provide West Coast representation on the committee. Our newest representative is currently evaluating formal course needs on the West Coast.

Selected Topics Statistics Course
Seated L to R: Frank Ortiz, LASL; John Jaech, Instructor, Exxon Nuclear; John O'Brien, LASL; Hiroki Smith, USNRC; James Hicks, Goodyear Atomic. Standing L to R: Jon Fager, BNW; Rick Stutheit, USDOE; John Stephens, Union Carbide; William Kiser, Union Carbide; Mark Laidlow, VEPCO; Matthew Suwala, B&W; William Vroman, ANL; Lavella Adkins, BCL; Harley Toy, BCL. Missing from the photo is Louie Perez, LASL.

REPROCESSING PLANT SAFEGUARDS—CONCEPTS AND POSSIBILITIES

We are pleased to present a summary of a poster session presented at the INMM meeting July 13-15, 1981, in San Francisco. This presentation was inadvertently omitted from the Proceedings issue of the Journal.

Pictures from each of the poster sessions are presented on the following pages.

S.J. HURRELL AND H.T. KERR
Engineering Technology Division
Oak Ridge National Laboratory

The Consolidated Fuel Reprocessing Program (CFRP) was established at Oak Ridge National Laboratory by the Department of Energy as the national management center for reprocessing research and development. The CFRP efforts are primarily focused on breeder fuel reprocessing with emphasis on facility designs and equipment developments that reduce radiological exposures and environmental releases while improving plant operating efficiency and safeguards. Extensive reliance on remote operation and maintenance capabilities—a concept called REMOTEX—and a modular design concept for the process equipment are the predominant features of the CFRP efforts. These and other features have been incorporated in the conceptual design of a pilot-scale reprocessing facility called the Hot Experimental Facility (HEF).

A variety of advanced safeguards concepts are potentially applicable in a remotely operated and maintained plant like the HEF. The separation of man from the nuclear material is maximized in this design, and the highly instrumented process area is ideally suited to process monitoring and dynamic accounting for safeguards purposes. Safeguards surveillance is also facilitated by the fact that specific commands must be transmitted from the operator to the in-cell equipment for all operational and maintenance activities. Integrating these and other safeguards measures into a comprehensive system will provide highly effective safeguards for the HEF.

The development and demonstration of improved process monitoring techniques for safeguards purposes has been an important objective for the CFRP. A concept called Microscopic Process Monitoring has been developed to provide rapid diversion detection capability as well as diagnostic information about process events. Process monitoring generally uses process control data and can provide some degree of tamper-indicating capability with minimal interference in non-safeguards activities.

Microscopic process monitoring was demonstrated during miniruns at the Barnwell Nuclear Fuel Plant in which the second and third plutonium cycles were operated with natural uranium. The results were very encouraging, and further development of the concept is planned.

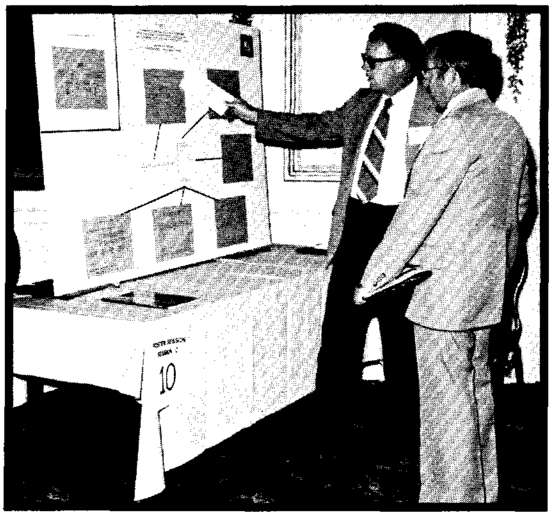
POSTER SESSION IS A FIRST AT 1981 ANNUAL MEETING

ROY G. CARDWELL
Session Chairman
Union Carbide Corporation
Oak Ridge, Tennessee

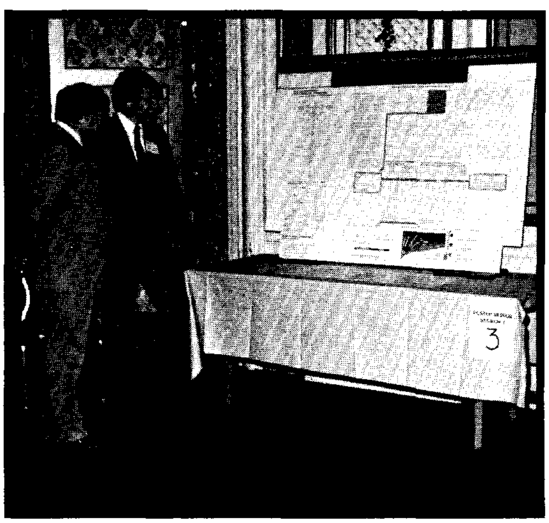
Because of the increasing popularity of the presentation of information by the poster method, the Program Committee included the first such session in an INMM Technical Program during their 22nd Annual Meeting in San Francisco.

Continuous presentations by fifteen participants were made from 8:30 a.m. to 12 noon on Tuesday and were well attended and received by a large number of meeting attendees. Reaction and comments indicate the probability of including poster sessions in future meeting programs.

Larry Harris, Science Applications, discusses his poster with Jerry Britschgi, Exxon Nuclear.

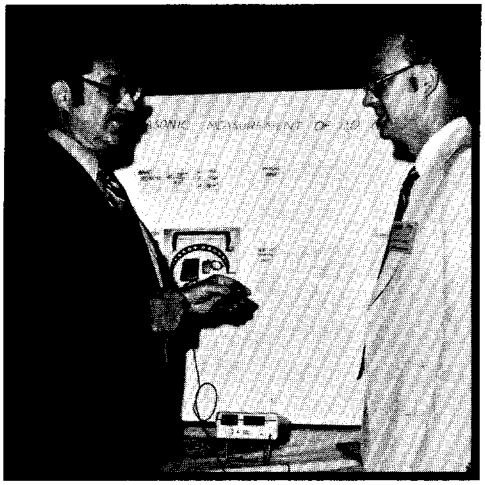


Chris McDonald, White Sands Missile Range, listens to the presentation of Dwane Ariowe, Sandia Labs.

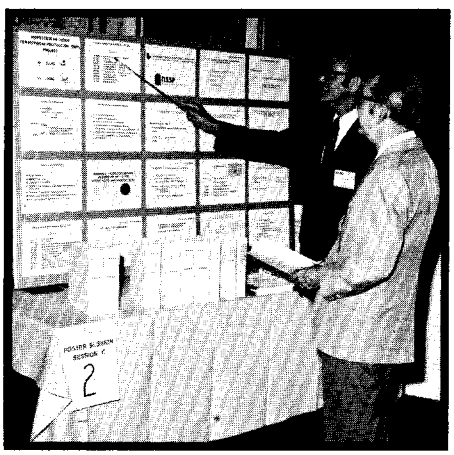


Roy Cardwell, Union Carbide, poses a question to Bob Eggers, Battelle PNL.

Herman Miller, INET Corporation, watches a demonstration by Manny Kanter, ANL.

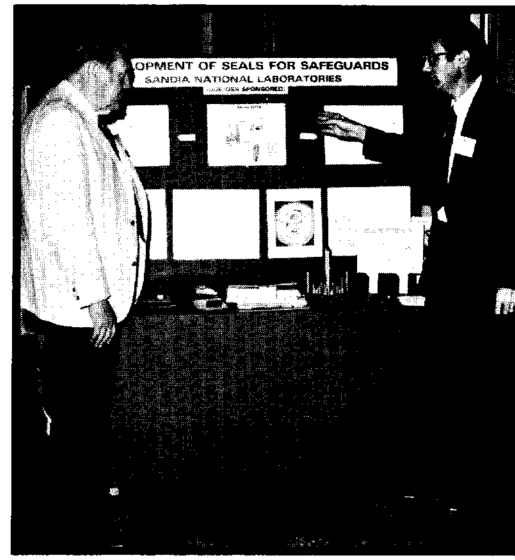


Marty Zucker, ANL, explains his project to Andrew Stirling, AECL.

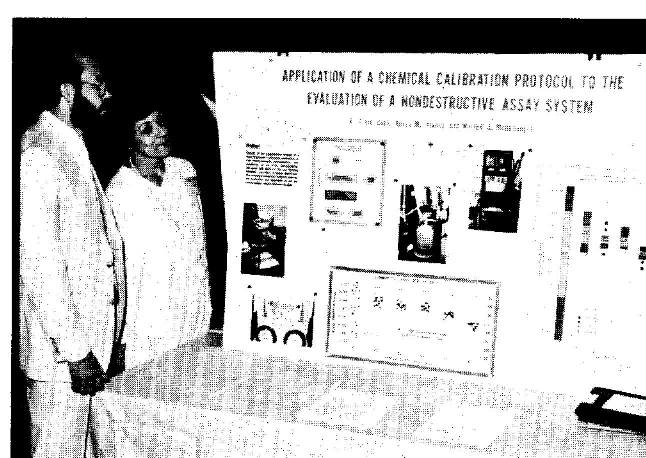


John Green, Lawrence Livermore, makes a point with Willy Higinbotham, BNL.

M.S. Smedly listens to the presentation of Ivan Waddoups, Sandia Labs.

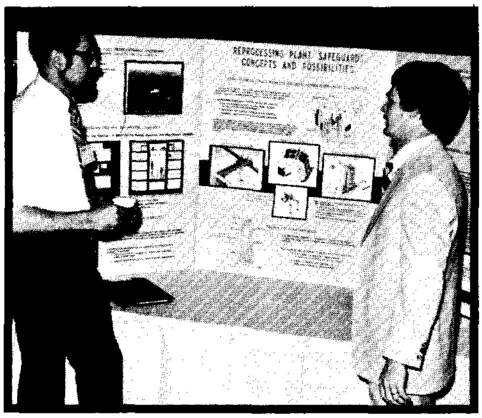


E.R. Johnson, E.R. Johnson Associates, and Homer Foust, Battelle Columbus, watch a video presentation by Larry Barnes, Allied General Nuclear Services.

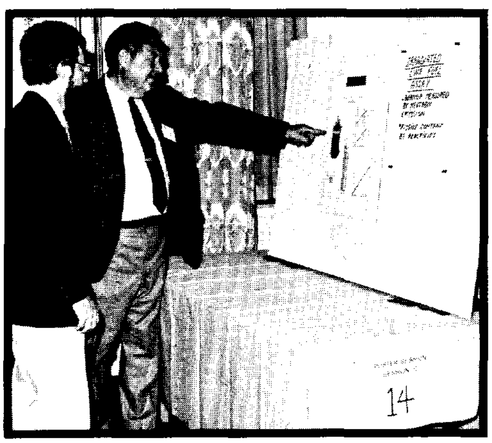


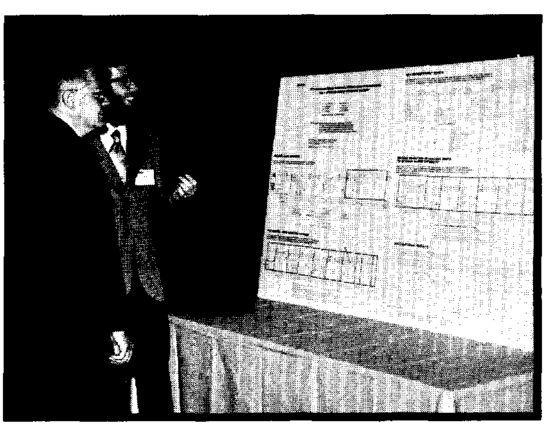
Creig Zook and Nancy Trahey, USDOE, make a final check of their poster layout.

Bill Rodenburg, Monsanto-Mound Labs, has some questions for Steve Hurrell, ORNL.

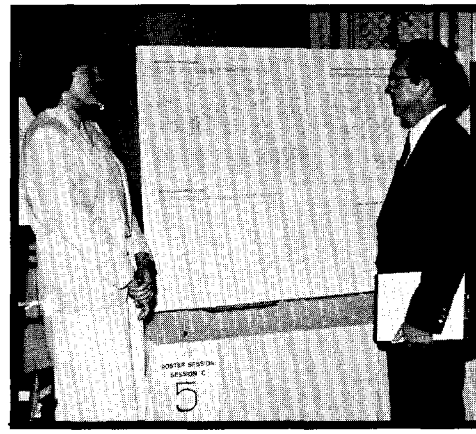


Sam Untermyer, National Nuclear, explains a detail of his poster to INMM Technical Program Chairman, John Glancy, Science Applications.

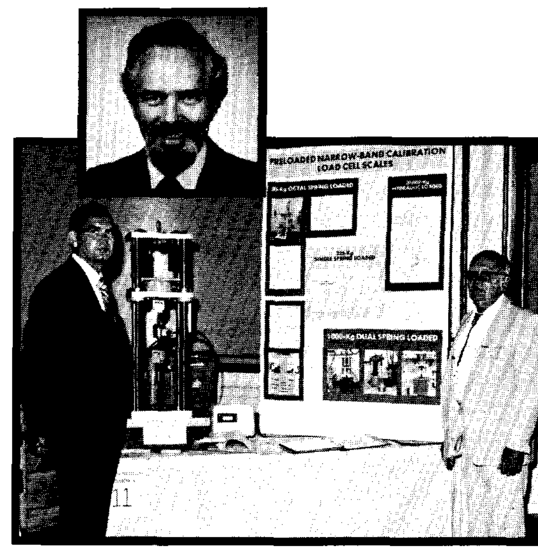




Bill Yates, Sandia Labs, studies the poster of Les Davenport, Battelle PNL.



J.L. Pindak, Battelle PNL, listens to questions from Henry McClanahan, Babcock & Wilcox.



Randall Schoonover and Paul Pontius, both of National Bureau of Standards, await their next group for presentation on the poster developed with Syl Suda, BNL (inset).

Hans Weber, IRT Corporation, discusses his poster with Tsahi Gozani, SAI.

CENTRAL REGION CHAPTER

TOM GERDIS
Vice Chairman
US Ecology, Inc.
Louisville, Kentucky

The Central Region Chapter of INMM including members from all or part of seven states held a very successful inaugural meeting attended by 60 individuals October 29-30 at the Holiday Inn in Oak Ridge, Tennessee.

The chapter includes a potential of some 120 members in Illinois, Indiana, Kentucky, Missouri, Ohio, Tennessee, and the western area of Pennsylvania.

Seventeen INMM members met at the Holiday Inn (I-64 and Hurstbourne) in Louisville, Kentucky on June 17, 1981 to approve a constitution and by-laws and to elect a slate of officers. At the meeting hosted by US Ecology, Inc., Harvey C. Austin of Union Carbide Corp. Nuclear Division (Oak Ridge) was elected the chapter's first chairman. Other officers elected: Thomas A. Gerdis, US Ecology, Inc., Louisville, vice chairman; E.A. DeVer, Mound Laboratory, Miamisburg, Ohio, secretary; John Wachter, ORNL, treasurer; Howard E. Crowder, UCC-ND, Sheldon Kops, CPA, Chicago, Illinois, and John F. Lemming, Mound, members of the executive committee.

W.O. (Bill) Harms, Director of Nuclear Reactor Technology Programs at UCC-ND, presented a very interesting talk at the evening banquet on various approaches to meeting this nation's future energy needs including the breeder reactor, reprocessing and fusion.

Wayne Harbarger (left) and Jim Hicks of Goodyear Atomic Corp. checked over overhead transparencies before Wayne's technical presentation.

John Lemming was in charge of the technical program for the meeting. Papers were presented as follows:

- "Accountability Measurements", Wayne B. Harbarger, Goodyear Atomic Corp., Piketon, Ohio.
- "Gamma-Ray Measurements for Simultaneous Calorimetric Assay", D.A. Rakel, Mound.
- "A Near Real-Time Nuclear Materials Safeguards System for a R & D Environment", L.M. Gray, UCC-ND.
- "Remedial Action—What and Why Is It?", Beverly Ausmus, Bechtel National Corp., Oak Ridge.
- "A Look at the International Scene", Kops.
- "NDA of Spent BWR Fuel by Active Neutron Interrogation", E.D. Blakeman, ORNL.
- "A Computerized Waste Accountability Shipping and Packaging System", Andy Jackson, Mound.
- "Nuclear Material Control at Battelle Columbus Laboratories", Harley L. Toy, Columbus, Ohio.
- "Power Plant Reactors", E.T. Wein, Commonwealth Edison, Chicago.
- "Application of Controllable Unit Approach (CUA) to a Low-Enrichment Uranium Fuel Facility", Clifford R. Rudy, Mound.
- "Operating Experience with a Near Real-Time Inventory Balance in Nuclear Fuel Cycle Plant", W.J. Armento, UCC-ND.
- "International Safeguards for the Portsmouth Gas Centrifuge Enrichment Project", D.W. Swindle, UCC-ND.

At the meeting Vincent J. DeVito, INMM Secretary, presented an overview of the current activities of the Japan, Pacific Northwest, Southeastern and Vienna chapters of INMM as well as the status of the new INMM Certification Program. Mr. DeVito is Manager of Safeguards and Security at Goodyear Atomic Corporation, Piketon, Ohio.

Steve Combs of the Oak Ridge Y-12 Plant did an excellent job of organizing and handling local arrangements for the meeting.

The chapter is considering holding its next meeting in March or April of 1982.

Cliff Rudy (left) of Mound Laboratory gave a paper. Walter Strohm has returned to Mound after a tour of duty with the International Atomic Energy Agency in Vienna, Austria under Project ISPO (International Safeguards Project Office).

Newly-Elected officers of the Central Region Chapter are (from left): John Lemming, Ed Crowder, John Wachter, Ev DeVer, Harvey Austin, Tom Gerdis and Shelly Kops.

Harvey Austin of ORNL welcomed members and guests to the chapter meeting. Austin chaired the chapter's first business meeting.

SOUTHEAST CHAPTER

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

The Southeast (North Carolina, South Carolina, Georgia, Florida) Chapter was organized in Aiken, South Carolina, on March 3, 1981, with 13 INMM members present. Executive committee members were elected (from a slate presented by a nominating committee appointed from among those present at the initial meeting) as follows:

Chairman:	Mary S. Dodgen, SRP-duPont
Vice Chairman:	Wendell L. Belew, SRO-DOE
Secretary/Treasurer:	Karl J. Bambas, AGNS
Members at Large:	William T. Dickenson, SRP-duPont Paul E. Ebel, AGNS Newton H. Seebeck, SRO-DOE

Proposed activities include:

1) Planning a fall (or winter) dinner meeting in conjunction with the AGNS contractors' review meeting;
2) Cooperating with the American Nuclear Society with developing and implementing plans for a 1983 joint topical meeting in the Southeast;
3) Providing opportunity for training in statistics (as applied to nuclear material accounting) in the Southeast.

Together we can advance the purpose of INMM and provide better communication among members while seeking to meet the needs in our geographical area of the nuclear community. Your suggestions and comments for accomplishing these objectives are encouraged and may be sent to: Mary S. Dodgen, E.I. duPont de Nemours & Co., Savannah River Plant, Building 703-34A, Aiken, South Carolina 29808.

SAFEGUARDS ANECDOTE THE PLANT INSTRUMENTATION PROGRAM OF 1970

WILLIAM H. HIGINBOTHAM
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By the summer of 1969, the U.S. Atomic Energy Commission's (AEC) safeguards R&D program was in full swing. The question was how to encourage the nuclear industry to use the product, especially non-destructive instrumentation.

Non-destructive assay (NDA) was not exactly a new development *at that time. For example, in 1958-59 Westinghouse performed* an extensive study of safeguards techniques for the AEC, which included evaluation of most of the active and passive NDA techniques that are used today, as well as surveys of destructive analytical techniques, tamper indicating techniques, process monitoring, etc., but that is another story.

The USAEC Office of Safeguards and Material Management decided to invite industrial nuclear facilities that processed high enriched uranium or plutonium to participate in a joint effort to learn how to use NDA instruments for improved material control and accounting. The proposal was written up and approved by a high-level AEC committee.

Although NDA instruments had been used for many years in some AEC contractor facilities, other contractor facilities and commercial nuclear facilities relied almost entirely on destructive measurements and surveillance. The contents of waste and scrap were generally operator's estimates or whatever wasn't measured. Also there was an allowance for "normal operating losses" in the MUF equation. The object of the Plant Instrumentation Program was to measure all inputs and outputs by classical and NDA methods in order to achieve fully measured material balances. Brookhaven National Laboratory was chosen to manage the program.

In January 1970, requests for proposals were sent out to 9 major companies. The following proposals were received, assessed and negotiated within two months:

- Numec, Apollo, Pa.—NDA for plutonium fuels
- Westinghouse, Cheswick, Pa.—NDA for plutonium fuels
- United Nuclear, Wood River Junction, R.I.—two active interrogation instruments to assay high enriched uranium scrap.
- United Nuclear, Pawling, N.Y.—NDA for plutonium fuels
- General Electric, Vallicitos, Cal.—NDA for plutonium fuels and an Integrated Safeguards Exercise to evaluate the performance of fully measured material balances on one or two mixed-oxide fuel fabrication campaigns.

In each case, the capital costs were shared. The companies paid for most of the R&D. There were to be 3 quarterly progress reports and a final report.

The result was that methods were demonstrated to measure all of the important nuclear materials (receipts, products, scrap and wastes), and the way was paved for government requirements for complete material accounting.

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Numec already had an NDA program underway, using high resolution gamma-ray spectrometry to measure the plutonium content of low level wastes in cans and in 55 gallon drums. In 1969 it had measured the plutonium content of a large number of small coupons, or platelets, for a fast critical assembly in this manner. They also obtained a neutron-well coincidence counter to measure PuO_2 receipts and scrap. The 3 quarterly progress reports contain much useful information on gamma-ray assay of low-level wastes, along with identification of anomolies which would still be misleading. The Numec program ran out of money before the final report was written and delivered. However, a few years later the techniques that had been developed were used effectively to account for the large amounts of mixed-oxide fuels fabricated for the Fast Flux Test Facility in Richland, Washington.

The Westinghouse bid was generous. It requested a small amount of money for instruments and reports. The Cheswick facility was experimenting with both co-precipitation and blending of mixed-oxide powders, and had a small scrap recovery process in glove-boxes. It fabricated a number of mixed-oxide fuel rods for recycle in U.S. and Japanese light-water reactors. It explored the use of passive gamma-ray and neutron measurements for mixed-oxide fuel rods, dry scrap, liquid and solid disposable wastes, and to measure the Pu/U in powder blends for production control. It delivered its 4 reports on-time, and used the knowledge it had gained in the design of a commercial-scale mixed-oxide fabrication plant, which it has not built, so far.

The three proposals of United Nuclear Corp., fared differently. The plutonium fuel development facility, in the township of Pawling, about 80 miles north of New York City, had a small research reactor, and glove-box lines to fabricate mixed UO_2/PuO_2 and UC/PuC pellets. One custodian was responsible for all of the plutonium in the vault or in the process equipment. When he was sick or on vacation, operations stopped. The analytical chemist was skillful in analyzing Pu-oxide and carbide materials. The project called for construction of a well-shielded room for the assay of feed, products and wastes by high-resolution gamma-ray spectrometry. The shielded room was completed, but that R&D facility ran into trouble before the NDA equipment was fully tested, and the final report was never written.

The United Nuclear high-enriched uranium scrap recovery facility at Wood River Junction completed both of its projects. The more ambitious project was construction and operation of a facility to measure the U-235 content of 55 gallon drums, using a small accelerator to generate neutrons for interrogation. The D-T pulsed power supply was purchased from a U.S. firm, and the sealed accelerator tube from Phillips (through Amperex). The instrumentation and equipment to handle the drums were housed in a heavily shielded enclosure. While the accelerator tube worked, the system performed very well. After about 1.5 years the tube failed. One replacement failed upon arrival; another was lost in transport. The company was not making money and this experiment ended. The 4 reports are still useful.

Bill Gallagher proposed to have an isotopic neutron source, active neutron interrogation system developed by General Atomics Radiation Technology Division (now IRT, Inc.). United Nuclear paid for one, that was sent to its Hematite, Mo. facility, and the AEC paid for the second that went to Wood River Junction. The instruments that were designed, built and delivered by Rad Tech in about 6 months (Interrogation Safeguards Assay System or ISAS) were the first in the family of isotopic-neutron-source, active-assay instruments in the U.S.

General Electric not only bid on the NDA demonstration program, but also proposed to cooperate in carefully studying and analyzing the kinds of data that could be generated by traditional plus NDA measurements. Although this had not been originally contemplated by the USAEC, the proposal was funded, and a trailer was rented for installation on the lawn of the Vallicitos nuclear center for visitors and analysts from Brookhaven.

There were a number of interested people at the G.E. facility with expertise in chemical analysis, calorimetry, gamma-rays and statistics. They were developing a computer system to control operations and to avoid critical excursions. Unfortunately, this was not completed in time to be used also for near-real-time-accounting. However, PuO_2 cans received from the AEC were measured by calorimetry and destructive analysis, product rods were scanned with a germanium detector, and scrap and wastes were measured by passive neutron coincidence. Before the experiment started, G.E. carefully made well characterized standards for the rods, scrap, and wastes. Additional experiments were conducted to check the statistical procedures and a completely measured and statistically analyzed material balance was performed for one batch of fuel rods. G.E. continued this work and produced follow-on reports for several years.

Although most of the participants expressed great interest in continuing these experiments and demonstrations, the AEC considered that it had done enough for private enterprise, and consented to contribute only a paltry sum to clean up some loose ends. Numec (and Babcock and Wilcox, which later purchased it) made good use of this experience, as I noted earlier. The United Nuclear laboratory near Pawling had an accident that contaminated an employee (not seriously) and closed its doors. The Wood River Junction plant continued to recover high-enriched uranium from naval and R&D scrap until recently. It made very good use of its ISAS until the AEC, in about 1974, decided to take it back and give it to the Chicago Operations Office. For some reason, the Wood River Plant was not able to get the ISAS from the Hematite plant, although the latter stopped processing high-enriched uranium.

10 little, 9 little, 8 little Indians—now there are none. Thank goodness we had the opportunity to develop safeguards at these very real facilities, and for the opportunity to work with Dean James, Bart Conroy, John Limpert, Bill Gallagher, Tsahi Gozani, Ed Kurtz, Bob Schamberger, Dennis Bishop, L.T. Hagie and all of those other great people.

BOOK REVIEW

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Active Nondestructive Assay of Nuclear Materials: Principles and Applications, by Tsahi Gozani, NUREG/CR-0602, SAI-MLM-2585 (United States Nuclear Regulatory Commission, Washington, D.C., 1981: 403 pages, $10)

Nondestructive assay (NDA) is a term applied to a group of radiation measurement techniques developed for bulk samples of nuclear material. Active NDA techniques use external sources of gamma rays or neutrons to stimulate radiation, usually from the induced fission reaction, in the contained nuclear material. Although much work has been done in this field in the last 15 years, very little has found its way into book form. Most remains in the report literature; some is described in journal articles and meeting proceedings. This is only the second book written on nondestructive assay. The other, THE DETECTION OF FISSIONABLE MATERIALS BY NONDESTRUCTIVE MEANS by R. Sher and S. Untermyer, deals with both active and passive techniques. This book contains a brief, general description of passive techniques, but it clearly emphasizes active assay procedures and instrumentation. T. Gozani was deeply involved with much of the early development of active assay techniques and is very well qualified to write this book.

The book's 403 pages are divided into the following chapters:

1. Background and Overview, 32p.
2. Interactions of Neutrons with Matter, 24p.
3. Interactions of Gamma-Rays with Matter, 16p.
4. Neutron Production and Sources, 35p.
5. Gamma-Ray Production and Sources, 17p.
6. Effects of Neutron and Gamma-Ray Transport in Bulk Media, 50p.
7. Signatures of Neutron- and Photon-Induced Fission, 34p.
8. Neutron and Photon Detection Systems and Electronics, 78p.
9. Representative ANDA Systems, 67p.
10. Instrument Analysis, Calibration, and Measurement Control for ANDA, 36p.

Chapters 1, 9 and 10 are written for the general NDA user and the others are oriented toward the NDA instrument developer. The author realizes the diversity of the potential audience and has tried to produce a comprehensive reference which, while it may not frequently be read cover to cover, will have useful sections for all readers.

Chapters 2, 3 and 6 all deal with the interaction of radiation with matter; they provide a good description of the basic physics, much like a text book. At times there may be more mathematical detail than is necessary for the intended audience. Chapter 6 includes extensive information on source moderator design; with its many graphs this should be very useful to the instrument designer.

Chapters 4 and 5 provide a good summary of the properties of neutron and gamma-ray sources. Isotopic neutron sources are covered in considerable detail including many which are probably not of use for nondestructive assay. One might have considered restricting the discussion more to AmLi, ^{252}Cf and Sb-Be which are the only ones enjoying widespread use. Chapter 7 continues with a systematic description of the characteristics of the fission signature giving a rather complete description of the yields, energy spectra and time characteristics of prompt and delayed neutrons and gamma rays from fission which provide the detected radiation for nearly all active assay techniques.

Chapter 8 contains a good description of thermal and fast neutron detectors and fast scintillators. It is the longest chapter in the book and at times seems a bit too comprehensive. There is an interesting discussion of fast pulse counting including a mathematical description of coincidence counting using multiple fast scintillator arrays. Shift-register coincidence circuits are only given a brief description because their application in active assay systems was minimal at the time this was written.

Chapter 9 contains a comprehensive survey of the various active assay systems developed over the past 15 years. Many systems are described briefly with direction to more complete discussions given in an extensive reference list. More detailed discussions are given for selected, important instruments such as Sb-Be assay systems, fission multiplicity detectors (ISAS, ISAF and Random Driver) and fuel rod scanners which use the delayed gamma-ray signature from fission. This chapter provides a good overview of the range of active assay systems for all interested readers. The list of instruments discussed is quite complete and includes those in reasonably widespread use as well as many which were only developed and tested in a single laboratory. The general reader might have found it helpful if more indication were provided as to which instruments have found their way into routine use.

The final chapter is also useful to the general interest reader or NDA user. It begins with a good summary of the typical parameters which influence nondestructive assay systems. The sections on calibration are taken largely from ANSI standards and provide sound, general guidance. The discussion is incomplete but it does emphasize the importance of a careful calibration and measurement control program and gives adequate reference to further information.

The intended audience of the book as indicated in the preface includes measurement supervisors, instrument operators, nuclear material managers, NRC and DOE safeguards professionals, nuclear engineers, instrument engineers and NDA system designers. This, of course, is too diverse an audience to please with each section of the book. I feel that the book succeeds best as a reference for the engineers and designers; the less technical reader will have difficulty extracting an overview of the subject from the text.

The book was written and published under a contract from the Nuclear Regulatory Commission. The NRC is not a publisher and as such, I suspect, does not have a staff to edit technical books. The book would have benefited from the help of a technical editor both in content and writing. In some chapters the typographical and grammatical errors are frequent enough to provide a minor annoyance to the reader. A very large effort was put forth to write this book and the added editorial help would have been worthwhile. Another useful addition would be a comprehensive index. This is a reference book which covers many different subjects and instruments; it will undoubtedly be used by many people to find information about specific NDA instruments or techniques. An index would greatly enhance its usefulness as a general reference.

In summary, this book is a comprehensive reference for active assay techniques and related physical principles. It is a must for the library of any NDA instrument designer and many instrument users. The book pulls together in one place information on all of the active assay techniques developed over the past 15 years.

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ON SUBDIVIDING MATERIAL BALANCES IN TIME AND/OR SPACE

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(1) The work of Dr. Avenhaus was sponsored by the Nuclear Materials Safeguards project of the Nuclear Research Center, Karlsruhe, Federal Republic of Germany.

Introduction

The concept of material accountability is basic to nuclear materials safeguards. For a given space, called a material balance area (MBA) and a given period of time, called a material balance period (MBP), material accountability involves calculating a performance index, called either the material unaccounted for (MUF) or the inventory difference (ID). (The term MUF is used in the balance of this paper). In a safeguards environment, the MUF is used to signal material diversion.

The determination of the MUF proceeds as follows. At the beginning of the MBP, the beginning inventory, I_o, is measured. (This quantity is only an estimate of the true beginning inventory because of the presence of measurement errors. A similar statement applies to the other MUF components as well.) Similarly, at the end of the MBP, the ending inventory, I_1, is measured. In the interval from the beginning to the end of the MBP, the net flows or transfers, inputs minus outputs, T_1, are measured. The sum, $I_o + T_1$, is referred to as the book inventory, and is compared with the ending physical inventory, I_1 to form the MUF.

$$MUF_1 = X_1 = I_o + T_1 - I_1$$

In order to localize losses or diversions, a facility may be subdivided into a number of MBA's, the argument being that a "significant" MUF (i.e., one that cannot be explained as being due to errors of measurement) in a given MBA is evidence of a loss or diversion having occurred in that particular MBA. Were the entire facility to consist of one MBA, a significant MUF would signal a loss or diversion somewhere within the facility, but a precise determination of where this occurred would not be possible. Similarly, if localization in time is desired, then the entire MBP would have to be subdivided into smaller time periods by conducting more frequent inventories and striking the material balance on the occasion of each inventory. Clearly, in this event, an abrupt diversion at a given point in time would be more readily detected.

Granted that subdivisions of a facility into smaller MBA's and of a time period into smaller MBP's does achieve localization of losses or diversions in space and time respectively, this does not necessarily mean that the overall detection capability of the accountability system is enhanced as a result of this effort. The argument is made that by striking balances in smaller spaces and/or over smaller time periods, the amount of material involved is obviously smaller and hence, the uncertainty of the MUF is smaller on an absolute basis. The uncertainty being smaller, the detection capability of the MUF-test (test power in statistical terminology) is improved, and the claim is made that detection sensitivity is increased by this action.

While this argument is valid for a given material balance, it fails to note what happens to detection sensitivity when decisions are to be made on losses or diversions over a specified time period, say one year, and for an entire facility, rather than for a given MBA. There are basically two ways MUF data may be combined: (1) A statistical test may be made for each MBA/MBP, and "detection" consists of a significant MUF for one or more of such tests; (2) the individual MUF's are algebraically summed, and a single statistical test of significance is made. In this latter instance, the net result, of course, is the same as if the subdivisions in space/time had not been made. (It is noted that other analyses may be made with the MUF data, e.g., special linear combinations of the MUF's may be formed. This possibility is not covered in detail here but an important result relative to this point is made later.)

The purposes of this paper are to present some important theorems relative to this problem, to give some examples illustrating how overall detection sensitivity may be lessened by striking frequent material balances over many MBA's, and to illustrate the application of a recently developed computer code that permits calculations of detection probabilities with correlated statistics.

Theorems

Three theorems which are extensions of earlier work of Avenhaus and Frick [1] and of Frick [2] are stated and proved in the Appendix. In applying these theorems to the problem under discussion, three important implications may be stated as follows:

(1) With respect to an overall reference time, such as one year, if the year is subdivided into a number of MBP's, then in the sense of applying the statistical test having maximum test power, i.e., having the highest *probability of detecting any loss or diversion of given total size*, the best test is one that ignores the intermediate physical inventories. That is to say, a single statistical test is made, using as the test statistic the algebraic sum of the MUF's for the individual MBP's. Effectively, this is the same as if the intermediate physical inventories had not been taken. (Since the test in question is "best" in detecting any loss or diversion pattern, it will clearly be best against an optimum diversion strategy.)

(2) The second theorem emphasizes this important result. Although it is contained already in the first theorem it is explicitly proven that even if the intermediate MUF's are linearly combined in some optimum way, such as using a weighted average to estimate the beginning inventory of a given MBP (see, e.g., Stewart [3]), the resulting combination of tests will still have a smaller overall detection probability than the simple global test that makes use of only the beginning and ending physical inventories and of the net flows for the entire MBP.

(3) If one limits the admitted test statistics to linear combinations of the MUF's for individual MBP's, then the results stated before naturally hold again. (This is mentioned here explicitly because these test statistics play a role in the literature, see, e.g., Jaech [4].

Some further comments on these theorems are helpful. First, it is noted that although the theorems are stated with regard to subdivisions in time rather than in space, the method of proof makes no assumptions regarding the correlations between successive MUF's. Thus, the results apply to subdivisions in space as well, and, for that matter, to a matrix of MUF's distributed in time and space. Secondly, it is important to realize that if the objective is to isolate losses in space or time, then clearly the more frequent material balances over smaller spaces meet this objective. The examples to follow will illustrate this. This ability to isolate losses, however, is at the expense of reduced detection sensitivity should the losses or diversions not be abrupt, but be spread over space and/or time. The third point to note is that "optimum" linear combinations of MUF's that are improvements over the simple algebraic sum can, and have been, derived to react to specified loss or diversion patterns. The conclusion that the simple MUF is optimum applies to the case of an unspecified loss or diversion pattern, which is quite clearly the most realistic in practice since in a safeguards situation, one must guard against the optimum strategy of the diverter. In fact, the third theorem has been derived from a game theoretical approach.

A general point to note is that in evaluating various test statistics and combinations thereof, one must control the value of the overall significance level which in our case has the concrete meaning of a *false alarm rate*. The three theorems given above indeed fulfill this requirement. This is especially important when many statistical tests are applied; if the value of the false alarm rate is not controlled, one or more tests would tend to produce a positive response due to chance alone. In our opinion, the control of the false alarm rate has not always been given due consideration.

A number of examples are now given to illustrate the conclusions discussed here.

Examples

In the examples to follow, a simplified error structure is assumed. This in no way detracts from the generality of the conclusions illustrated by the examples. Clearly, the examples cannot hope to cover all kinds of situations, and simplicity is preferred over completeness.

The basic MUF equation given in the Introduction is

$$X_1 = I_o + T_1 - I_1 \qquad (1)$$

where X_1 is the MUF for MBP 1, I_o is the beginning physical inventory, I_1 the ending, and T_1 the net flow or transfers. For subsequent MBP's, the equations are

$$\begin{aligned} X_2 &= I_1 + T_2 - I_2 \\ X_3 &= I_2 + T_3 - I_3 \\ &\text{etc.} \end{aligned} \qquad (2)$$

Over N MBP's, the cumulative MUF, which is the same as the overall MUF in the event no intermediate inventories are taken, is

$$\sum_{i=1}^{N} X_i = I_1 + \sum_{i=1}^{N} T_i - I_N \qquad (3)$$

For the simplified error structure assumed in these illustrative examples, let

σ_I = standard deviation of inventory

σ_T = standard deviation of throughput, for a single MBP.

These are assumed to be random error standard deviations; systematic errors are assumed to be non-existent. Then, the variance of X_i is, for all i,

$$\sigma_X^2 = 2\,\sigma_I^2 + \sigma_T^2 \qquad (4)$$

The variance of the sum of k X_i's is

$$\text{Var}\left(\sum_{i=1}^{k} X_i\right) = \sigma^2_{\Sigma X_i} = 2\,\sigma^2_I + k\,\sigma^2_T \qquad (5)$$

The covariance between X_i and X_j is

$$\text{cov}\,(X_i, X_j) = \sigma_{X_i X_j} = \begin{cases} -\sigma_I^2 & \text{for } j = i+1 \\ 0 & \text{otherwise} \end{cases} \qquad (6)$$

The basic model is studied for a number of cases, consisting of various combinations of conditions as follows:

σ_I = 1 unit for all cases

σ_T = 0.1, 0.5, 1 unit

M = amount lost or diverted

= 0, 4, 6, 10 units

(0 units corresponds to false alarms)

n = number of material balances struck, or number of MUF's calculated

= 12, 6, 4

N = total number of MBP's in time interval of interest

= 12

μ_i = amount diverted or lost in MBP i, summing up to M for a given case.

Calculations of detection probability are performed for 39 cases, defined as follows:

Case	σ_T	M	n	μ_i
1	0.1	0	12	0 for all i
2	0.1	4	12	1/3 for all i
3	0.1	4	12	2/3 for odd i; 0 for even i
4	0.1	4	12	4 for i=6, 0 for other i
5	0.1	0	6	0 for all i
6	0.1	4	6	2/3 for all i
7	0.1	4	6	4/3 for odd i; 0 for even i
8	0.1	4	6	4 for i=3, 0 for other i
9	0.1	0	4	0 for all i
10	0.1	4	4	1 for all i
11	0.1	4	4	2 for odd i; 0 for even i
12	0.1	4	4	4 for i=2, 0 elsewhere
13	0.5	0	12	0 for all i
14	0.5	6	12	0.5 for all i
15	0.5	6	12	1 for odd i; 0 for even i
16	0.5	6	12	6 for i=6, 0 for other i
17	0.5	0	6	0 for all i
18	0.5	6	6	1 for all i
19	0.5	6	6	2 for odd i; 0 for even i
20	0.5	6	6	6 for i=3, 0 for other i
21	0.5	0	4	0 for all i
22	0.5	6	4	1.5 for all i
23	0.5	6	4	3 for odd i; 0 for even i
24	0.5	6	4	6 for i=2, 0 for other i
25	1	0	12	0 for all i
26	1	10	12	5/6 for all i
27	1	10	12	5/3 for odd i; 0 for even i
28	1	10	12	10 for i=6, 0 for other i
29	1	0	6	0 for all i
30	1	10	6	5/3 for all i
31	1	10	6	10/3 for odd i; 0 for even i
32	1	10	6	10 for i=3, 0 for other i
33	1	0	4	0 for all i
34	1	10	4	2.5 for all i
35	1	10	4	5 for odd i; 0 for even i
36	1	10	4	10 for i=2, 0 for other i
37	0.1	4	1	$\Sigma\mu_i=4$
38	0.5	6	1	$\Sigma\mu_i=6$
39	1	10	1	$\Sigma\mu_i=10$

Some comments on the above table are helpful. Note that the first 36 cases are divided into groups of 12 and are further subdivided into subgroups of 4. Within each group of 12, σ_T is constant and the amount lost or diverted, M, is either 0 (for the false alarm case) or a constant. With each subgroup of 4 cases, the number of MBP's is constant. For a frame of reference of one year, n=12 corresponds to monthly MBP's, n=6 to bi-monthly, and n=4 to quarterly. Within each subgroup of 4 cases, there are three types of loss or diversion patterns. The first pattern represents uniform loss or diversion; the last pattern represents an abrupt loss or diversion; the intermediate pattern represents uniform loss or diversion occurring during every other MBP, and no loss or diversion in the remaining MBP's.

The final three cases give the results when a single material balance is struck. They represent guaranteed probabilities of detection using the single calculated MUF in the statistical test, the detection probability being independent of the loss or diversion pattern.

Before presenting the results for the 39 cases in tabular form, it is helpful to illustrate the calculations for a few cases. In all cases the desired overall α value is fixed at 0.05.

Case 38

$$\sigma_{\Sigma X_i} = \sqrt{2(1)+12\ (0.25)} \quad \text{, from (5)}$$

$$= \sqrt{5}$$

Find Prob $(\Sigma X_i > 1.645\sqrt{5} \mid \Sigma\mu_i=6)$

$= \text{Prob}\ (Z > 1.645 - 6/\sqrt{5})$

$= \text{Prob}\ (Z > -1.038070)$, where Z is N(0,1).

This probability is 0.8504

Case 13

Two sets of results are found, one labeled, "approximate" and one labeled "exact". For the approximate case, the correlation between successive MUF's is ignored, i.e., they are assumed to be independent. In this event, the overall detection probability is fixed at 0.05. The α value for any one of the 12 statistical tests is

$$1 - (0.095)^{1/12} = 0.004265$$

For the "exact" results, the correlation between successive MUF's is taken into account. From (6),

$$\sigma_{X_i,X_{i+1}} = -1$$

and

$$\rho_{X_i,X_{i+1}} = -1/\sigma^2_{X_i}$$

$$\sigma_{X_i} = 2 + 0.25 = 2.25, \text{ from (4)}$$

$$\rho_{X_i,X_{i+1}} = -4/9$$

In finding the "exact" probability of detection (i.e., overall α value), use is made of a computer program written by A. Kraft and using an approximation to the multivariate normal distribution reported by Rice et al [5]. For α = 0.004265 defined for the approximate case, the probability is found that a standardized normally distributed random variable takes on a value smaller than 2.63071 (corresponds to the 0.004265 probability) for all 12 tests, taking into account the above correlation coefficients. The detection probability is then one minus the probability in question.

Case 15

For the approximate calculation, and for an odd numbered MBP, the probability that the critical value is not exceeded is

$$\text{Prob } (Z < 2.63071 - 1\sqrt{2.25})$$

$$= \text{Prob } (Z < 1.964043) = 0.975238$$

For the even numbered MBP's, this probability is 1 - 0.004265 or 0.995735. Therefore, the overall approximate detection probability is

$$1 - (0.975238)^6(0.995735)^6 = 0.1615$$

For the exact calculation, use is again made of the computer program as in Case 13.

The detection probabilities are now tabled. In the three tables below, S_1, S_2, and S_3 refer to the three kinds of loss or diversion scenarios. The top entry in each cell is the approximate detection probability assuming independence of test statistics, and the bottom entry is the exact detection probability that takes into account the correlation between successive MUF's. For n=1, the exact and approximate probabilities are the same, and so only one entry is shown. Table I covers cases 1-12 and case 37; Table II includes cases 13-24 and case 38; while in Table III, the results for cases 25-36 and case 39 are displayed. The case numbers are shown in the corner of each cell entry. Keep in mind that for M=0, the probability of detection is equal to the false alarm rate α.

Table I
Detection Probabilities for M=4 and for M=0; σ_T=0.1

	M=0	M=4		
		S_1	S_2	S_3
12	1/ 0.05 0.0442	2/ 0.0951 0.0809	3/ 0.1118 0.0947	4/ 0.5951 0.5963
6	5/ 0.05 0.0476	6/ 0.1545 0.1463	7/ 0.2254 0.2110	8/ 0.6796 0.6890
4	9/ 0.05 0.0496	10/ 0.2281 0.2366	11/ 0.3810 0.3816	12/ 0.7274 0.7413
1	0.05	37/ 0.8648	37/ 0.8648	37/ 0.8648

Table II
Detection Probabilities for M=6 and M=0; σ_T=0.5

	M=0	M=6		
n		S_1	S_2	S_3
12	13/ 0.05 0.0454	14/ 0.1222 0.1061	15/ 0.1615 0.1397	16/ 0.9185 0.9230
6	17/ 0.05 0.0486	18/ 0.2158 0.2117	19/ 0.3604 0.3493	20/ 0.9238 0.9286
4	21/ 0.05 0.0500	22/ 0.3196 0.3371	23/ 0.5693 0.5755	24/ 0.9199 0.9251
1	0.05	38/ 0.8504	38/ 0.8504	38/ 0.8504

Table III
Detection Probabilities for M=10 and M=0; σ_T=1

	M=0	M=10		
n		S_1	S_2	S_3
12	25/ 0.05 0.0474	26/ 0.1739 0.1601	27/ 0.2726 0.2508	28/ 0.9992 0.9993
6	29/ 0.05 0.0497	30/ 0.3109 0.3159	31/ 0.5650 0.5638	32/ 0.9957 0.9960
4	33/ 0.05 0.0503	34/ 0.4327 0.4515	35/ 0.7570 0.7615	36/ 0.9870 0.9884
1	0.05	39/ 0.8479	39/ 0.8479	39/ 0.8479

The following comments are offered;

(1) In comparing approximate results with exact results, note that for these examples, the results are quite comparable. This result should not be generalized; however, with different assumed error structures, e.g., when systematic errors dominate, one could obtain quite incorrect results by failing to take into account the correlations between pairs of test statistics.

(2) Striking numerous material balances greatly reduces the detection probability in the event of any loss or diversion scenario that approaches uniformity. The greater the number of material balances, the greater the loss in detection sensitivity. From Table I, it is also seen that under some conditions, even in the event of abrupt loss or diversion, the detection ability may be smaller with frequent closings than with a single closing.

(3) As the loss or diversion scenario approaches abruptness, the detection probability increases for a given number of MBP's, except in the case of single MBP.

Throughout this discussion, it should be kept in mind that subdivisions in space and/or time are indeed necessary if localization of losses in space and/or time are required. However, given that the false alarm rate is held fixed, this ability to localize an abrupt diversion is at the expense of a reduction in detection probability, a reduction that may be quite significant as the examples illustrate. This suggests the solution that both types of tests be made, one series of tests on individual MBA's and for individual MBP's, and one global test, summing the MUF's over MBA's and MBP's. Although not demonstrated in the examples here, this solution also reduces test sensitivity in the event of losses or diversions that approach a uniform characteristic because of the need to control the false alarm rate.

Appendix

The idea of the solution to our problem is to construct a Neyman Pearson (NP) test for fixed alternative hypothesis and to minimize the power of this test with respect to all admitted alternative hypotheses. In the following, the components X_i; i=1, 2, ..., N, of the random vector $\underline{X}$ may be interpreted to be the MUF's, given by equations (1) and (2) of the main text. The theorems are valid, however, for a much more general covariance structure than that given by equation (6) of the main text.

Theorem 1

Let $\underline{X}$ be a normally distributed random vector with known regular covariance matrix $\underline{\underline{\Sigma}}$. Let δ be a test for the two hypotheses H_0 and H_1,

$$H_0 : E(\underline{X}) = 0$$

$$H_1 : E(\underline{X}) = \underline{\mu} : \underline{e}' \cdot \underline{\mu} = M > 0$$

($\underline{e}$ being the unity vector, which makes the components of $\underline{X}$ observed MUF's) with fixed significance level α and power $1-\beta_\delta(\underline{\mu})$.

Then the power $1-\beta_{\delta^{**}}$ of the test δ^{**}, defined by

$$\delta^{**} = \begin{cases} 1 & \text{for } \underline{e}' \cdot \underline{X} > k_\alpha \\ 0 & \text{otherwise,} \end{cases}$$

(where k_α is the significance threshold) fulfills the relations

$$1-\beta_{\delta^{**}} = \min_{\{\mu\}} \sup_{\{\delta\}} (1-\beta_\delta(\mu)) = \sup_{\{\delta\}} \min_{\{\mu\}} (1-\beta_\delta(\mu))$$

$$= \Phi\left(\frac{M}{\sqrt{\underline{e}' \cdot \underline{\underline{\Sigma}} \cdot \underline{e}}} - U_{1-\alpha}\right)$$

Here, $\{\mu\}$ explicitly means $\{\mu : e' \cdot \mu = M\}$, Φ is the normal or Gaussian distribution function and U its inverse.

Proof

For given alternative hypothesis $E(\underline{X}) = \underline{\mu}$ the critical region K_{δ^*} of the best test δ^* is according to the Lemma of Neyman and Pearson given by

$$K_{\delta^*} = \left\{ \underline{x} : \frac{\exp(-\frac{1}{2} \cdot (\underline{x}-\underline{\mu})' \cdot \underline{\underline{\Sigma}}^{-1} \cdot (\underline{x} - \underline{\mu}))}{\exp(-\frac{1}{2} \cdot \underline{x}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{x})} > k \right\}$$

and which means that the test statistic is given by

$$\underline{X}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu}.$$

As this linear form of multivariate normally distributed random variables is normally distributed with expectation values

$$E(\underline{X}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu}) = 0 \text{ under } H_0 \text{ and } E(\underline{X}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu}) =$$

$$\underline{\mu}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu} \quad \text{under } H_1$$

and with variance

$$\text{var } (\underline{X}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu}) = \underline{\mu}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu} \quad ,$$

the power of this test is given by

$$\sup_{\{\delta\}}(1-\beta_\delta(\underline{\mu}) = 1-\beta_{\delta^*}(\underline{\mu}) = \Phi\left(\sqrt{\underline{\mu}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu}} - U_{1-\alpha}\right),$$

where α is the significance level of the test.

As Φ (.) is a monotonic function, the minimum of the power is given by the minimum of the scalar form $\underline{\mu}' \cdot \underline{\underline{\Sigma}}^{-1} \cdot \underline{\mu}$. Using the Lagrange formalism, the vector $\underline{\mu}^*$ which minimizes this form subject to $e' \cdot \mu = M$ is given by

$$\underline{\mu}^* = \frac{M}{\underline{e}' \cdot \underline{\underline{\Sigma}} \cdot \underline{e}} \cdot \underline{\underline{\Sigma}} \cdot \underline{e} \quad ,$$

therefore, the minimum of the power is given by

$$\min_{\{\mu\}}(1-\beta_\delta(\underline{\mu})) = \min_{\{\mu\}}\sup_{\{\delta\}}(1-\beta_\delta(\underline{\mu})) =$$

$$\Phi\left(\frac{M}{\sqrt{\underline{e}'\cdot\underline{\Sigma}\cdot\underline{e}}} - U_{1-\alpha}\right).$$

Now, as one sees immediately, we have

$$\underline{e}'\cdot\underline{\Sigma}\cdot\underline{e} = \mathrm{var}\,(\underline{e}'\cdot\underline{X}).$$

As we have $E(\underline{e}'\cdot\underline{X}) = M$ under H_1, the minimum of $1-\beta_{\delta^*}(\underline{\mu})$ in fact is the power of the test based on the *statistic* $\underline{e}'\cdot\underline{X}\cdot$ This we can see also if we insert the optimal diversion strategy $\underline{\mu}^*$ into the Neyman Pearson test statistic, we get

$$\underline{X}^{-1}\cdot\underline{\underline{\Sigma}}\cdot\underline{\mu}^* = \frac{M}{\underline{e}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e}}\ \underline{X}^{-1}\cdot\underline{e}\ ,$$

which is up to an irrelevant factor the test statistic

$$\underline{X}^{-1}\cdot e = \underline{e}'\cdot\underline{X} = \sum_{i=1}^{N} X_i$$

Let δ_0 be a test characterized by the test statistic $\underline{e}'\cdot\underline{X}$. As this test has the same power for all $\underline{\mu}$ satisfying the condition $\underline{e}'\cdot\underline{\mu} = M$, we have

$$\min_{\{\mu\}}(1-\beta_\delta(\underline{\mu})) = \min_{\{\mu\}}\sup_{\{\delta\}}(1-\beta_\delta(\underline{\mu})).$$

Now we have in general

$$\sup_{\{\delta\}}\min_{\{\mu\}}(1-\beta_\delta(\underline{\mu})) \geq \min_{\{\mu\}}(1-\beta_\delta(\underline{\mu})),$$

therefore

$$\sup_{\{\delta\}}\min_{\{\mu\}}(1-\beta_\delta(\underline{\mu})) \geq \min_{\{\mu\}}\sup_{\{\delta\}}(1-\beta_\delta(\underline{\mu})). \quad (*)$$

Furthermore, we have in general

$$\min_{\{\mu\}}\sup_{\{\delta\}}(1-\beta_\delta(\mu)) \geq \sup_{\{\delta\}}\min_{\{\mu\}}(1-\beta_\delta(\mu)) \ . \quad (**)$$

From (*) and (**), however, we get equality of both sides which completes the proof. □

The following theorem shows that one obtains the same result if one considers instead of the original random vector $\underline{X}$ a linearly transformed vector:

Theorem 2

Let $\underline{X}$ be a normally distributed random vector with regular known covariance matrix $\underline{\Sigma}$, and let $\underline{Y} = \underline{A}\cdot\underline{X}$ be a linearly transformed vector with regular transformation matrix $\underline{\underline{A}}\cdot$ Then *Theorem* 1 holds also if the test procedure is based on the transformed vector $\underline{Y}$ instead of the original vector $\underline{X}$.

Proof

As the expectation vector of $\underline{Y}$ is

$$E(\underline{Y}) = \underline{O} \text{ under } H_0 \text{ and } E(\underline{Y}) = \underline{\underline{A}}\cdot\underline{\mu} \text{ under } H_1\ ,$$

and as the covariance matrix of $\underline{Y}$ is

$$\underline{\Lambda} = \mathrm{var}(\underline{Y},\underline{Y}') = \underline{\underline{A}}\cdot\underline{\underline{\Sigma}}\cdot\underline{\underline{A}}'\ ,$$

the Neyman Pearson test statistic of the test for fixed $\underline{\mu}$ is given by

$$\underline{Y}'\cdot\underline{\Lambda}^{-1}\cdot\underline{\underline{A}}\cdot\underline{\mu}\ ,$$

and the power of this test is given by

$$\Phi\left(\sqrt{(\underline{\underline{A}}\cdot\underline{\mu})'\cdot\underline{\underline{\Lambda}}^{-1}\cdot\underline{\underline{A}}\cdot\underline{\mu}} - U_{1-\alpha}\right).$$

As we see immediately, we have

$$\underline{\mu}'\cdot\underline{\underline{A}}'\cdot\underline{\underline{\Lambda}}^{-1}\cdot\underline{\underline{A}}\cdot\underline{\mu} = \underline{\mu}'\cdot\underline{\Sigma}^{-1}\cdot\underline{\mu}\ ,$$

thus, we have the same expression as for the test using the original random vector $\underline{X}$. □

Frick (1979) has treated the case of a test statistic which is a linear combination of the single observations x_i, i=1 ...N. Even though his result is now a special case of Theorem 1, we present it here, because this statistic has played a role in the literature.

Theorem 3

Let $\underline{X}$ be a normally distributed random vector with known regular covariance matrix $\underline{\underline{\Sigma}}$. Let δ be a test for the two hypotheses H_0 and H_1,

$$H_0 : E(\underline{X}) = 0$$

$$H_1 : E(\underline{X}) = \underline{\mu} : \underline{e}' \cdot \underline{\mu} = M > 0$$

with fixed significance level and power $1-\beta_\delta(\underline{\mu})$, defined by

$$\delta = \begin{cases} 1 & \text{for } \underline{a}'\cdot\underline{X}\ ,\ c > 0 \\ 0 & \text{otherwise,} \end{cases}$$

where $\underline{a}' = (a_1 \ldots a_N)$ is an arbitrary real vector. Then the power $1 - \beta_{\delta^{**}}$ of the test δ^{**}, defined by

$$\delta^{**} = \begin{cases} 1 & \text{for } c\cdot\underline{e}'\cdot\underline{X},\ c > 0 \\ 0 & \text{otherwise,} \end{cases}$$

is that test statistic which fulfills the relations

$$1-\beta_{\delta^{**}} = \min_{\{\mu\}} \max_{\{\delta\}} (1-\beta_\delta(\mu)) =$$

$$\max_{\{\delta\}} \min_{\{\mu\}} (1-\beta_\delta(\mu)).$$

The minimizing alternative hypothesis is

$$\mu^* = \frac{M}{\underline{e}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e}} \cdot \underline{\underline{\Sigma}} \cdot \underline{e}\ .$$

Proof

As the linear form $\underline{a}'\cdot\underline{X}$ of multivariate normally distributed random variables is normally distributed with expectation values

$$E(\underline{a}'\cdot\underline{X}) = 0 \text{ under } H_0 \text{ and } E(\underline{a}'\cdot\underline{X}) = \underline{a}'\cdot\underline{\mu} \text{ under } H_1$$

and with the variance

$$\text{var}\ (\underline{a}'\cdot\underline{X}) = \underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a},$$

the power of the test is

$$1-\beta_\delta(\mu) = \Phi\left(\frac{\underline{a}'\ \underline{\mu}}{\sqrt{\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a}}} - U_{1-\alpha}\right)\ .$$

Because of the monotonicity of Φ we only have to prove

$$\frac{\underline{a}^{*\prime}\cdot\underline{\mu}^*}{\sqrt{\underline{a}^{*\prime}\cdot\underline{\underline{\Sigma}}\cdot\underline{a}^*}} = \min_{\mu} \max_{a} \frac{\underline{a}'\cdot\underline{\mu}}{\sqrt{\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a}}}$$

$$= \max_{a} \min_{\mu} \frac{\underline{a}'\cdot\underline{\mu}}{\sqrt{\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a}}}$$

We perform this by showing that the *saddle point criterion*

$$\frac{\underline{a}^{*\prime}\cdot\underline{\mu}}{\sqrt{\underline{a}^{*\prime}\cdot\underline{\underline{\Sigma}}\cdot\underline{a}^*}} \geq \frac{\underline{a}^{*\prime}\cdot\underline{\mu}^*}{\sqrt{\underline{a}^{*\prime}\cdot\underline{\underline{\Sigma}}\cdot\underline{a}^*}} \geq \frac{\underline{a}'\cdot\underline{\mu}^*}{\sqrt{\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a}}}$$

is fulfilled. Now, these two inequalities are equivalent to

$$\frac{M}{\sqrt{\underline{e}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e}}} \geq \frac{M}{\sqrt{\underline{e}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e}}} \geq$$

$$\frac{M}{\sqrt{\underline{e}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e}}} \cdot \frac{\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e}}{\sqrt{\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a}}}\ ,$$

which means that it suffices to show

$$(\underline{e}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e})\cdot(\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{a}) \quad (\underline{a}'\cdot\underline{\underline{\Sigma}}\cdot\underline{e})^2.$$

As the symmetric and regular matrix $\underline{\underline{\Sigma}}$ can be represented as the product of a regular matrix $\underline{\underline{D}}$ and its transposed matrix $\underline{\underline{D}}'$,

$$\underline{\underline{\Sigma}} = \underline{\underline{D}}' \cdot \underline{\underline{D}} ,$$

this inequality is equivalent to

$$(\underline{\tilde{a}}'\cdot\underline{\tilde{a}}) \cdot (\underline{\tilde{e}}'\cdot\underline{\tilde{e}}) \geq (\underline{\tilde{a}}\cdot\underline{\tilde{e}})^2 ,$$

where $\underline{\tilde{a}}$ and $\underline{\tilde{e}}$ are defined as

$$\underline{\tilde{a}} = \underline{\underline{D}} \cdot \underline{a},\ \underline{\tilde{e}} = \underline{\underline{D}} \cdot \underline{e} \quad ;$$

this, however, is nothing else than the *Schwartz' inequality* which completes the proof. $\square$

The application of these theorems to the problems discussed in the main text is straightforward. With $X_i = I_{i-1} + T_i - I_i$ we have

$$\underline{\underline{\Sigma}} = (\mathrm{cov}\,(X_i,X_j)) = \begin{cases} \sigma_x^2 & \text{for } i = j \\ -\sigma_I^2 & \text{for } j = i+1 \\ 0 & \text{otherwise} \end{cases}$$

and furthermore,

$$E(X_i) = 0 \text{ for } H_0 \text{ and } E(X_i) = \mu_i \text{ for } H_1,$$

where μ_i is the amount of material lost or diverted in the MBP.

Theorem 1 says that in the sense of the overall probability of detection the optimal test statistic is

$$\underline{e}'\cdot\underline{X} = \sum_i X_i .$$

Theorem 2 says that this is still true if one takes linear combinations of the X_i's. In fact, Stewart's weighed average (1958) for the starting inventory for the i-th inventory period,

$$S_i = c_i\cdot B_{i-1}+(1-c_i)\cdot I_{i-1},$$

where B_{i-1} is the ending book inventory of the foregoing inventory period, leads to the following modified book physical inventory differences

$$Y_i = c_i\cdot B_{i-1}+(1-c_i)\cdot I_{i-1}+T_i-I_i = c_i\cdot Y_{i-1}+X_i,$$

which thus appear to be linear combinations of the original S_i' s.

References

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[5] Rice, J., Reich, T., Cloninger, C. R., and Wette, R., "An Approximation to the Multivariate Normal Integral; Its Application to Multifactorial Qualitative Traits', Biometrics, Vol. 35, pp. 451-460, 1979.

SAFEGUARDS INSTRUMENTATION: A COMPUTER-BASED CATALOG

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ABSTRACT

Safeguards Instrumentation: A Computer-Based Catalog is a reference book compiled for the U.S. Department of Energy, Office of Safeguards and Security (DOE/OSS). The information is needed to help plan U.S. policies and procedures regarding international safeguards. The Catalog contains descriptions stored in a computer data base of about 175 items of equipment, including both instruments for nondestructive assay (NDA) and devices for containment and surveillance (CS), and either listings (when known) or estimates of their purchase and operating costs and useful lifetime. Since the Catalog was written to aid in the formulation of international safeguards policies, devices for physical protection are not included. Though comprehensive systems are included, no attempt was made in compiling the Catalog to define complete safeguards systems for facilities.

I. INTRODUCTION

Safeguards Information: A Computer-Based Catalog[1] was assembled by the Technical Support Organization at Brookhaven National Laboratory in response to a request from the U.S. Department of Energy, Office of Safeguards and Security. The information contained in this Catalog will provide a data base for safeguards studies and help establish criteria and procedures for international safeguards for nuclear materials and facilities.

The Catalog primarily presents information on new safeguards equipment. It also describes a few safeguards systems for certain applications, but it does not describe the inspection procedures that would require use of the equipment. Because international safeguards as administered by the International Atomic Energy Agency (IAEA) do not include physical security, devices for physical protection (as opposed to containment and surveillance) are not included.

A key goal was to obtain cost information. An attempt was made to list capital costs, annual maintenance costs, replacement costs, and useful lifetime for the equipment. Some of these data were difficult or impossible to determine. Recognize especially that, whereas costs in the Catalog for commercially available equipment are almost always actual supplier prices (list--without discounts), costs for equipment under development are almost always estimates, though by individuals having long experience with nuclear instrumentation. Shipping costs to the IAEA from the U.S. typically add 10-20% to the listed price. In all cases, the costs refer to U.S. dollars in early 1981.

For equipment which is commercially available, representative sources are listed whenever available. It was not the intention to give exhaustive lists of suppliers. A citation in no way represents a recommendation of those suppliers, nor does omission of a supplier imply that such a supplier is less qualified than those given.

In this article we describe in Section II the computer data base used to store the equipment information and give sample entries. In Section III we present a list of the equipment contained. We discuss possible improvements to this work in Section IV and finally, in Section V, we outline its background.

II. THE COMPUTER DATA BASE

A computer data base was developed to store the information contained in the Catalog and to produce the Catalog itself. Three separate files were established: for equipment, for references, and for sources. The information in the last two is self-explanatory. That in the first requires a line-by-line explanation, which follows several illustrative examples from the three files.

A. Examples

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E Q U I P M E N T   F I L E

EQUIPMENT NAME : High-Level Neutron Coincidence Counter (HLNCC)

USE CATEGORY : Materials Accountancy
GENERAL TYPE : NDA: Passive Neutron
MATERIAL TYPE : Plutonium
STATUS : Class IV : Production Model
USEFUL TO : Inspector
FACILITIES : Fabrication
Reprocessing
Critical
CAPITAL COST : 43,000
SOURCE 1 : IRT
SOURCE 2 : LANL
REFERENCE 1 : 1978 IAEA
REFERENCE DETAIL : Krick, Evans, Ensslin, Hatcher, Menlove, Sapir, Swansen, DeCarolis & Ramalho; V. 2, 51.
DESCRIPTION :

The portable high-level neutron coincidence counter (HLNCC) was developed for the assay of Pu. The counter was designed to measure the effective Pu-240 mass in Pu samples which may have a high Pu content. The term "high-level" refers to the high neutron count rates produced by large (several kg) Pu oxide or metal samples. The counter measures coincident fission neutrons in the presence of a random neutron background with an efficiency of about 1%. Total Pu content is calculated from the Pu isotopic composition. Correction procedures for removing nonlinearities in the counter response due to multiplication effects in the samples are being developed for Pu metal and oxide samples. The detector consists of 18 He-3 proportional counters embedded in six polyethylene slabs, which form a hexagonal well. Top and bottom end-plugs can be used to form a closed sample-counting cavity. The detector weighs approximately 35 kg. A portable electronics package featuring shift-register coincidence counting electronics was designed for use with the detector. The electronics package is interfaced to a Hewlett-Packard HP-97 programmable calculator and to standard data communications devices. Two AmLi neutron sources for about $6000 each can make this into an active device (see AWCC). About $28,000 of the cost is for the detector and about $15,000 for the versatile electronics package used for this and several other related neutron counters.

EQUIPMENT NAME : Fuel-Assembly Ident. Device (BWR FAID Ultrasonic)
USE CATEGORY : Containment-Surveillance
GENERAL TYPE : Seal
MATERIAL TYPE : Fuel
STATUS : Class II : Development Prototype
USEFUL TO : Inspector
FACILITIES : Fabrication
Reactor
Reprocessing
Fuel Storage
CAPITAL COST : 3,000
MAINTENANCE COST : 100
LIFETIME : 5 Years
SOURCE 1 : Exxon
SOURCE 2 : SNL
REFERENCE 1 : 1980 ESARDA
REFERENCE 2 : SAND 80-0002
REFERENCE DETAIL : McKenzie, Deveney, Sheldon, Sellers, Nilson, Patterson, Fanton, Synder & Crutzen; 455.
DESCRIPTION :

The ultrasonic seal snaps onto one of the tie rods which hold the top and bottom frames that hold the fuel rods together. The tie rod must be notched for the seal snap-on ring. The seal contains a random distribution of acoustic discontinuities. The ultrasonic signature can be read accurately by placing the transducer in contact with the seal. The unique signature is obtained by pulsing the ultrasonic transducer and recording the pattern of reflections as a function of time. The reflections are due to the discontinuities in the seal itself and to the attachment to the tie rod.

The seal was originally designed at Ispra. It has been applied to BWR fuel assemblies which have been exposed to typical exposures (burnups) in BWR's. The seals were not appreciably degraded. However, variations in transducers and problems in precisely attaching the transducers to the seals underwater in spent fuel storage pools have, so far, not been entirely overcome.

The capital cost is for the ultrasonic verifier while the maintenance cost is the capital cost for the BWR FAID itself.

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R E F E R E N C E   F I L E

REFERENCE : 1978 IAEA
TITLE : Nuclear Safeguards Technology 1978
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1979
PUBLISHER : International Atomic Energy Agency
CITY : Vienna
STATE OR COUNTRY : Austria

REFERENCE : 1980 ESARDA
TITLE : 2nd Annual Symposium on Safeguards and Nuclear Materials Management
TYPE OF REFERENCE : Conference Proceedings
COPYRIGHT DATE : 1980
PUBLISHER : ESARDA (Joint Research Centre)
CITY : Ispra
STATE OR COUNTRY : Italy

REFERENCE : SAND 80-0002
TITLE : Containment & Surveillance Equipment Compendium
AUTHORS : Frederick O. Luetters
TYPE OF REFERENCE : Technical Report
COPYRIGHT DATE : 1980
PUBLISHER : Sandia National Laboratories
CITY : Albuquerque

STATE OR COUNTRY : New Mexico

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SOURCE FILE

SOURCE : Exxon
SOURCE NAME : Exxon Nuclear Company, Inc.
CONTACT : R. Nilson
ADDRESS : 2101 Horn Rapids Road
Richland, WA. 99352

SOURCE : IRT
SOURCE NAME : IRT Corporation
CONTACT : Kenneth Alvar
ADDRESS : P.O. Box 80817
7650 Convoy Ct.
San Diego, CA. 92138

SOURCE : LANL
SOURCE NAME : Los Alamos National Lab.
CONTACTS : R. Walton
H. Menlove
ADDRESS : MS 551
P.O. Box 1663
Los Alamos, N.M. 87545

SOURCE : SNL
SOURCE NAME : Sandia National Labs.
CONTACTS : I. Waddoups
T. Sellers
ADDRESS : Division 1754
P.O. Box 5800
Albuquerque, N.M. 87185

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B. Explanation of Equipment File Terminology

EQUIPMENT NAME - Self-explanatory.

USE CATEGORY - One of four terms:

1. Materials Accountancy (MCA)
2. Containment-Surveillance (CS)
3. Process Monitoring (PM)
4. Inspector Use (IU)

In a sense, the first three of these (and possibly the first two) exhaustively categorize all equipment, with the last overlapping the others. With the caveat that the terms are not mutually exclusive, the IU category should be understood as describing those instruments that an inspector would literally carry around or are under the inspectorate's exclusive control; generally, IU instruments are also MCA instruments.

GENERAL TYPE - One of many precise descriptive terms for the equipment. At present, these are as follows (Section III lists the equipment by these categories):

1. Activity Monitor
2. Bundle Counter
3. Communication
4. Density Measurement
5. Identification
6. Isotope Measurement
7. Mass Measurement
8. Material Monitor
9. NDA: Active Gamma
10. NDA: Active Neutron
11. NDA: Heat
12. NDA: Passive Alpha
13. NDA: Passive Gamma
14. NDA: Passive N&G
15. NDA: Sound
16. NDA: Passive Neutron
17. Optical Surveillance
18. Portal Monitor
19. SNM Monitor
20. Seal
21. Transportation
22. Volume Measurement

The distinction between equipment for nondestructive assay (NDA) and as a special-nuclear-material (SNM) monitor is that the former is intended primarily for quantitative purposes--generally, for MCA purposes--while the latter is intended for qualitative or alarm purposes--generally, for CS purposes. N&G in point 14 above means neutrons and gamma rays.

MATERIAL TYPE - One of many descriptive or inclusive terms giving the primary material upon which the equipment operates or with which it is associated. At present, these terms are as follows:

1. Containments
2. Fresh Fuel
3. Fuel
4. Gamma Emitters
5. Gases or Liquids
6. Laboratory Samples
7. Liquids
8. Miscellaneous
9. Plutonium
10. Radioactive Material in Any Form
11. Reactor
12. SNM Neutron Emitters
13. SNM Samples
14. SNM in Solutions
15. SNM in Waste
16. Spent Fuel
17. Uranium
18. Uranium Hexafluoride

STATUS - One of four classifications[2]:

CLASS I: Laboratory Device - The purpose of this equipment is to demonstrate the principle of operation and the nature of the data that will be produced so the IAEA can comment on the approach and future design options. In most cases the equipment will be operated by the designer.

CLASS II: Development Prototype - The purpose of this equipment is to allow joint IAEA-U.S. evaluation, including laboratory and limited field testing. Technical experts at the IAEA will be trained to use the equipment. A preliminary equipment manual will be provided and a preliminary safety analysis will be completed.

CLASS III: Field Evaluation Unit - The purpose of this equipment is twofold: to permit (1) final evaluation of the device prior to developing a production capability and (2) limited use during IAEA inspections. The unit will have undergone a complete safety and reliability analysis. A complete equipment manual and development report will be provided. Where limited quantities are required to meet IAEA needs, these units could be put into full operation by the IAEA after the field evaluation is complete.

CLASS IV: Production Model - Equipment developed to this point will have complete production drawings, production specifications, test procedures, etc., such that the IAEA can obtain commercial supplier quotes on fabrication, testing and delivery of multiple quantities.

Three caveats apply. First, not all of the equipment in this Catalog has been designed expressly for the IAEA; this blurs the distinction between Classes II and III. Second, a text note sometimes indicates that development of a device has halted before production; usually, this means that a better device has supplanted it. Third, equipment for which there is only a serious proposal but not even a laboratory prototype is included in Class I.

USEFUL TO - A statement of whether the equipment is primarily useful to the Inspector or to the Operator of the Plant or is significant to both.

FACILITIES - A list of the facilities in the nuclear fuel cycle for which the equipment would be useful. "Fuel Storage" in some entries in the Equipment File refers to either fresh or irradiated nuclear material.

CAPITAL COST - The cost of purchasing and possibly installing the equipment (in early 1981 U.S. dollars). For seals, this is often the cost of the verification device. Qualifications may appear in the DESCRIPTION. For example, not all equipment prices include the cost of electronic packages used in several instruments.

MAINTENANCE COST - Annual repair costs, film costs, battery costs, or other operating costs. For seals, this is the capital cost of the seal itself. Note that a commonly used rule of thumb for estimating annual maintenance costs is to take 15% of an item's capital costs. This rule has not been applied in this Catalog. Only maintenance costs reported by contributors have been listed.

REPLACEMENT COST - The cost of replacing the equipment without paying again the structural installation costs.

LIFETIME - The useful lifetime in years due generally to obsolescence or breakdown. Another factor bearing on the lifetime of certain devices is the decay of radioactive sources.

SOURCE 1,2 - A brief descriptive term referring to a complete listing in the Source File. This would be either a commercial supplier of the equipment or a laboratory or contractor developing it.

REFERENCE 1,2 - A brief descriptive term referring to a listing in the Reference File.

REFERENCE DETAIL - If REFERENCE 1,2 is not a topical report, then this item gives additional bibliographic information--always the authors and possibly a page number, a volume number, an issue number, and a year of publication. This will always refer to REFERENCE 1 unless two items of detail are numbered, referring to REFERENCE 1 and REFERENCE 2 respectively.

DESCRIPTION - Self-explanatory.

III. EQUIPMENT LIST

We now present a list of the equipment contained in the data base as of 10 August 1981, the date when the information was extracted to produce the published Catalog. The list is ordered alphabetically by the GENERAL TYPE term and, within each such group, alphabetically by EQUIPMENT NAME.

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E Q U I P M E N T   L I S T

	EQUIPMENT NAME	GENERAL TYPE
1.	Ball Valves with Valve-Position Indicators	Activity Monitor
2.	Laser Spent-Fuel Cover	Activity Monitor
3.	Secure Crane-Load Sensor	Activity Monitor
4.	Ultrasonic Surveillance System	Activity Monitor
5.	Valve Tamper Device	Activity Monitor
6.	CANDU Core Input Monitor	Bundle Counter
7.	Pebble Counter	Bundle Counter
8.	Spent-Fuel-Bundle (CANDU) Gamma-Ray Verifier	Bundle Counter
9.	Spent-Fuel-Bundle Counter (CANDU)	Bundle Counter
10.	Spent-Fuel-Bundle Counter (Sandia)	Bundle Counter
11.	Spent-Fuel-Element Monitor	Bundle Counter
12.	Computerized Material-Control & Accounting System	Communication
13.	DYMAC	Communication
14.	Integrated Process & Safeguards Monitoring Systems	Communication

15.	Plutonium Product-Area Monitor	Communication
16.	RECOVER Monitoring Unit	Communication
17.	RECOVER On-Site Multiplexer	Communication
18.	RECOVER Portable Verification Unit	Communication
19.	RECOVER Resident Verification Unit (RVU)	Communication
20.	RECOVER System	Communication
21.	High-Precision Level and Density Sensor Box	Density Meas.
22.	Vibrating Tube (Anton-Parr) Densimeter	Density Meas.
23.	Bar Coding	Identification
24.	Fuel-Assembly Ident. Device (FAID Eddy-Current)	Identification
25.	Fuel-Assembly Ident. System (Magnetic-Inclusion)	Identification
26.	Atomic-Emission Spectroscopy	Isotope Meas.
27.	Mass Spectrometer (On-Line Gas-Phase)	Isotope Meas.
28.	Mass Spectrometer (Thermal-Emission)	Isotope Meas.
29.	Mass Spectrometer (Transportable Quadrupole)	Isotope Meas.
30.	Balances (Electronic)	Mass Measurement
31.	Load Cells	Mass Measurement
32.	Semi-Portable Cylinder Load Cell	Mass Measurement
33.	Uranium-Hexafluoride-Cylinder Weight Standards	Mass Measurement
34.	Conductivity-Level Device	Material Monitor
35.	Electromagnetic Flowmeter	Material Monitor
36.	Fuel-Pellet Inspection System	Material Monitor
37.	Gyroscopic-Coriolis Mass Flowmeter	Material Monitor
38.	Optical Liquid In-Line Sensor	Material Monitor
39.	Orifice Flowmeter	Material Monitor
40.	Pressure Switches	Material Monitor
41.	Thermal Flow Sensor	Material Monitor
42.	Thermal Flowmeter with Low-Flow Alarm	Material Monitor
43.	Transfer-Jet Monitor	Material Monitor
44.	Tubing Block	Material Monitor
45.	Ultrasonic Flowmeter	Material Monitor
46.	Ultrasonic Level Detector with High Alarm	Material Monitor
47.	Ultrasonic Liquid In-Line Sensor	Material Monitor
48.	Vortex-Shedding Flowmeter	Material Monitor
49.	Gamma Absorptiometer	NDA: Active Gamma
50.	Gamma Absorptiometer (Dual-Energy)	NDA: Active Gamma
51.	In-Line Gas-Phase Enrichment Meter	NDA: Active Gamma
52.	K- or L-Edge Densitometer	NDA: Active Gamma
53.	Segmented Gamma Scanner	NDA: Active Gamma
54.	X-Ray Fluorescence (Portable)	NDA: Active Gamma
55.	X-Ray Fluroescence Analysis (Energy Dispersive)	NDA: Active Gamma
56.	Active Well Coincidence Counter (AWCC)	NDA: Active Neutron
57.	DENIS (Time-Delayed Neutrons)	NDA: Active Neutron
58.	Differential Die-Away System for Waste Assay	NDA: Active Neutron
59.	Fuel-Rod Scanner	NDA: Active Neutron
60.	Fuel-Rod-Scanner Standard Fuel Rods	NDA: Active Neutron
61.	Fuel-Subassembly Assayer	NDA: Active Neutron
62.	Isotopic Source Assay System & Fissometer	NDA: Active Neutron
63.	Lead Slowing-Down Spectrometer	NDA: Active Neutron
64.	Neutron Collar	NDA: Active Neutron
65.	Random Driver	NDA: Active Neutron
66.	Resonance-Neutron Radiography	NDA: Active Neutron
67.	SIGMA	NDA: Active Neutron
68.	Sb-Be Photoneutron Interrogation System	NDA: Active Neutron
69.	Shuffler (Californium-252)	NDA: Active Neutron
70.	Small Sample Assay System	NDA: Active Neutron
71.	Calorimeter	NDA: Heat
72.	Infrared Detector	NDA: Heat
73.	On-Line Alpha Monitor	NDA: Passive Alpha
74.	Autoradiography	NDA: Passive Gamma
75.	Hand-Held Enrichment Monitor	NDA: Passive Gamma
76.	High-Resolution Gamma-Ray Spectrometer	NDA: Passive Gamma
77.	Leached-Hull Monitor	NDA: Passive Gamma
78.	NDA Reference Materials for Scrap and Waste	NDA: Passive Gamma
79.	Portable Microprocessor	NDA: Passive Gamma
80.	Rocky Flats Assay Meter	NDA: Passive Gamma
81.	Stabilized Assay Meter (SAM-II)	NDA: Passive Gamma
82.	Threshold Detector for Gamma Spectrometry	NDA: Passive Gamma
83.	Brookhaven Survey Assay Meter (BSAM)	NDA: Passive N&G
84.	Fuel-Drawer Scanner	NDA: Passive N&G
85.	In-Line Liquid-Phase Enrichment Monitor	NDA: Passive N&G
86.	Multi-Energy Gamma Assay System (MEGAS) II	NDA: Passive N&G
87.	Multichannel Analyzer (Portable)	NDA: Passive N&G
88.	Multichannel Analyzer (Stationary)	NDA: Passive N&G
89.	Spent-Fuel Multielement Detectors	NDA: Passive N&G
90.	Ultrasonic Gauge	NDA: Sound
91.	Channel Coincidence Counter	NDA: Passive Neutron
92.	Dual-Range Thermal-Neutron Coincidence Counter	NDA: Passive Neutron

93.	High-Level Neutron Coincidence Counter (HLNCC)	NDA: Passive Neutron
94.	In-Line Thermal-Neutron Coincidence Counter	NDA: Passive Neutron
95.	Large Omnidirectional Neutron Detection System	NDA: Passive Neutron
96.	Neutron Well Coincidence Counter	NDA: Passive Neutron
97.	Portable Neutron Coincidence Counter	NDA: Passive Neutron
98.	Reactor-Power Monitor (New)	NDA: Passive Neutron
99.	Reactor-Power Monitor (Old)	NDA: Passive Neutron
100.	Reactor-Power Track-Etch Monitor	NDA: Passive Neutron
101.	Shielded Neutron Assay Probe (SNAP)	NDA: Passive Neutron
102.	Spectral-Index Core Monitor	NDA: Passive Neutron
103.	Trap-Material Enrichment Meter	NDA: Passive Neutron
104.	Advanced Television Surveillance System (CCTV)	Optical Surveillance
105.	CANDU Closed-Circuit Television System	Optical Surveillance
106.	CANDU Film Camera System	Optical Surveillance
107.	Cerenkov Viewing (Night-Vision) Device	Optical Surveillance
108.	Computer-Controlled CCTV Alarm Assessment System	Optical Surveillance
109.	Deep-Drawn Container	Optical Surveillance
110.	Digital Timer (PI-200)	Optical Surveillance
111.	EURATOM TV System	Optical Surveillance
112.	Environment-Resistant CCTV Camera	Optical Surveillance
113.	Flight Research Camera	Optical Surveillance
114.	Fuel Verification Periscope	Optical Surveillance
115.	IAEA TV Transmission Security System	Optical Surveillance
116.	KFK Eumig Camera System	Optical Surveillance
117.	Kodak Analyst Camera	Optical Surveillance
118.	Minolta Surveillance Camera	Optical Surveillance
119.	NBS Surveillance Camera System	Optical Surveillance
120.	Polavision Cameras	Optical Surveillance
121.	Portable Television Surveillance System	Optical Surveillance
122.	Psychotronic Surveillance System	Optical Surveillance
123.	Robot Film Camera	Optical Surveillance
124.	Semi-Automatic Super-8 Movie-Film Scanner	Optical Surveillance
125.	Semi-Automatic TV-Tape Scanner	Optical Surveillance
126.	Spent-Fuel-Bundle (CANDU) Cerenkov Verifier	Optical Surveillance

127.	Television Surveillance System (NBS)	Optical Surveillance
128.	Television Surveillance System (SNL)	Optical Surveillance
129.	Zeiss Contarex Camera System	Optical Surveillance
130.	Gamma Walk-Through Doorway Monitor	Portal Monitor
131.	Personnel Doorway Monitor	Portal Monitor
132.	Portal Monitor (Booth-Type)	Portal Monitor
133.	Portal Monitor (Rotor-Type)	Portal Monitor
134.	Portal Neutron Monitor	Portal Monitor
135.	Portal Radiation Monitor	Portal Monitor
136.	Secure Counter Panel	Portal Monitor
137.	Unattended Personnel Portal Monitor	Portal Monitor
138.	Vehicle (Large) Portal Monitor	Portal Monitor
139.	Vehicle Gate (Sodium Iodide) Monitor	Portal Monitor
140.	Vehicle Gateside (Organic) Monitor	Portal Monitor
141.	Vehicle Portal Monitor (Liquid Scintillator)	Portal Monitor
142.	Vehicle Portal Monitor (Modular, He-3 Based)	Portal Monitor
143.	Vehicle Roadbed Monitor	Portal Monitor
144.	(Yes/No) Electronic Dosimeter	SNM Monitor
145.	(Yes/No) Radio-Luminescent Dosimeter	SNM Monitor
146.	Hand-Held Monitor	SNM Monitor
147.	Mechanical Cell Monitor	SNM Monitor
148.	Plutonium-Vault Neutron Monitoring System	SNM Monitor
149.	Radiation Monitor with High Alarm	SNM Monitor
150.	Shelf Monitor System	SNM Monitor
151.	Spent-Fuel Integrated Monitoring System	SNM Monitor
152.	Spent-Fuel Monitor (Scintillator)	SNM Monitor
153.	Thermoluminescent Dosimeter (TLD)	SNM Monitor
154.	Unattended Loading-Dock Monitor	SNM Monitor
155.	Unattended Material or Equipment Pass-Through	SNM Monitor
156.	Cup-and-Wire Seal (Improved Type E)	Seal
157.	Cup-and-Wire Seal (Type E)	Seal
158.	Fiber-Optic (Active) Seal	Seal
159.	Fiber-Optic (Digital) Seal	Seal
160.	Fiber-Optic (Passive) Seal (I)	Seal
161.	Fiber-Optic (Passive) Seal (II)	Seal
162.	Fuel-Assembly Ident. Device (BWR FAID Ultrasonic)	Seal
163.	Fuel-Assembly Ident. Device (MTR FAID Ultrasonic)	Seal

164.	Label (Adhesive) Seal	Seal
165.	Shrink-Tubing Seal for UF-6 Cylinder Valves	Seal
166.	Ultrasonic Cap Seal and Secure Rod	Seal
167.	Ultrasonic Cup-and-Wire Seal	Seal
168.	Light-Weight Air-Transport Accident-Resistant Container (LAARC)	Transportation
169.	Mobile Safeguards Van	Transportation
170.	Tight Shipping Container for Pu Oxide	Transportation
171.	Digital Pressure Transducer	Volume Meas.
172.	Pulsed Sonar Sounding Device	Volume Meas.
173.	Quartz Bourdon-Tube Electromanometer	Volume Meas.
174.	Time-Domain Reflectometer	Volume Meas.
175.	Turbine-Flowmeter Automated Tank Calibrator	Volume Meas.

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IV. IMPROVEMENTS

Since the contents of the Catalog are stored in a computer data base, it is straightforward to design other report styles, make immediate queries about the information in the data base, and keep the information current. Indeed, if additional equipment or additional information about equipment already included warrants, future editions of the Catalog will be issued. Readers can aid in this effort by continuing to contribute research reports, critical commentary, and new product or price data.

Note in addition that direct access to the computer data base by outside users is being considered.[3]

V. BACKGROUND

Original references for this work were letters sent to Guy Inman of the Department of Energy's Office of Safeguards and Security by Roddy B. Walton of Los Alamos National Laboratory, Ivan G. Waddoups of Sandia National Laboratories, and Martin S. Zucker of Brookhaven National Laboratory. With their remarks as leads, the information presented in the Catalog was obtained from available literature and from numerous conversations with technical staff members of U.S. Government and foreign national laboratories engaged in safeguards research and development, with contractor personnel, and with representatives of commercial organizations. Regarding literature, emphasis was placed on generally available sources, primarily proceedings of recent safeguards conferences. An attempt was made to provide an entree to the literature--not an exhaustive bibliography. Two very recent references that were especially valuable in the preparation of the Catalog are the Containment and Surveillance Compendium,[4] compiled by Frederick O. Luetters, and the book, The Detection of Fissionable Materials by Nondestructive Means,[5] by Rudolph Sher and Samuel Untermyer II. Both contain valuable conceptual remarks regarding safeguards equipment that go beyond the brief descriptions found in the Catalog. Another book with great detail on the physics of active NDA instrumentation is Active Nondestructive Assay of Nuclear Materials,[6] by Tsahi Gozani. An even more general reference, soon to be published, is the Handbook of Nuclear Safeguards Measurement Methods.[7]

Those individuals who have contributed to our work are too numerous to mention here; they are noted in the Catalog. We do, however, wish to thank particularly William A. Higinbotham of Brookhaven National Laboratory, who read and criticized drafts of the manuscript very carefully. Also of great value were Dave Kirby of Brookhaven, who programmed the computer data base and report procedures, and Bonnie Biittner of Brookhaven, who typed all of the information into the data base.

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2. International Safeguards Project Office, Program for Technical Assistance to IAEA Safeguards, Brookhaven National Laboratory, Upton, N.Y. (May, 1980); see especially p. 19.

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APPLICATION OF COMPUTER GRAPHICS TO NUCLEAR SAFEGUARDS AND SECURITY ANALYSIS

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The interpretation of large amounts of data is often difficult on a timely basis. Many times trends in the data are the most significant characteristics of their behavior. This analysis problem is often present in nuclear safeguards and security systems. With the widespread use of computers in these systems the power to generate almost instantly large volumes of data has become possible. This data has the potential to give an accurate characterization of a system but it also can immerse the user in so much data that the effectiveness of the calculation and subsequent analysis is greatly decreased. The problem now arises of how to interpret quickly the almost infinite amount of data available from computer systems. Computer graphics has proven to be a very useful tool in this endeavor.

Computer graphics capabilities are readily available at such places as national laboratories, but the full power of an on-line system is often not as easily attained by the more business-application-oriented user. Recently, several devices have become available that allow for on-line graphics to be done easily and inexpensively on more generally available computer systems. These devices have been employed for consideration of some nuclear safeguards and security problems. These devices provide on-line main-frame operation with such features as drawing preview on a high resolution graphics storage tube and hard copy by means of either a screen printer or a plotter if color is desired.

The basic design of the system provides an interactive two screen work station, in which a standard computer terminal is used for alpha-numeric interaction with the host system, and a high resolution graphics monitor is used to display graphics images prior to final output to a color plotting device. In order to facilitate the construction of graphs quickly, accurately, and as easily as possible, a multi-tiered computer graphics system has been developed from the basic graphics device.

It was evident early in the design, development, and subsequent programming process of the graphics system that a wide variety of users with varying backgrounds would be using the system for varied purposes. Flexibility was a major goal in this design work. Non-computer-oriented users should be able to train themselves quickly in the use of the graphics system with minimal outside intervention required. In order to use the system the operator needs only to type in one key word and the desired file name.

A major problem that is often encountered in computer graphics applications is how to keep track of and input the necessary data. The present system allows for graphics data to be retrieved from any accessible computer data file or member that is in the correct format. This greatly reduces the complexity of data interfaces since all data that is stored on the computer is readily available. To initiate the system, the user simply types in the name of the data file after a single graphics key word. The system then automatically accesses the designated file by means of programs associated with the basic graphics system.

Due to the wide variety of user backgrounds, it was necessary to design the graphics system such that it would allow any level user to operate it. In addition, a provision should be made to educate and more importantly encourage and not penalize the development of expertise in the use of the available functions.

In order to accomplish this, a family of related programs, each operated by a different key word, was developed. These programs cover a range in the degree of operator expertise required, from the first time user to a high production experienced user. The user is readily able to use more or less sophisticated techniques by simply typing in the next command in the hierarchy of commands available. As experience in graphics is acquired, the user may no longer wish to have as much detailed guidance and can shift if desired to a more direct and faster operating level.

By the use of computer graphics it has been possible to enhance the analysis of safeguards and security in several initial applications. It has been possible to quickly display graphically such data as isotopic composition of fuel as a function of burnup and thereby eliminate much of the confusion associated with handling large computer outputs.

Isotopic data of this type is routinely calculated on large computers during the operation of a reactor, and often requires a large amount of editing for quick interpretation of the significance of the data to be possible. The present graphics system allows access to main data files and hence provides a method to put this data in a format such that it is quickly usable for various purposes. An example of this usage can be seen in Figure 1.

In addition to aiding in the analysis of technical data, graphics has proven to be very helpful in considering economic alternatives. Figure 2 is a hypothetical example in which the cost of expanding a guard force is considered in terms of its effectiveness. In this example the effectiveness of three different guard force allocation schemes are considered as a function of the number of guards available. In order to make an optimum decision, the trends of each allocation scheme must be understood. Graphics allows for a quick understanding of these trends and the present system allows access to records that are contained on the corporate computer data files in addition to large scale computing power. Various other considerations such as yearly expenditures and comparisons quickly lend themselves to this type of analysis.

In order to consider the impact of possible modifications to security systems, a monte carlo type intrusion analysis system has been developed. In this system a physical structure is digitized on an cartesian coordinate grid. Possible physical intrusion or diversion paths are then simulated on a random basis. This technique has proven to give a quick scoping analysis of a proposed change and thereby has reduced the amount of detailed fault tree analysis that need be done.

A basic problem associated with this type of analysis is the generation of random numbers. In an attempt to provide a non-repeatable random number generator, a multichannel analyzer has been interfaced to the computer. This provides randomly occurring numbers in a range and frequency dependent on the particular isotope being counted. Should wide variations in numbers be desired, an isotope with a broad peak could be chosen, or more simply the physical configuration of the detector system could be changed. Similarly, if a narrow variation is desired, a narrow peak can be chosen. A variety of equipment and calculational combinations have been tried and have produced usable results.

Since the present computer graphics system is operated in an on-line mode, it is possible to trace the previously described intrusion or diversion path calculation directly as it is happening. This greatly reduces the need to analyze large amounts of data, the significance of which are not readily obvious.

As a result of the use of the on-line computer graphics system described previously, it has been possible to greatly reduce many tedious plotting tasks. The ease with which the system operated has allowed the use of graphical analysis on a much expanded scale and has thereby allowed different analysis methods to be applied to various topics that had previously not been considered.

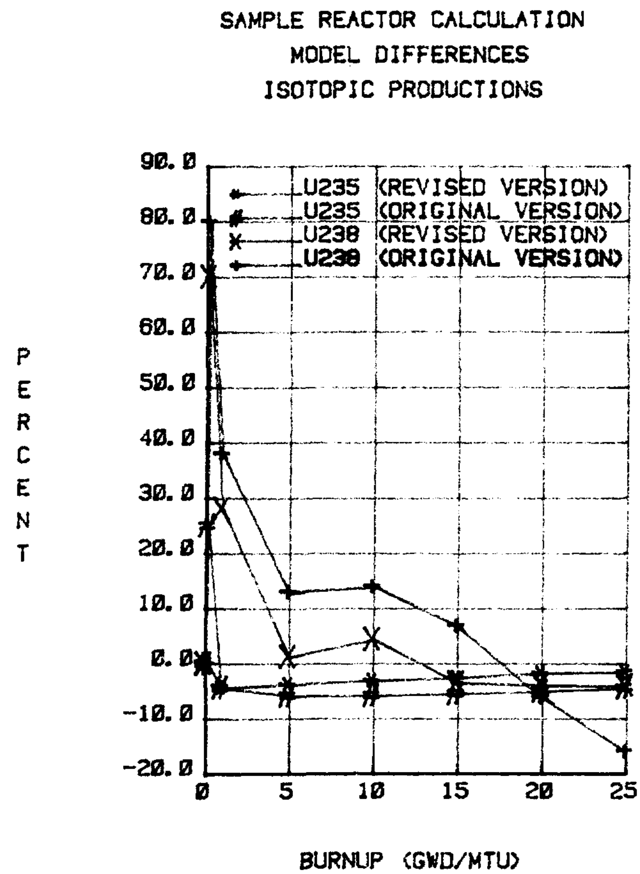

Figure 1

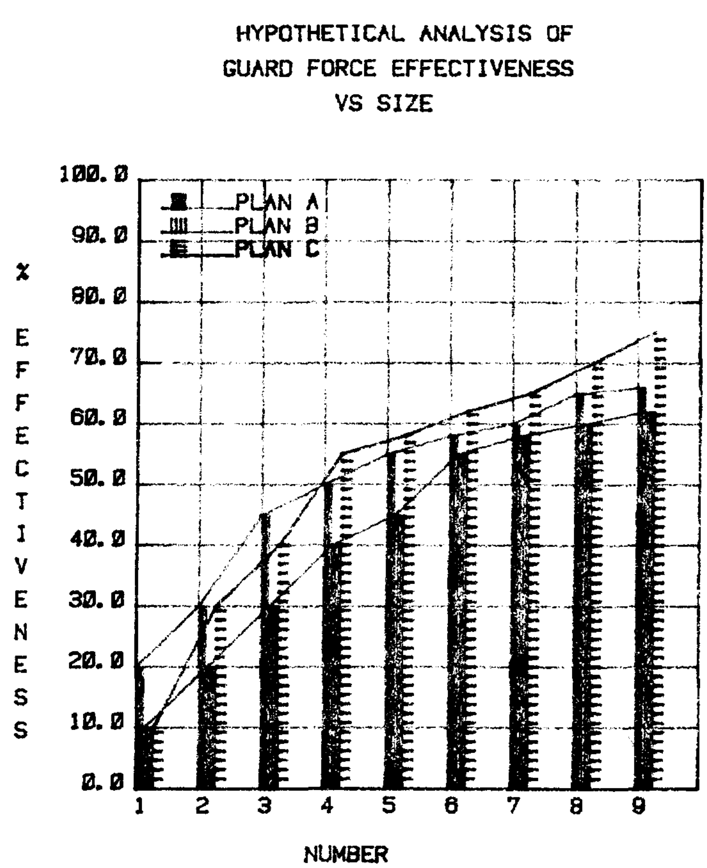

Figure 2

RESIN BEAD MASS SPECTROMETRY AS A SAFEGUARDS VERIFICATION TECHNIQUE*

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ABSTRACT

The resin bead technique for isolation of uranium and plutonium from highly radioactive solutions and subsequent mass spectrometric analysis has been successfully tested in a field experiment. Agreement between this technique and older mass spectrometric methods is excellent. We thus propose a protocol for implementation of the resin bead method as an International Atomic Energy Agency procedure for assay of spent fuel dissolver solutions. The advantages and limitations of the procedure are discussed and compared to the dry spike technique now in use.

INTRODUCTION

Using resin beads as a vehicle for loading samples for mass spectrometric analysis was first suggested by Freeman et al.[1] Work done at the U. S. National Bureau of Standards (NBS)[2,3] and the Oak Ridge National Laboratory (ORNL)[4-8] proved that it was suitable for measuring extremely small samples of uranium and plutonium (1-3 ng) from solutions typically encountered in the nuclear fuel cycle. The instruments required to analyze such samples have been described previously.[9-11] This capability has been of interest to the Safeguards community since it was first demonstrated.[4] The International Atomic Energy Agency (IAEA) has been involved in the development of this technique for use as a safeguards tool for acquiring samples at fuel reprocessing facilities in several member states.

Under appropriate conditions of acid and uranium strength, resin beads will selectively adsorb uraniuim and plutonium from solutions containing other actinides and fission products.[12] With 1 μg of uranium per bead in 8 $\underline{M}$ HNO_3 solution, about one ng of uranium will be adsorbed by each bead. For example, if 1000 beads are to be loaded, a solution containing about 1 mg of uranium would be exposed to them. Plutonium is present at about one percent of the level of uranium in typical spent fuels; because plutonium is more strongly adsorbed, the amounts of the two elements on a single bead are roughly equal.

Each bead serves as a sample for mass spectrometric analysis. Advantages beyond ease of handling accrue from using beads as a vehicle for sample introduction. The bead serves as a point source of ions, thus tending to optimize ion optical conditions; it serves as a reducing medium, virtually eliminating loss of sample as oxide species, and it seems to serve as a sample reservoir, feeding sample to the ionization region in a relatively controlled manner.[13] Plutonium and uranium are analyzed sequentially from the same bead.

This report summarizes the results of field tests completed to date and presents a proposal for the implementation of this technique as a routine IAEA safeguards procedure.

RESULTS OF FIELD EXPERIMENTS

The first major test of this resin bead technique in the field resulted from the cooperation of the IAEA with the International Safeguards Project Office of the USA and with the Federal Republic of Germany. A field test was designed and carried out at the Gesellschaft fur Wiederaufarbeitung von Kernbrennstoffen at Karlsruhe.[14] Three spent fuel solutions were sampled, and each was divided into three subsamples. Following chemical treatment to achieve isotopic equilibration between the samples and enriched spike material, resin beads were prepared at the sampling site (Field Resin Beads) and shipped to the Safeguards Analytical Laboratory (SAL) of the IAEA and to ORNL. Aliquots of the spiked and unspiked samples containing about 100 ng plutonium were also dried and shipped to SAL and ORNL for use in preparing resin beads under laboratory conditions (Laboratory Resin Beads). Finally, the rest of the samples, each containing about 10 μg of plutonium, were also dried and sent to SAL where they were measured with a conventional surface ionization mass spectrometer.

The results of this first exercise were as follows:[14]

a) Good agreement was observed on the

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plutonium concentrations measured form laboratory prepared beads and the conventional technique;

b) However, the measurements of plutonium concentrations from field-prepared beads were scattered;

c) Uranium concentration measurements were in good agreement for all three spent fuel solutions;

d) Both plutonium and uranium isotopic measurements of the unspiked samples were in good agreement and within the limits of instrumental error.

Complete chemical equilibration between sample and spike isotopes is just as essential with the resin bead technique as in conventional isotope dilution analysis. The conclusion from this first exercise was that the hydroxylamine/nitric acid treatment used for valence adjustment of plutonium in the field had failed, while the perchloric acid fuming used in the laboratory succeeded.

A second resin bead field exercise was carried out under the Tokai Advanced Safeguards Technology Exercise (TASTEX) program, subtask J.[15] This took place at the Power Reactor and Nuclear Fuel Development Corporation (PNC) reprocessing plant in Tokai-mura, Japan, using PNC operators trained at ORNL in the proper handling of resin beads. Here, five spent fuel input solutions were used, with field resin beads being prepared by PNC for analysis at SAL and ORNL; dried residues for preparation of laboratory resin beads at both SAL and ORNL were also prepared. The preparation at PNC included spiking and Fe(II)/nitrite valence adjustment; this procedure has been found to be >99% effective and is now the preferred technique for fresh solutions.[16]

The results of the original TASTEX-J exercise indicated that the problem of chemical equilibration observed at WAK was not a significant factor. Instead, discrepancies were noted in the uranium concentration measurements which were ascribed to contamination of the samples. Since resin beads contain only nanogram amounts of uranium and plutonium, it is necessary to provide clean facilities for their handling. This is obviously difficult for an operation such as a reprocessing facility where kilogram quantities of material are routinely processed. As before, the isotopic measurements of the unspiked samples showed acceptable agreement.

The most recent test of the resin bead method has taken place as a follow-up to the TASTEX-J experiment. A new bead handling procedure was developed at ORNL[17] and further training of PNC personnel carried out. This new "bulk" technique was designed to reduce the risk of contamination by handling 100 times more sample and a much larger number of resin beads (1000 beads vs. 10). A single spent fuel solution was sampled and five subsamples prepared. Each of these was spiked and subjected to the operator's normal chemical equilibration procedure before bead preparation. Beads were distributed to SAL and ORNL along with dried residues for conventional mass spectrometric analysis at SAL. Parallel measurements were made at PNC using their normal measurement scheme.

The results of all resin bead measurements and those of PNC have been compared, with excellent agreement being achieved.[15] The coefficients of variation of the laboratory means were 0.33% for uranium (Table 1) and 0.47% for plutonium (Table 2). Table 3 analyzes the results for sources of systematic error; no significant sources were identified. All isotopic measurements of the spike and unspiked sample were in good agreement (Table 4).

This experiment was the culmination of years of experience with the resin bead technique under actual field conditions. It proved that the resin bead technique meets the accuracies required for the verification of the accountancy of spent fuel dissolver solutions.[18]

Implementing the Technique

One of the principal advantages of the resin bead sampling method is that, due to the small amounts of material involved, it allows shipment of a number of samples (up to 10) as exempted quantities under the regulations of the IAEA[19] and International Air Transport Association (IATA).[20] Since fission products and other actinides (e.g., Am, Cm) are not adsorbed on the beads, the only restriction on their transport results from the amount of plutonium present. Assuming that each resin bead contains less than 1 ng of plutonium having an isotopic composition typical of power reactors (See Table 5), it would hold about 1×10^{-10} Ci of plutonium. The exemption limit set by the IAEA is 2×10^{-6} Ci, thus allowing about 8900 resin beads to be sent as exempted quantities. A tenth of these quantities, i.e., 2×10^{-7} Ci or 890 beads, may be air mailed and still be in compliance with the regulations of the Universal Postal Union[21] and in agreement with the IAEA recommendations.[19]

Air-mailing resin bead samples of dissolver solutions offers at present the only real chance of receiving these samples at the verification laboratory within a week of sampling. Typical delays between sampling and receipt of samples at SAL are now 1-2 months.

The spent fuel samples from PNC are now shipped in Type A containers. Each container carries one unspiked and one spiked sample of the same dissolver solution. The shipment of a single container costs approximately US $140.

Samples from WAK in the Federal Republic of Germany are handled by a private company and shipped in Type B containers for a charge of approximately US $500 per container.

In contrast, the resin bead samples of one to ten batches of dissolver solutions may be conveniently mailed in a single and conventional postal package as "registered air mail letter" for an approximate cost of US $10 per package.

Resin beads make excellent and convenient samples for mass spectrometry. A single resin bead may be mounted in the instrument, without any additional pretreatment, and provides a complete isotopic analysis of both uranium and plutonium. The simpler handling of the samples should save some 20% of the manpower cost for the measurements at the verification laboratory.

Because of the small amount of time involved, SAL, if requested, may report within 24 hours the analyses of a spent fuel sample received in the form of resin beads, provided the samples of only one dissolver batch are received at a time.

Six essential steps of the verification procedure must be performed at the plant by the operator personnel if the resin bead technique is to be used:

a) sampling
b) dilution
c) subsampling
d) spiking
e) chemical equilibration
f) loading of the beads

The inspection procedure now in use requires the same first four steps to be done at the plant, so equilibration of sample and spike and loading it on beads are the only additional operations necessary. Thus, more assistance is needed from the operator to implement the resin bead technique than has previously been necessary. This means a priori a higher risk of tampering with the samples and also a greater dependence on the plant operator for correct sample treatment.

However, the dry spike procedure now in use is a lengthy one: the fuming and evaporation of the samples require at least six hours. Thus, although the preparation of the resin beads involves more steps, it requires less time than the present procedure. It is of fundamental importance that operations carried out by the operator for IAEA samples be observed by IAEA personnel. Because of the reduced time involved, the resin bead method is more practical in this respect than the older technique.

The two problem areas exposed in the first two field experiments, valence adjustment of plutonium and contamination of uranium, have been brought under control. The last TASTEX-J exercise proves that the risks of contaminating resin bead samples have been mastered. There is certainly no reason to anticipate more problems with the scaled-up "bulk" procedure tested during this exercise than in the preparation of the conventional samples: both procedures involve the handling of similar amounts of sample, 1 mg of uranium and 10 μg of plutonium. In the two TASTEX-J tests, chemical equilibration with the Fe(II)/nitrite valence cycle was never a problem. A recent study at Los Alamos confirms that this treatment is the best one found to date.[16]

In any case, an independent verification procedure must guard against risks of this kind; retaining archive samples and submitting appropriate control samples will provide these assurances. Storage of such archival samples on resin beads is a simple matter. One hundred or more beads may be sealed to a glass microscope slide with collodion (to prevent oxidation) and stored for long periods. Beads stored for more than two years have been successfully analyzed at ORNL.

Although the quality of resin bead measurements is sufficient for the present needs of safeguards, the precision and accuracy under routine conditions remains at present 3 to 5 times poorer than what is possible with conventional mass spectrometry under ideal conditions. We note, however, that the day-to-day performance using the conventional procedure is not as good as what is achieved under ideal conditions and is typically no better than the performance of the resin bead samples under TASTEX-J.

Furthermore, ORNL and NBS have demonstrated that, under ideal conditions, resin bead measurements can be performed with precisions and accuracies of 0.1 to 0.2%. ORNL is also evaluating for the Agency under the ISPO program several improvements in instrumentation and methodology whose goals are to ensure precisions and accuracies of 0.2% or better in routine measurements.[22] These measurements are aided by the fact that the bead is close to an ideal sample for the mass spectrometer.

ORNL and NBS are presently preparing and certifying resin beads loaded with isotopic standards for IAEA. Use of such reference materials will strengthen the accuracy of resin bead measurements by serving calibration and quality assurance functions.

CONCLUSIONS AND RECOMMENDATIONS

The last TASTEX sampling experiment conclusively demonstrates the applicability of the resin bead technique to international safeguards as sample acquisition, shipping, and as mass spectrometric sample-loading devices. Since this technique represents the only practical means of obtaining timely results from spent fuel solutions and other highly radioactive sources we recommend its incorporation into routine safeguards operations.

Figure 1 shows a proposed scheme for implementation of the resin bead technique. After aliquots are taken for the operator's mass spectrometry measurements, resin beads would be loaded using the "bulk" method[17] and the resin beads divided for shipment to SAL. Most of the resin beads could be stored at the facility for archival purposes. In addition, the mixed spike used by the operator would be loaded on resin beads for shipment to SAL. Two control samples, one concentrated to simulate a spent fuel input solution, and one representing a diluted dissolver solution, would be treated identically with the inspection samples, with measurements performed at SAL. These would provide checks on contamination and generally serve quality assurance purposes.

We recommend that initially this procedure be tested in parallel with the present inspection procedure. Aliquots of the diluted dissolver solution would be mixed with the dried IAEA spikes and sent to SAL as dried material. The operator would then carry out his normal liquid spiking and chemical equilibration procedure, followed by resin bead sample preparation and shipment to SAL. This parallel inspection procedure should be applied to enough batches in the same reprocessing campaign to provide the basis for a reliable statistical analysis. If no problems are identified with the resin bead procedure, it would be adopted to replace the present procedure.

SUMMARY

The results of the TASTEX-J experiments have shown that the resin bead technique is capable of acceptable analytical precision and accuracy. The "bulk" method of resin bead preparation has proven to be simple and free of contamination problems. Use of the operator's normal spiking and chemical treatment at PNC has resulted in no problems due to incomplete isotopic equilibration. Shipment of resin beads from Japan to SAL and ORNL has been successfully completed. Therefore it is proposed that an inspection procedure be implemented using the resin bead technique, first in parallel with the established method, then by itself. With this development, safeguards measurements can be made with less delay and expense and with no sacrifice of analytical precision and accuracy.

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Table 1. Statistical evaluation of the isotope dilution analysis of uranium in spent fuel solution

Uranium Concentration - g/l

Sample	SAL-RB	ORNL-RB	PNC	SAL-DRIED
1	164.24	163.69	164.88	164.68
2	163.77	164.08	164.89	164.48
3	165.38	163.97	164.74	165.15
4	165.35	163.68	164.46	165.29
5	164.68	164.33	164.53	164.57
Mean	164.68	163.95	164.70	164.83
SD	0.70	0.27	0.20	0.36

Total Mean	164.54		
Total SD	0.53	(0.32%)	DF = 19
Within Lab SDI	0.43	(0.26%)	DF = 16
Between Lab SDH	0.35	(0.21%)	DF = 3

Table 2. Statistical evaluation of the isotope dilution analysis of plutonium in spent fuel solution

Plutonium Concentration - g/l
(corrected to PNC date of measurement)

Sample	SAL-RB	ORNL-RB	PNC	SAL-DRIED
1	1.497	1.490	1.509	1.491
2	1.506	1.498	1.505	1.484
3	1.495	1.495	1.505	1.501
4	1.495	1.488	1.509	1.493
5	1.496	1.491	1.506	1.491
Mean	1.498	1.492	1.507	1.492
SD	0.0047	0.0040	0.0020	0.0061

Total Mean	1.497		
Total SD	0.0074	(0.49%)	DF = 19
Within Lab SDI	0.0044	(0.29%)	DF = 16
Between Lab SDH	0.0066	(0.44%)	DF = 3

Table 3. Sources of systematic errors in isotope dilution analyses

U concentration

Laboratory Technique	Mixture 233/238	Sample 233/238	Spike 233/238	Sample Atom.fraction U	Concentration
PNC	1.10492	0	339.02	0.9851	164.70
SAL Beads	1.10509	0	350.77	0.9850	164.68
ORNL Beads	1.10992	0	350.12	0.9851	163.95
SAL-DRIED	1.10404	0	350.77	0.9852	164.83
Effective difference introduced into concentration calculation					
PNC-SAL Beads	0.01	-	0.01	0.01	0.01
PNC-ORNL Beads	0.45	-	0.01	0.01	0.45
PNC-SAL-DRIED	0.08	-	0.01	0.01	-0.08

Pu concentration

Laboratory Technique	Mixture 242/239	Sample 242/239	Spike 242/239	Sample Atom.fraction Pu	Concentration
PNC	1.14985	0.06937	27.728	0.6032	1.507
SAL Beads	1.15166	0.06945	26.919	0.6034	1.498
ORNL Beads	1.15515	0.06950	27.243	0.6037	1.492
SAL-DRIED	1.15284	0.06889	26.919	0.6044	1.492
Effective difference introduced into concentration calculation					
PNC-SAL Beads	0.16	0.01	0.0013	0.03	0.60
PNC-ORNL Beads	0.46	0.01	0.0008	0.10	1.0
PNC-SAL-DRIED	0.26	0.06	0.0013	0.29	1.0

Table 4. Results of the isotopic analyses of spent fuel solutions

Uranium Isotopic Composition in wt.%

Laboratory Technique	234	235	236	238
PNC	0.0191	1.0942	0.3746	98.512
SAL-DRIED	0.0211	1.0876	0.3718	98.519
SAL Beads	0.0206	1.0905	0.3699	98.519
ORNL Beads	0.0201	1.0965	0.3722	98.511

Plutonium Isotopic Composition in wt.%

Laboratory Technique	238	239	240	241	242
PNC	1.458	60.178	22.623	11.515	4.227
SAL-DRIED*	1.369	60.301	22.642	11.483	4.206
SAL Beads*	1.375	60.171	22.599	11.624	4.231
ORNL Beads*	1.366	60.232	22.635	11.529	4.239

*Valid for operator's date of measurement (80-10-10)

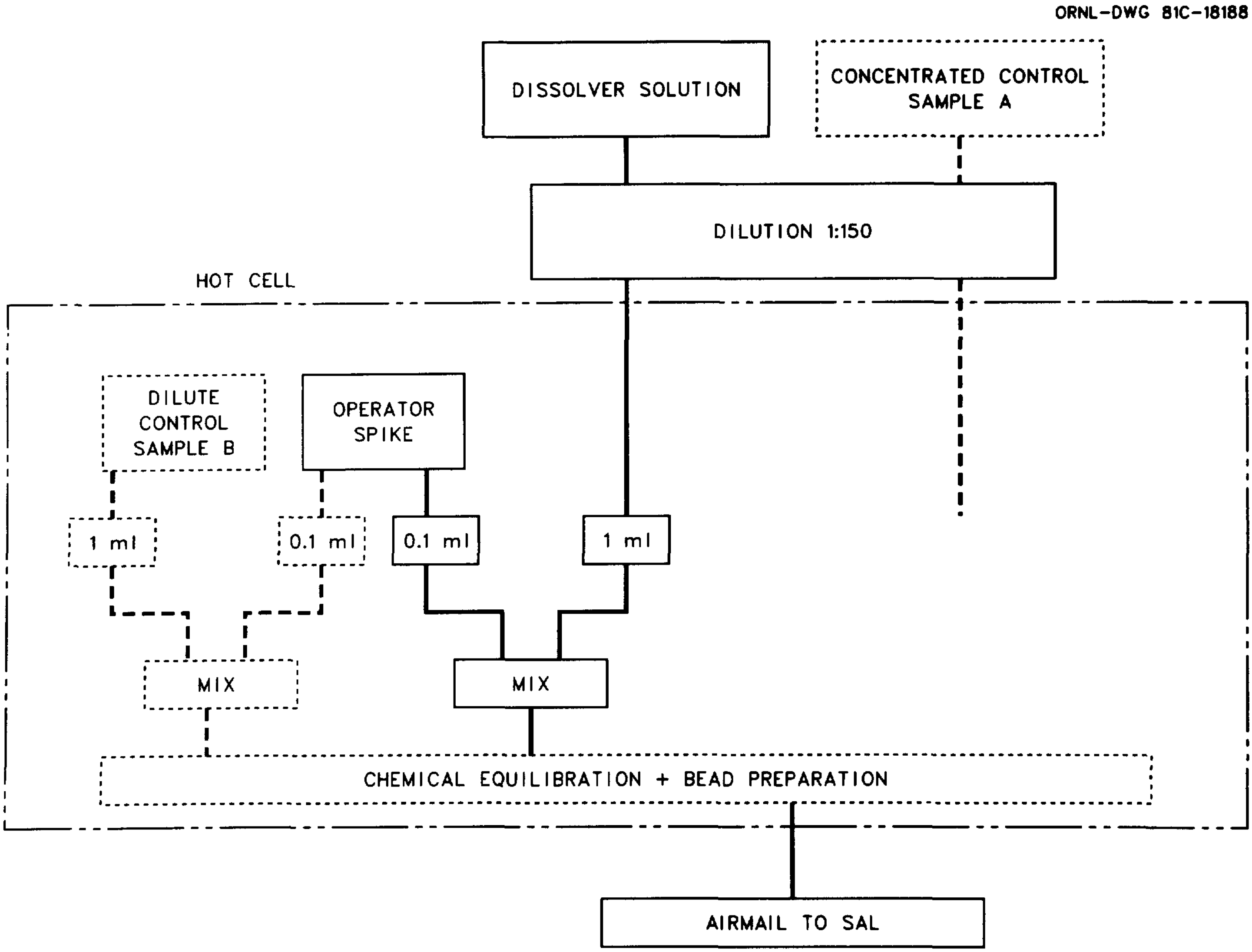

Figure 1 - Proposed plan for implementation of the resin bead sampling technique in Safeguards.

A SYSTEM FOR MONITORING MOVEMENT OF SPENT FUEL

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ABSTRACT

A prototype containment and surveillance system for monitoring the movement of spent fuel has been developed by Sandia National Laboratories. It offers the possibility of reducing the cost of effective international safeguards of spent nuclear reactor fuel. System tests conducted at an existing nuclear power generating station, on a fuel shipping vehicle, and at a spent fuel storage facility demonstrate the feasibility of this monitoring system. The system operates unattended for extended periods, incorporates self-checking and tamper-detection devices, continuously records all spent fuel movements, and assists in the independent verification of the item inventory. During a two-year feasibility demonstration, the containment and surveillance system monitored all fuel shipments without a false alarm. Based on the results of the demonstration tests an advanced version of the prototype system is being developed for International Atomic Energy Agency evaluation at an operating facility.

INTRODUCTION

Spent nuclear reactor fuel contains fissile plutonium and is a potential target for diversion by nonweapons states that operate power reactors. Independent verification of the status of spent fuel is required. The current U.S. inventory of spent nuclear reactor fuel exceeds 6,000 MTU and is projected to exceed 64,000 MTU in 1995.[1] The world-wide inventory is predicted to exceed 150,000 MTU by the year 2000.[2] Implementation of reprocessing will not significantly reduce these quantities of stored spent fuel. Safeguarding the spent fuel is particularly difficult because the material is stored in numerous locations around the world and a large percentage of the inspection manpower of the International Atomic Energy Agency (IAEA) is currently devoted to safeguarding spent fuel.

Sandia National Laboratories, under the sponsorship of the Department of Energy/Office of Safeguards and Security, is tasked to investigate the feasibility of utilizing advanced containment and surveillance equipment to provide reasonable safeguards while minimizing the cost to both the IAEA and the safeguarded facility. As part of this task Sandia has designed, developed, and tested essential components of a prototype containment and surveillance (C/S) system to monitor spent fuel movements. The components of the prototype system include sensors, tamper detectors, tamper resistant data communication links, a data collection module and data display capability. The design incorporated both fixed site and transportation monitoring elements and these are described below.

FIXED-SITE SYSTEM DESCRIPTION

The IAEA applies safeguards for the purpose of verifying that nuclear material is not diverted from peaceful nuclear activities to the production of nuclear weapons. These safeguards utilize both materials accounting and C/S techniques.

The Sandia Laboratories C/S equipment allows the IAEA to monitor the facilities continuously without requiring the presence of a full-time inspector at each facility. The equipment records all fuel transfers into or out of the facility between inspector visits. This information allows the IAEA to verify the integrity of the state-supplied material accounting data. Surveillance is applied in a manner that assures potential diversion is not concealed by improper procedures or by falsification of material accounting data.

The fixed site system utilizes existing physical features of the facility as containment boundaries. Surveillance techniques are applied to all passageways penetrating the containment boundary that are large enough to permit the transit of spent fuel. By continuously monitoring these passageways the system detects all spent fuel movements into and out of the facility and thus maintains continuity of knowledge of the spent fuel location and movement.

During normal facility operations, the spent fuel is moved into or out of the facility in a shipping cask. An overhead crane transports each cask through passageways in the containment boundary. A surveillance zone is established at each passageway that permits transit of a shipping cask. When the cask moves through the surveillance zone, a crane monitor detects the movement and direction of travel. Concurrently, radiation sensors detect spent fuel in the shipping cask. The system uses this information to distinguish spent fuel movements from other activities and stores essential movement information for later retrieval by an IAEA Inspector.

The data collection module (DCM) is the heart of the C/S system. Its primary purpose is to identify and record fuel movements. The DCM identifies fuel movements by processing the radiation and crane sensor data with a fuel movement identification algorithm. The algorithm is based on fuel movement characteristics which allow the system to distinguish fuel movements from other activities such as the movement of an empty cask. The DCM determines when a fuel movement occurs, whether the fuel entered or departed the facility, and when necessary, triggers an assessment camera. When a fuel movement is identified, the DCM records the date, the time, and the direction of travel for later retrieval. The system verifies all authorized movements and detects any unauthorized fuel movements.

The DCM also monitors the operational status and tamper detectors of each system element once every second. The system stores all component failures and tamper information. The fuel movement, operational status, and tamper information are retrieved by the IAEA inspector during normal visits to the facility.

The sensors are located in tamper indicating sensor modules (TISMs). These modules provide each sensor with tamper detection capability and the electronics required to interface with the DCM. The TISMs are similar in that they all contain identical tamper-sensing devices, power supplies, microprocessors, command and control electronics, fiber optics and communications interfaces. Typical tamper detection elements include magnetic switches, microswitches, vibration switches, strain gauge and infrared detectors. Each TISM is powered by the data collection module.

The TISM microprocessor accumulates and stores sensor data, tamper status, and operational status. It also performs data formatting, and depending on sensor type, data processing functions. The DCM polls the tamper status of each TISM every second and receives updated sensor data every 15 seconds.

Each radiation detector (Figure 1) consists of radiation sensors and support electronics packages inside a TISM. The sensors continuously monitor the surveillance zone for spent fuel gamma rays that penetrate the shipping cask. The initial TISM sensors measured gamma ray intensity only. However, other radiation detectors are being adapted to the system. Shielding provides the radiation detectors with directional capability while reducing the background radiation signal.

The crane detector monitors movement of the overhead crane. Data acquisition is simplified by mounting the sensors on the rails rather than on the moving crane. The detector consists of eight strain gauges mounted on the rails (Figure 2) and configured in two bridge circuits, and support electronics packaged inside a TISM. Mounting the gauges on the rails places them outside the TISM tamper detection elements. In order to deter tampering, detection circuitry was developed and incorporated into the electronics of each bridge circuit. Normal operational and environmental constraints required the development of sensitive temperature compensation electronics and low drift, high, gain amplifiers.

Prototypes of the C/S system were installed at an operating commercial nuclear power generating station and at a spent fuel handling facility for demonstration tests. The equipment at each facility consisted of two radiation sensor modules, one crane sensor module, an optical assessment subsystem, and a data collection module. The crane and radiation detectors were installed where the shipping cask passes through the facility containment boundary. Thus, movement of spent fuel either into or out of the facility requires the shipping cask to pass through the C/S sensor field. And hence, all normal cask movements are detected by the C/S system.

Data links installed between Sandia and each facility simplified data retrieval by allowing regular interrogation of each system from the Albuquerque control center. All data collected by the system is transmitted over the links. The links also permit triggering the assessment cameras of each facility upon command from the control center.

The C/S equipment has operated successfully in the facility environments since the spring of 1979. The system has collected and processed sensor data regularly at each facility since initial installation. During this entire period the C/S equipment monitored each facility without the aid of onsite operations personnel.

Since the spring of 1979 there have been sixteen spent fuel transfers between the two facilities. The C/S information collected by the radiation detectors, crane monitors, and assessment equipment permitted identification of each movement of a cask containing spent fuel either into or out of the facilities. Crane movements are regular occurrences at the facilities and the C/S system correctly identified them as non-fuel movement events. During the extended periods of time between spent fuel transfers, the C/S equipment operated with high reliability and without generating a single false alarm.

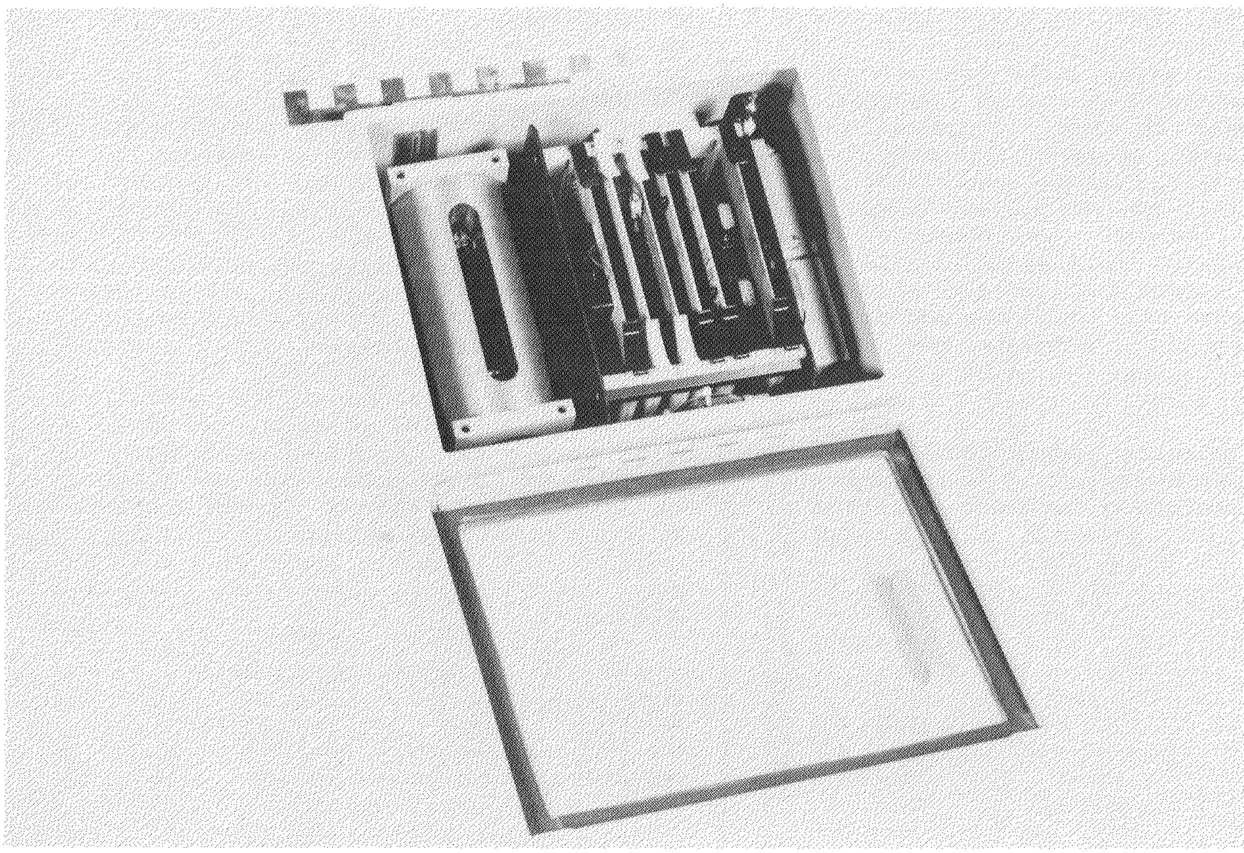
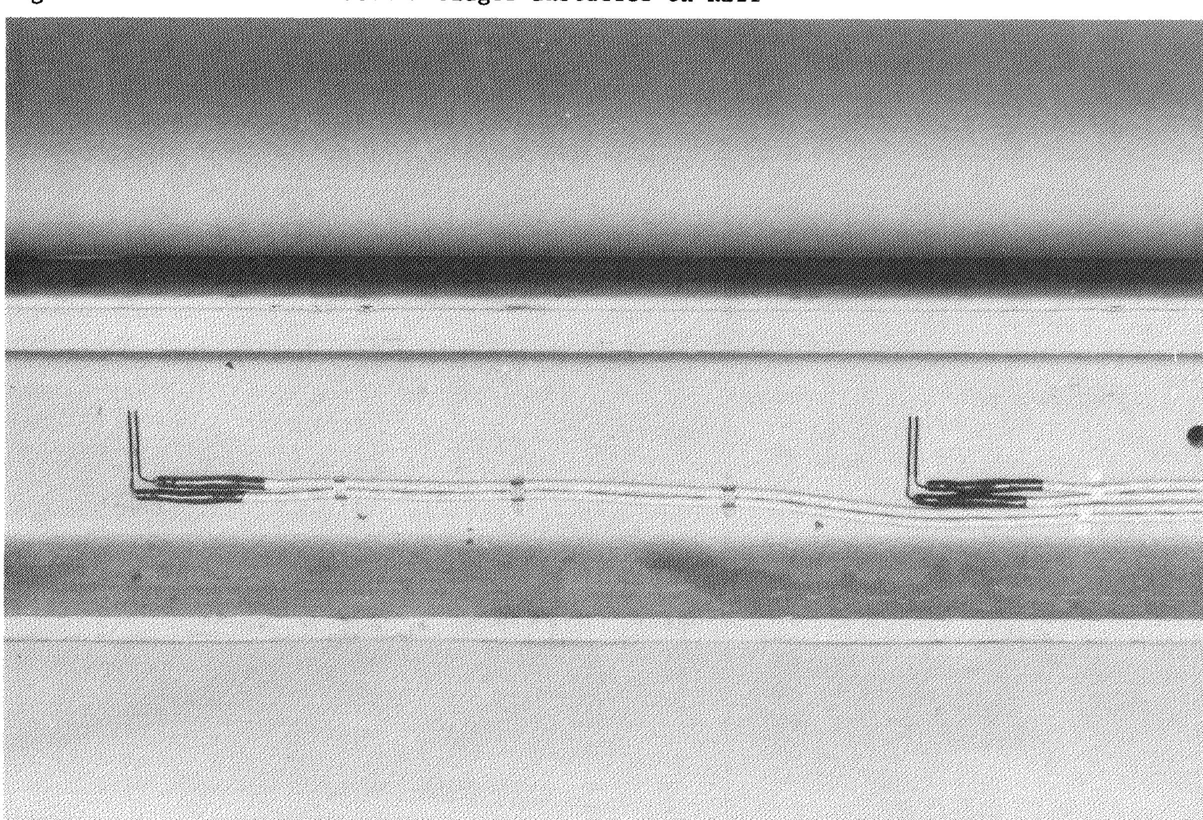


Figure 1. Radiation Sensor Mounted in TISM

Figure 2. Crane Monitor Strain Gauges Installed on Rail



TRANSPORTATION MONITORING DESCRIPTION

Diversion of spent fuel during transportation between handling facilities is of potential safeguards interest in some scenarios. One possible scenario includes stopping the vehicle during the journey, removing spent fuel assemblies from the cask, and replacing them with counterfeit assemblies having radiation characteristics similar to spent fuel. Transportation monitoring equipment can provide the IAEA with a means of verifying that the spent fuel was not diverted during transportation. Separate equipment could also be used for domestic safeguards applications.

Portions of the containment and surveillance equipment were adapted to monitor removal of the cask from the trailer or removal of the spent fuel from the cask during shipments. The monitoring equipment consisted of a modified data collection module, radiation sensors, load sensors, tamper detection instruments, battery power supply, radio transmitter, radio receiver and antenna. This equipment was mounted on a spent fuel shipping trailer (Figure 3) and operated unattended while traveling betwen facilities. Sensor data, tamper information, battery condition and system status were transmitted to the control center evey fifteen minutes using the DOE/SECOM radio communication system. However, tamper alarms or emergency conditions were programmed for immediate transmisson.

The shipment monitoring equipment was tested on a shipping trailer during ten fuel shipments. These tests demonstrated the feasibility of continuous monitoring during transportation of spent fuel. The equipment reported a cask containing spent fuel during the trips to the storage facility and an empty case during the return trips. The Albuquerque control center maintained radio contact regularly during the cross-country trips.

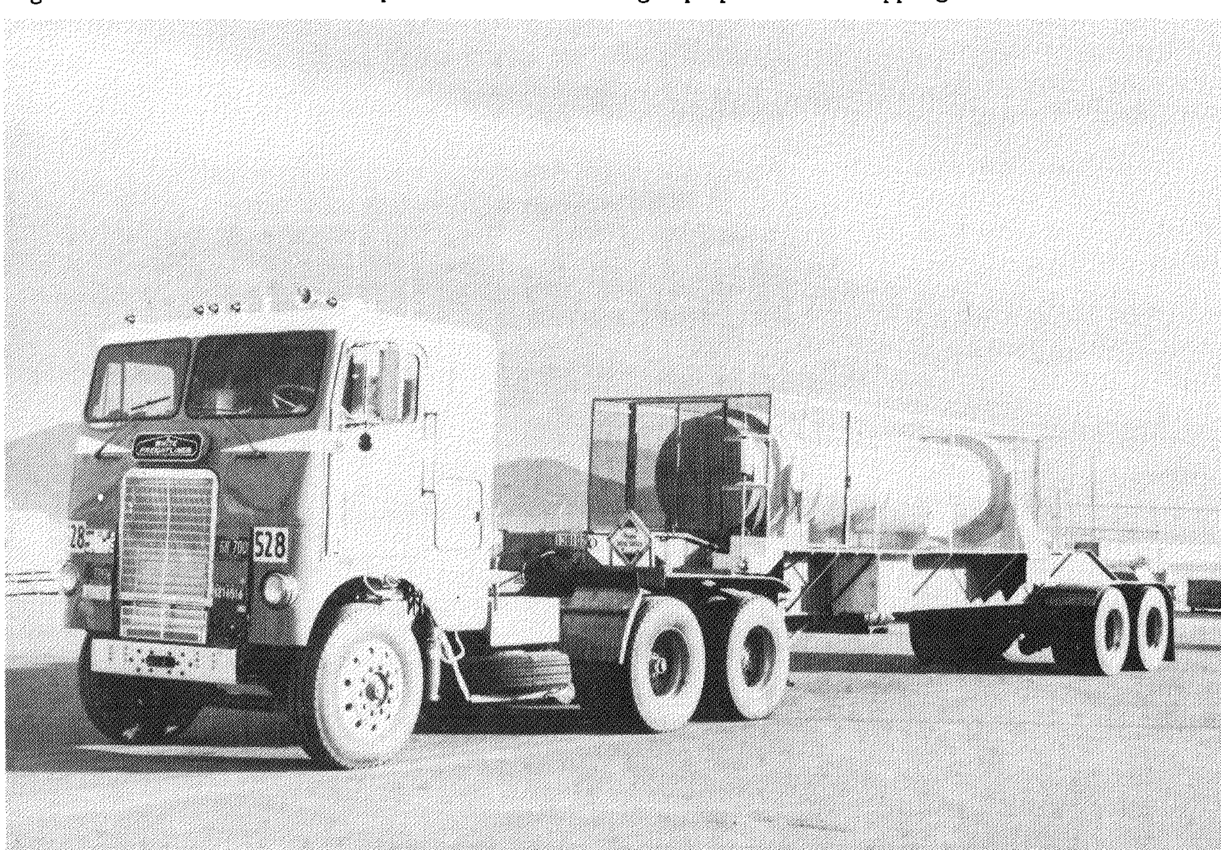
CONCLUSIONS

Based on the results of the above operational tests, several conclusions are warranted:

1. A spent-fuel movement monitoring system can provide efficient safeguards for spent fuel handling facilities while poentially reducing the inspection requirements.
2. The system elements are unobtrusive and are compatible with normal facility operations.
3. Implementation of a reliable modular system is practical with current technology.
4. The transportation monitoring sensors can provide reliable cask shipping data even in adverse road and weather conditions. Adequate radio contact can be maintained along the entire route.

The operational tests demonstrated the feasibility of both the C/S concept and the

Figure 3. Installation of Spent Fuel Monitoring Equipment on Shipping Trailer



prototype components. The information gained from these tests provided the basis for improvements to the C/S system. These improvements have been incorporated into an advanced C/S system. The advanced C/S system is based on microprocessor technology, so it is smaller, requires less power, is easier to install, and operates on battery backup.

The advanced system is installed and operating in a spent fuel handling facility. Initial operation and tests to data are highly successful. Extensive systems tests are planned and detailed documentation will be available after these tests are completed.

Under the sponsorship of the International Safeguards Project Office (ISPO), plans are underway for the IAEA to install and evaluate this advanced equipment in an operational facility for which the IAEA has safeguards responsibilities.

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INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

INVITATION TO EXHIBIT

23rd INMM Annual Meeting

Washington, D.C. ▪ July 18-21, 1982

The 1982 annual meeting of the Institute of Nuclear Materials Management [INMM] is being held at the Hyatt Regency Hotel, Washington, D.C., July 18-21, 1982. As part of this meeting, the Institute welcomes exhibits which are of interest to INMM members.

Traditionally, the exhibits are simple, informative, and often of the table top variety. The exhibit space will be located in a room immediately adjacent to the meeting room. Coffee breaks and a poster session are planned to give maximum exposure to the exhibits. Booth display hours are limited to normal session hours.

You are invited to participate as an exhibitor in the 1982 meeting. The fee for participation is $250. This fee entitles your organization to space equivalent to one table and one registration for the meeting. A covered table [6 by 3 foot] will be provided. 110V electrical service is available.

Space will be allocated on a first come basis, based on the date of receipt of your check, payable to INMM. Please call me [714/454-3811] if you have any questions. We look forward to your participation in this important meeting.

Sincerely, **TOM McDANIEL,** Exhibits Chairman

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