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FEATURE TECHNICAL ARTICLES

INMM

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JOURNAL OF THE INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

EDITORIAL

Hopes to Fill Obvious Gaps

By Dr. William A. Higinbotham
Brookhaven National Laboratory
Upton, Long Island, New York

In the fall issue, **Dennis Wilson** summarized the replies received to the membership questionnaire. I will comment, briefly, on the advice provided regarding the Journal, chastened by the advice to provide more technical articles and fewer editorials.

In response to the question, "What about the Journal do you find most useful?", 40 said the technical articles, 12 the committee reports, 5 the editorials, and 5 the business news. "Least useful" drew: advertisements (18), statistical articles (9), business news (9), committee reports (5), technical articles (5), and book reviews (4). A majority of those commenting on the Journal appear to find some of it worthwhile. A minority prefer to review books themselves.

As technical editor, I was especially interested in the comments on the technical articles. We do have a competent technical review committee. In spite of the fact that **T. Gerdis** needles about 50 potential contributors months before each issue, we do not have an abundance of contributions. The surplus of articles on statistics is due to the fact that our statistically-oriented members feel obliged to support the Journal by submitting papers. If the rest of you had as much dedication, there would be a better balance.

Adequate reviewing and rewriting takes time, even if (as is most unlikely) the reviewers and the authors are not already overburdened. Sometimes I have been too busy and added delays. Today, with all that is going on, most of the exciting potential authors and astute reviewers are tied-up meeting other deadlines for NASAP, INFCE, or an EIS. We do the best that we can under the circumstances.

Someone wanted more discussion of NRC and DOE policies and regulations. Another requested bi-weekly news reports. The INMM Journal cannot hope to compete with **Nuclear News, Nucleonics Week, Science,** or **Time.** I am more sympathetic to those who want more on international safeguards, or more industry input, or more on materials management and less on techniques. If you-all would write Tom or me and explain where to solicit such articles, we would do our best to fill these obvious gaps.

For the last several issues, we have bludgeoned members at major safeguards R&D labs to contribute annotated bibliographies of their documents. These are generally very difficult to find. I hope that this innovation will have been useful to some of us.

Thanks for your thoughtful comments. We could use some help. Any volunteers?

Dr. Higinbotham

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1979: Year of Emphasis On Communications and Professionalism

By G. Robert Keepin, Chairman
Institute of Nuclear Materials Management
Los Alamos, New Mexico

On a recent trip to Japan, it was my privilege to visit a number of government and nuclear industry facilities, research establishments and Universities, and to participate in the Second Pacific Basin Fuel Cycle Conference held in Tokyo September 25-29. From Japan, I proceeded directly (over the North Pole—literally) to Europe for the IAEA Symposium on Safeguarding Nuclear Material, in Vienna Oct. 2-6. Some highlights of the visit to Japan and Europe are chronicled in an article elsewhere in this issue by Journal Editor **Tom Gerdis.** I would only add here that from the INMM viewpoint it was extremely gratifying to see the high level of interest and enthusiasm for the Institute and its expanding program that was clearly evident both in Japan and Europe. INMM meetings were held in Tokyo (with the Japan Chapter) and in Vienna, both during and following the IAEA Safeguards Symposium. Petitions to form a Vienna Chapter of the Institute and a Pacific Northwest Chapter (U.S.) have recently been received by the Institute, and both petitions were approved by the INMM Executive Committee at our Fall meeting November 7-8 in Palm Beach, Florida. Thus, in accordance with the INMM Constitution and Bylaws, both the Vienna and the Pacific Northwest chapters will shortly be officially established and functioning. Pending formal election of officers, the Vienna Chapter is headed by acting Chairman **Carlos Buchler** and the Pacific Northwest chapter is headed by acting Chairman **Bill DeMerschman.** To each of these new INMM chapters, we extend our congratulations and best wishes for a successful and productive future.

During the Vienna Symposium, the INMM Chairman and the Secretary, **Vincent DeVito,** were invited to meet with ESARDA (European Safeguards Research and Development Association) officials to explore areas of mutual interest and possibilities for future cooperation between INMM and ESARDA. Two areas were indicated for increased cooperation, i.e., mutual participation in technical meetings and cooperation in international safeguards standards (both consensus standards and physical standards, round robin intercomparisons, etc.). Further details on this and other INMM related activities at the Vienna Symposium are reported in a separate regular column by the INMM Secretary on page 8 in this issue. Also a technical review of highlights of the Vienna Safeguards Symposium has been prepared for this issue of the Journal by the Scientific Secretary of the Symposium, **Jim Lovett** of IAEA.

Turning now to INMM professional activities on the home front, during the coming year the Institute will be placing special emphasis in two key areas of concern to me and to us all. These broad areas may be termed (1) **Communications** (with the lay public, with government, and with our colleagues in the nuclear community) and (2) **Professionalism** in the field of safeguards and nuclear materials management. The first area, communications, clearly involves both our Public Information and Safeguards standing committees while the second area, professionalism, involves mainly our Education and Certification committees. Public Information Committee Chairman **Herman Miller** has put together a plan of action that would draw information primarily from the Safeguards Committee (Chaired by **Syl Suda**), but also from INMM members, government and industry sources, and through cooperation with other societies, ANS, AIF, ANEC, etc. During the first year, the plan will concentrate on the major topic "Nuclear Material Safeguards," and is expected to include news releases, press conferences, etc. informing the public that effective systems, personnel and equipment do exist and are in place for safeguarding nuclear materials, and that these are constantly being improved still further through coordinated, well-funded R&D and in-plant evaluation programs in the U.S. and in other countries.

One effective mechanism for getting this type of positive message across would be a press visit to an operating nuclear facility that has an extensive, modern material accountability and control system in place and functioning. The Public Information Committee is currently in the process of arranging such a press visit that would concentrate on the computerized material accountability system at the General Electric LWR fuel fabrication facility at Wilmington, North Carolina. Assuming this approach proves successful, similar visits to other facilities may be arranged in the future. More information on the organization and action plans of our new Public Information Committee is contained in Herman Miller's P.I. report, elsewhere in this issue. Since so many INMM members have complained (and with reason) about our lack of an effective P.I. program in the past, we hope that you will now pitch in and actively participate in the Institute's new P.I. program and "put your pen where your mouth is (or was)!"

The other INMM committee directly involved in the key area of Communications is the Safeguards Committee which, as already noted, is the major source of information and input for our Public Information program. Current Safeguards Committee activities include the design of an informative "Safeguards Awareness Poster," setting forth in simple English the importance of safeguards and security of nuclear materials, and the rewards and penalties associated with the misuse of such materials. It is planned to distribute the poster to some 100 or more nuclear facilities in the U.S. in order to build awareness of safeguards among nuclear plant employees (especially new employees).

Another important area designated for Safeguards Committee action is establishing contacts with Congressional staff, regulatory agencies, etc., to provide expert testimony at government hearings and inquiries in the area of safeguards and materials management. A timely case in point is the upcoming Senate Hearings on ratification of the U.S./IAEA Agreement on IAEA safeguards inspection in U.S. nuclear facilities.

The Safeguards Committee is also looking into the recent spate of publicity surrounding amateur bomb makers, e.g., the book "Mushroom" by Phillips and Michaelis (Norton Press, 1978) and the appearance of Nader and Phillips, (the Princeton student who designed an atomic device) on NBC's **Phil Donahue** program entitled "Nuclear Proliferation", aired in New York City Oct. 9, and widely rebroadcast around the U.S. since then. In co-authorship with **John Abbotts, Ralph Nader** has also published a rabidly anti-nuclear book "The Menace of Atomic Energy," (Norton Press, 1977.)

Clearly much remains to be done in the vital Communications area, and the challenge we face can only be met through our full support of the combined efforts of the Public Information and Safeguards Committees. I urge your personal support in this key activity of the Institute.

In the second key area of Institute emphasis—which I have called Professionalism—priority is currently being given to developing a General Entry Examination for qualification as a Safeguards Intern (or Associate), and after sufficient experience—e.g., 3 years—working in the field, further specialized examination and advancement to full accreditation as a Certified Safeguards Specialist.

To achieve this important goal, an Ad-Hoc Certification Program Committee has been established under the chairmanship of **Frank O'Hara** of Battelle Columbus Laboratories. The ad-hoc committee has set a goal of developing the requisite examination regimen (a series of examination questions in various topic areas) by March 1979. Further details of the Institute's Certification Program, including organization, procedures and examination topical areas are contained in an update report on the INMM standing committee on Certification, currently chaired by **Fred Forscher,** is assisting in this important effort, and will be charged with implementation of the INMM Certification Program. See page 20.

It is noteworthy in this connection that the Idaho National Engineering Laboratory (INEL) has recently proposed a Nuclear Material Management Certificate Program to be offered through the University of Idaho (27 college credit hours). The proposed course offerings and requirements are being examined from the standpoint of consistency with the INMM examination regimen and requirements for professional certification by the INMM as a Certified Safeguards Specialist. The steadily increasing interest in INMM-sponsored Statistics Courses taught by **John Jaech**, and, in general, the growing impetus for more formal academic training in various areas of our profession underscores the close relationship and often common objectives shared between the Education and Certification Committees.

A notable recent undertaking of the Education Committee (supported by the Safeguards Committee) was the INMM Workshop on the Impact of IAEA Safeguards held in Washington, D.C. in December. We believe this workshop provided a timely and valuable information service to many in the nuclear industry who are concerned about the practical effects of IAEA inspection and safeguards on their plant operation. A summary report on the INMM Workshop has been prepared by Workshop Chairman **Russ Weber** and his session Chairmen, **Harley Toy, Syl Suda,** and **Tom Bowie** especially for this issue of the Journal.

Workshop logistics, registration desk activities, etc., were all handled very smoothly and efficiently through the combined efforts of a number of INMM stalwarts including **Ed Owings, Tom Gerdis, Ev DeVer, Vince DeVito, Larry Wheeler,** and **Gary Molen.**

Because of the current emphasis being placed on the areas of Communications and Professionalism, I've devoted nearly all of the present discussion to these topics. There are, of course, many other important areas of INMM activity represented by our various other standing committees; each Committee is doing a vital job for the Institute, and I certainly intend to devote attention to each one of them in forthcoming issues of the Journal.

Although by the time you read this, it'll be somewhat after the fact, I still want to take this opportunity to wish each one of you a happy, prosperous, and productive new year, 1979!

Dr. Keepin

Treasurer's Report for Period
July 1, 1977 Through September 30, 1978

Cash Balance July 1, 1977		$ 20,065.92
Receipts:		
Dues	17,046.50	
Journal Income		
Subscriptions	5,789.00	
Advertising	4,337.00	
Page Charges	6,827.50	
Miscellaneous	1,187.33	
Reprints	477.00	
Proceedings Income		
Annual Report	8,145.00	
Page Charges	5,075.00	
Miscellaneous Income	845.74	
Education-Statistics School	10,186.80	
Annual Meeting		
Registration	27,038.51	
Exhibitors	1,750.00	
Interest Income	339.05	
Total Receipts		$ 89,044.43
Expenditures:		
Journal Editor	11,001.87	
Journal Editor-Travel	1,975.56	
Proceedings		
Printing	9,215.47	
Postage	1,605.49	
Clerical	461.34	
Miscellaneous	237.61	
Journal		
Printing	14,020.54	
Postage	2,778.36	
Clerical	2,577.13	
Miscellaneous	1,287.23	
Office Supplies	72.12	
Typing Service	164.25	
Telephone	28.87	
Photography	161.52	
Annual Meeting		
Chairman and Committee Expense	364.12	
Registration Refunds	550.00	
Reception	1,744.02	
Luncheons	2,958.73	
Speakers Breakfast	406.98	
Miscellaneous	451.23	
Administration	726.47	
Equipment	232.87	
Publicity	481.02	
Pre-Registration and Registration	8,548.37	
Meeting Favors	1,372.28	
Administration	2,649.07	
Education		
Committee	244.71	
Statistics	6,937.45	
Miscellaneous	1.36	
N-15 Standards	87.06	
Certification	2.71	
Membership	1,127.67	
Safeguards	94.77	
Awards	365.62	
Student Awards	926.00	
Chapter Expense	3,082.49	
General Miscellaneous	81.10	
IAEA Workshop	186.93	
Total Expenditures		$ 79,210.39
Cash Balance September 30, 1978		$ 29,899.96
Savings Account Balance July 1, 1977		$ 16,108.25
Interest Income		1,385.47
Savings Account Balance September 30, 1978		$ 17,493.72
Net Gain or Loss:		
Total Receipts		$ 89,044.43
Interest Income		1,385.47
Total Income		$ 90,429.90
Total Expenditures		79,210.39
Net Gain		$ 11,219.51

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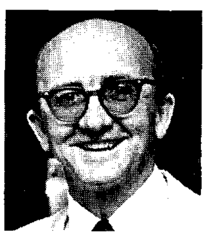
Technical Working Groups For INMM Members Under Study

By G.F. Molen, Vice Chairman
Institute of Nuclear Materials Management
Allied-General Nuclear Services
Barnwell, South Carolina

At the recent Executive Committee meeting in West Palm Beach, Florida, the chairman appointed me to develop a plan of action and scope of activities for the new Technical Working Groups or Committees. The Executive Committee is excited about this bright prospect of involving more members in the Institute activities. Several Executive Committee members volunteered to assist me in my ad hoc assignment. I am sure with this kind of enthusiasm we will be able to "kick-off" this new idea successfully. Basically, we want these Technical Working Groups to represent the Institute's interest in a more direct and effective way. As an example, if we had had such working groups, one of them would have been responsible for our recent workshop on the impact of IAEA requirements. As it was, we had to execute this activity on an ad hoc basis. This is not a good practice for an organization that is growing as rapidly as the Institute.

G.F. Molen



The Institute is getting more active in a number of other areas such as cosponsoring topical meetings, establishing foreign and regional chapters, and playing a more active role in the field of public relations. The N-15 Standards Committee is taking a fresh look at itself and how it goes about accomplishing the standards activities. These are all good signs of growth. The Executive Committee is making every effort to be responsive to the desires of the membership as expressed in the Members' Interest Questionnaire. If you are one of those who is interested in becoming more active in Institute activities then let us know. Simply jot **Bob Keepin** (LASL) or me a note or give us a call and we will see **that you do get more involved.**

In keeping with the pace of other changes in Institute activities, the Annual Meeting Committee has also been quite active. We have had several preliminary planning meetings and both the Program Committee under the leadership of **John Jaech** and the Meeting Arrangements Committee under the leadership of **Joe Stiegler** have the plans for the Albuquerque meeting well under way. We have restructured the Albuquerque meeting hoping to attract more interest by offering more diversified sessions. We will have several "invited paper" sessions covering a wide range of topics. We are also trying some new approaches to our "extracurricula" activities. We have several delightful surprises planned for our evenings around the Olympic size swimming pools. We think the whole family will enjoy visiting Albuquerque next July. So make your plans now to attend our 20th Annual Meeting in Albuquerque, New Mexico, on July 16, 17, and 18, 1979. For more information on the meeting be sure to read John Jaech's Program Chairman's column and also Joe Stiegler's Meeting Arrangements column.

INMM Presents High Visibility in Vienna

By Vincent J. DeVito
INMM Secretary
Piketon, Ohio

There was noticeable INMM participation at the recent International Safeguards Symposium held in Vienna, October 2-6, 1978. Over sixty INMM members from twelve countries attended the symposium, and were recognizable by the INMM ribbons attached to their name tags. **James E. Lovett,** former chairman of the INMM, was the scientific secretary of the symposium.

There were ten sessions of which three were chaired by INMM members, including **Bob Keepin,** the current chairman of the INMM.

A total of 109 papers were presented at the meeting of which 57 papers were presented individually and the balance were presented in 11 rapporteur sessions. Approximately 50 percent of the total papers presented were either authored or co-authored by INMM members.

Executive Committee members in attendance at the symposium in addition to Chairman Bob Keepin included Secretary **Vince DeVito,** and member at large **Bill DeMerschman, Herman Miller,** the current Public Information Chairman, also attended.

There were twelve agency papers of which five were presented by INMM members. The members were **Tom Shea, Yvonne Ferris, Saurabh Sanatani, Tom Beetle,** and **Gordon Hough.** In addition, James Lovett presented a paper authored by he and Bob Keepin. A critique of the symposium will be presented in the Journal by James Lovett and Bob Keepin.

Due to the large number of INMM members present in Vienna, a reception was held on October 4, 1978, for approximately 80 members and guests. Approximately 45 INMM members attended. The reception aided in developing the idea for a Vienna Chapter and was also instrumental in providing new members.

On October 11, 1978, a meeting was held in Vienna with 15 INMM members and 10 prospective members to discuss the formation of a Vienna Chapter. Tom Shea of the IAEA acted as chairman pro tem and the group moved to petition the INMM Executive Committee for a Viennese Chapter. The petition was subsequently received and approved by the Executive Committee at the fall meeting on November 9, 1978. There are currently 34 INMM members at the Agency and two members at the U.S. Mission. It is anticipated that by the time the Chapter constitution and by-laws are approved, over 40 members will be active in the Vienna Chapter.

During the symposium, Chairman Bob Keepin took the opportunity to discuss international safeguards and the role the INMM can play in international safeguards with **H. Gruemm,** Deputy Director General, IAEA Safeguards. Chairman Bob Keepin and Secretary Vince DeVito met with **F. Klik,** Director of Operations, Division A, and **M. Ferraris,** Head, Operations A, North American Section to discuss the INMM workshop dealing with international safeguards. Chairman Bob Keepin and Secretary Vince DeVito also met with members of the European Safeguards Research and Development Association (ESARDA) to discuss ways the INMM and ESARDA can co-assist and co-sponsor safeguards activities. The new ESARDA chairman beginning November 1, 1978, will be Dr. **D. Gupta,** who is a long standing INMM member.

The role of the INMM in promoting international safeguards, conducting international seminars, developing dialogue with international groups, the formation of two foreign chapters, and the significant participation and attendance at the International Safeguards Symposium would indicate that the INMM can now be truly called an international organization. The INMM cannot rest on past or current achievements, but must continue to foster those ideas which will provide an adequate international as well as domestic safeguards posture.

V.J. DeVito

Herman Miller of National Nuclear Corp. is the newly-appointed Chairman of the INMM Public Information Committee. He and his wife Joanne helped to make the INMM Reception a "huge success."

Bob (former INMM Treasurer) and Kitty Curl welcome old friends from the U.S.

Old and new members of INMM listen to Tom Shea and discuss the merits of a Vienna Chapter.

John Mahy of the U.S. Mission signs the Vienna Chapter petition as Rudy Scher of IAEA looks on.

Thomas Shea explains the purpose for starting the Vienna Chapter and reads the petition to the group.

Bill DeMerschman (center), member of the INMM Executive Committee, discusses the merits of a Vienna Chapter with Peter Filss. Yvonne Ferris, returning to Rockwell International (Rocky Flats) shortly and presently with IAEA, listens intently to the questions of a prospective INMM member.

Walt and Lois Strohm of Mound Laboratory of Monsanto Research Corp.

Ronald Perry of Argonne National Laboratory visited with Norman Beyer of IAEA. Mr. Beyer, a member of Journal Editorial Advisory Committee, was with ANL before coming to the IAEA.

Members (l. to r.) James Lovett, Cecil Sonnier and Carlos Buchler attended the meeting to discuss the proposal for a Vienna Chapter of the Institute.

Gordon Hough of IAEA and Iain Hutchinson, also of IAEA, discuss INMM membership.

Catherine Morimoto at work at the Agency.

IAEA Director General To Be Keynote Speaker

By John L. Jaech, Chairman
Annual Meeting Program Committee
Exxon Nuclear Co., Inc.
Richland, Washington

By the time this is published, the invited papers sessions for the July meetings in Albuquerque will have been firmed up. As of this writing, commitments have been made by several speakers, and I can assure you that with the able assistance of session leaders identified below, meeting attendees will be assured of a balanced program of interesting and informative papers.

The Keynote Speaker at the Plenary Session on Monday morning, July 16, will be **Dr. Sigvard Eklund,** Director General of the International Atomic Energy Agency. We can look forward to his remarks in tune with the theme for the annual meeting, "International Safeguards". A firm commitment to speak at the Plenary Session has also been made by **Dr. Lawrence Scheinman,** Director of the Program on Science, Technology, and Society and Professor of Government at Cornell University. Dr. Scheinman has played an active role in U.S. policy making related to nuclear development, and he promises to join us "in a vigorous give and take on the issues of nuclear development and international safeguards." Invitations have also been extended to three additional prominent speakers for the Monday morning Plenary Session, and I am enthusiastic about the prospects for an outstanding "kick-off" session at Albuquerque.

Following the Monday morning Plenary Session, we will begin concurrent technical sessions on Monday afternoon. Depending upon the response to the call for contributed papers, and on the Contributed Papers Chairman **Dick Chanda's** selection of such papers, we may choose to go to some tri-current sessions this year. The facilities at the Albuquerque Hilton Inn are well suited for such an action.

At each concurrent session, there will be an invited papers session and one or more contributed papers sessions. The chairmen of the invited papers sessions have done a truly outstanding job in lining up speakers, a process which is about completed at this writing, and the reactions of the invitees has been most gratifying. The tentative schedule, subject to change, is as follows:

Monday Afternoon:	"Safeguards in ESARDA (European Safeguards Research and Development Association)"; **Charles Beets,** Chairman
Tuesday Morning:	"Safeguards Concerns of Utilities"; **Bob Kramer,** Chairman
Wednesday Morning:	"Safeguards Measurements Technology"; **George Huff,** Chairman
Wednesday Afternoon:	"Estimation and Control of Measurement Errors"; **Darryl Smith,** Chairman

On Tuesday afternoon, a special invited papers session on the very timely topic "Safeguards and Alternative Fuel Cycles" will be chaired by **Bill DeMerschman.** Because of the special interest in this topic, this will not be a concurrent session so that all attendees will have a chance to hear the papers. This session will follow the student paper and replaces the panel format used the past several years.

As Program Chairman, I hope the above description of how the program is developing whets your appetite. Make plans now to attend the Albuquerque meetings on July 16-18, 1979. See you there.

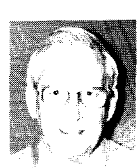
*Dr. John O'Leary, Deputy Secretary, DOE, and Dr. Bertram Wolfe, Vice President and General Manager of General Electric's Nuclear Energy Program Division have also accepted invitations to speak.


Beets


Chanda


DeMerschman


Eklund


Huff


Jaech


Kramer


Scheinman


Smith

Considerable Planning Underway For 1979 INMM Meeting

By Joseph E. Stiegler, Chairman
Annual Meeting Arrangements Committee
Sandia Laboratories
Albuquerque, New Mexico

The Meeting Arrangements Committee had its first meeting in West Palm Beach, Florida, in early November 1978. The members of the Committee are: (1) **Duane Dunn**—Registration; (2) **Roy Crouch**—Local Arrangements; (3) **Tom Gerdis**—Communications and Publicity; and (4) **John Glancy**—Exhibits and Displays.

The Meeting Arrangements Committee is making every effort to make the Albuquerque meeting run smoothly. We have learned from our past experience and we are attempting to correct past deficiencies. Hopefully, the registration and advance publicity for the meeting will be as successful as the very fine job done at the Cincinnati meeting. A pre-meeting planning session for committee members is planned at the Albuquerque Hilton Hotel prior to July. During this meeting we will iron out any last minute details.

As for local arrangements, Roy Crouch is doing a fine job of lining up a number of fine attractions for our entertainment during the evening hours. We intend to take every advantage of the southwestern culture and atmosphere. We are considering such things as a colorful Mariachi band with Flamenco dancers. We are planning numerous activities for the ladies and their children. We will have our usual complimentary ladies' coffee with appropriate condiments, etc. We are also planning a number of bus tours to historic as well as naturally beautiful New Mexico sites. With the mountains nearby, there are a number of breathtaking views available to those who care to take the short drive to the mountain slopes.

The Meeting Arrangements Committee is excited about the Albuquerque meeting and we are anxious for you to attend. So make your plans now to be in Albuquerque July 16, 17, and 18, 1979. It is a great place for a vacation so why not bring your entire family along. See you there.

Crouch

Dunn

Glancy

Stiegler

Emphasis on Professionalism and Communication

By D.M. Bishop, Chairman
N15 Standards Committee
(Nuclear Materials Control)
General Electric Company
San Jose, California

As Institute Chairman **Bob Keepin** has indicated, the main thrust of INMM efforts during 1979 will be focused in two very timely areas: (1) increased **technical professionalism,** and (2) heightened public awareness through improved **external communication.** In these times of an uncertain nuclear future, such emphasis is clearly vital to improved public acceptance of the adequacy of domestic and international safeguards systems in particular, and the nuclear energy alternative in general.

In order to support these goals, the N15 Standards Committee has defined an aggressive set of 1979 goals, including the following:

(1) **Improved External Visibility and Communication.** A scope definition document and action plan is under development to highlight and coordinate N15 activities.

(2) **Expanded Domestic Scope.** To address recent safeguards needs and more fully utilize member expertise, several new subcommittees are currently being planned.

(3) **Added International Scope.** To assure forthcoming international requirements are adequately addressed, possible N15 contributions are under review.

(4) **Increased Member Participation.** An increase from the current 23% to 40% of the active membership is planned.

(5) **Shorter Issue Cycle Time.** By obtaining prior approval of work scopes and establishing internal priorities, a significantly shorter issue cycle is planned.

(6) **Six Draft Standards Submitted for ANSI Balloting.** These standards are the result of several years of N15 effort.

In order to satisfy these goals, some restructuring and addition to the historical N15 organization and scope is underway. Although still in the development stages, the 1979 N15 Standards Committee will look, to some extent, as it has in the past, but with several significant additions to reflect recent changes in the safeguards arena and updated INMM goals. This past progress and future plan is reflected in the nearby summary tables (see page 40).

Based on this organization, the N15 Standards Committee will represent a significant resource of nearly 200 engineers and scientists from all segments of the domestic nuclear industry.

In its tenth year of existence, the INMM N15 Standards Committee has grown with the USA safeguards program to become the single most effective contributor of consensus standards per capita member in the ANSI organization. As shown above, N15 has produced an impressive track record of over 40 standards in various stages of development and use. Yet this achievement is not enough. In the last decade, anti-nuclear sentiment has attacked the very basis of the profession. The uncertainty which has resulted has brought into question the societal benefit of nuclear energy in general, and specifically the benefit of such consensus standardization programs as the INMM N15 Standards Committee. As with most serious illnesses, early detection and proper professional care can arrest this otherwise terminal disease. It is for this reason that the 1979 INMM program (Professionalism and Commonication) can go a long way toward replacing public apathy and concern with assurance on timely nuclear issues.

In particular, Institute programs such as personnel certification, public information and working groups on timely technical and political issues provide an unparalleled opportunity for the Institute to reach out from behind a historical pinnacle of superior knowledge clouded by technical jargon and communicate with the public when and where it counts.

Toward this end, the N15 Standards Committee has always been a cornerstone of the Institute's professional efforts. Such standards provide a bedrock basis for demonstrating that our technical house is in order, and

(Continued on Page 40)

D.M. Bishop

51 New Members In First Five Months Of New Year

By James W. Lee, Chairman
INMM Membership Committee
North Palm Beach, Florida

The Membership Committee reports receipt of 51 new applications during the present fiscal year, to date.

The new applications have been categorized as follows:

Government and Government Contractors	23
Industry	14
Utilities	3
Foreign	11

We wish to thank **Dennis Bishop,** chairman of N-15, for his excellent suggestion that we screen the members of the various sub-committees of N-15 for persons who do not presently belong to the Institute and invite them to join. This list of 55 prospects is now about ready for solicitation by a special invitational letter.

Tom Gerdis is doing an efficient job of acknowledging approved applications as well as fielding a number of inquiries for INMM information.

New Members

The following 29 individuals have been accepted for INMM membership as of November 30, 1978. To each, the INMM Executive Committee extends its welcome and congratulations.

New members not mentioned in this issue will be listed in the Spring 1979 (Volume VIII, No. 1) issue to be sent out May 1, 1979.

Betty Lou Alspaugh, Computer Programmer, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

David H. Alspaugh, Computer Programmer, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Werner G. Bahm, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Dr. **Norton Baron,** Staff Member, Los Alamos Scientific Laboratory, Los Alamos NM 87545.

Dr. **Edward J. Dowdy,** Alternate Group Leader, Q-2, Los Alamos Scientific Laboratory, Los Alamos NM 87545.

James E. Doyle, President, CMS, Inc., 1345 Norman Firestone Road, Goleta CA 93017.

James R. Fako, Partner, Price Waterhouse and Company, 600 Grant Street, Pittsburgh PA 15219.

William L. Frankhouser, Member, Research Staff, System Planning Corporation, 1500 Wilson Boulevard, Arlington VA 22209.

David F. Frech, Nuclear Engineer, Duke Power Company, Steam Production Department, P.O. Box 33189, Charlotte NC 28242.

Wallace J. Hendry, Manager, Regulatory Compliance, General Electric Company, P.O. Box 780, M/C J-26, Wilmington NC 28402.

Dr. **Michael B. Hughes,** Research Chemist, Babcock & Wilcox/Lynchburg Research Center, P.O. Box 1260, Lynchburg VA 24505.

Iain Hutchinson, Senior Officer, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Dr. **Rush O. Inlow,** Chief, Nuclear Safeguards Branch, U.S. DOE, Albuquerque Operations Office, P.O. Box 5400, Albuquerque NM 87115.

Mr. Lee

Michael F. Kelly, Statistician, United Nuclear Corporation, 67 Sandy Desert Road, Uncasville CT 06482.

Gary P. Kodman, Manager, Safeguards and Inventory Management, Allied Chemical Corp., 550 Second Street, Idaho Falls ID 83401.

Dr. **Kenneth Lewis,** Chief, Chemistry and Instrumentation Development Branch, U.S. DOE, New Brunswick Laboratory, 9800 South Cass Avenue, Argonne IL 60439.

David M. Lund, Manager, SALE Program, U.S. DOE, New Brunswick Laboratory, D-350, 9800 South Cass Avenue, Argonne IL 60439.

Dr. **Arthuro Maimoni,** Leader, Material Control Project, Lawrence Livermore Laboratory, P.O. Box 808, Livermore CA 94550.

Carl A. Ostenak, Staff Member, Safeguards, Los Alamos Scientific Laboratory, MS 541, Los Alamos NM 87545.

Antonio Ramalho, Senior Officer, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Dr. **Junaid Razvi,** Senior Engineer, General Atomic Company, P.O. Box 81608, San Diego CA 92138.

Dr. **Saurabh Sanatani,** First Officer, International Atomic Energy Agency, P.O. Box 645, A-1011, Vienna, Austria.

Dr. **Robert L. Seale,** Professor and Head, Department of Nuclear Engineering, University of Arizona, Tucson AZ 85721.

Dr. **Rudolph Sher,** Visiting Expert, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Varis Smiltnieks, Business Development Manager, Technology Division, DSMA Atcon, LTD., 4195 Dundas Street, West, Toronto, Ontario, Canada M8X 1Y4.

Joseph E. Stiegler, Department Manager, Facilities Physical Protection Program, Sandia Laboratories, Org. 1750, Albuquerque NM 87185.

Robert E. Tharp, Head, Security Department, Oak Ridge National Laboratory, P.O. Box P, Oak Ridge TN 37830.

Masayori Tsutsumi, Inspector for Safeguards, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Kenneth Veevers, Safeguards Inspector, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

Address Changes

The following changes of address have been received by the INMM Publications Office (Phone: 913-532-5837) at Kansas State University, 20 Seaton Hall, Manhattan, Kansas USA 66506, as of November 30, 1978.

Ralph G. Gutmacher, Los Alamos Scientific Laboratory, MS 541, Los Alamos NM 87545.

Thomas J. Haycock, Jr., ISPO Project Office, Brookhaven National Laboratory, Bldg. 197C, Upton NY 11973.

Mary Alice Thom, Route 4, Box 49, South Bellin Road, Idaho Falls ID 83401.

Robert A. Williams, 493 Longvue Drive, New Kensington, PA 15068.

Scope of Activities

By Harley L. Toy, Chairman
INMM Education Committee
Battelle's Columbus Laboratories
Columbus, Ohio

Activities of the Education Committee during the past quarter included the following:

Scope of Activities

At the direction of the Chairman at the Cincinnati meeting, the Education Committee drafted a proposed Scope of Activities. The Scope was approved by EC member, **Frank O'Hara,** who has oversight responsibility for the Education Committee, and was forwarded to the Chairman for concurrences.

Scope

Provide overall direction, formulation, and implementation of the Institute's educational program. Educational programs are defined here as specific courses of study and training in the several disciplines of nuclear materials management and safeguards. Not included within the scope of the Education Committee would be responsibility for the presentation of topical meetings unless otherwise directed by the Executive Committee. Also excluded from this scope would be public education unless otherwise directed by the Executive Committee.

Specific functions of the Education Committee include:

- Identification of educational and training needs; keeping the Executive Committee appraised of educational requirements
- Formulate curriculum, provide faculty, and arrange physical facilities for presentation of formal courses
- Maintain current files on availability of courses and seminars in the area of nuclear materials management and safeguards; to include continuing dissemination of course and seminar information to the membership through the Journal
- Perform and assist such specific educational activities as the Executive Committee may so direct

International Statistics Courses

John Jaech presented a two-day statistics course at Heathrow, England on September 28-29, 1978. The two-day course was arranged under auspices of the United Kingdom Atomic Energy Authority with sponsorship by the INMM. The course was presented under a fixed fee arrangement of $1500. Expenses to INMM totaled $1079.66. Thus, a profit of $420.34 to INMM.

Through a contact by **Herm Miller,** negotiations are under way with a Dr. **Ing Harold Bucher** of West Germany to present the five-day "Selected Topics Statistics" course in Europe sometime in early 1979. John Jaech is conducting the ongoing negotiations.

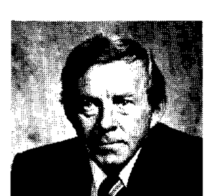
Three-Day "Introductory Statistics" Course

The first three-day "Introductory Statistics" course was held at Battelle's Columbus Laboratories on October 10-12, 1978. The minicourse was presented to twelve attendees. A total of sixteen students had preregistered for the course. However, due to government budgetary problems four students had to cancel the course (three from DOE and one from NRC) just prior to the starting date of October 10, 1978.

The course was well received as indicated by a course evaluation questionnaire returned by the attendees. There continues to be a demand for both (three-day and five-day) statistics courses. Several telephone inquiries have been received during the past month for information on upcoming courses. It should be noted once again that the INMM is most fortunate in obtaining the services of John Jaech and his unique capabilities for the Institute's educational program.

DOE and NRC Liaison in Educational Matters

Liaison has been established with Mr. **Peter Goldman,** Training Coordinator for NRC. We have agreed to exchange information on educational training needs and ongoing programs. According to Mr. Goldman, the majority of NRC training courses are conducted in-house and most programs are designed for the NRC Inspection and Enforcement Branch. However, NRC is willing to keep us advised of their needs and will cooperate in



Mr. Toy

Those taking part in the recent three-day INMM Introductory Statistics Course in early October at Battelle Columbus Laboratories (front row, l. to r.) Harley L. Toy (host), Robert Eggers and Matthew Hykel. Back row (l. to r.) Eddie Stone, Jack Streightiff, Don Majors, Richard Siebelist (standing), David Martinez, John Jaech (Instructor, Staff Consultant, Exxon Nuclear Co., Inc., Richland, Wash.), Lavella Adkins (Secretary to Mr. Toy), Angela Strickland, Mary Bunker, Gretchen Ford and Elizabeth Stasny.

disseminating information relative to our education activities.

Liaison has also been established with a Mr. **Walter Waldrop,** Training Officer at DOE's Albuquerque Operations Office. Mr. Waldrop advises that approximately 85 percent of their training programs are contractual. They presently utilize thirty-seven user organizations for their training needs. (It is interesting to note that two staff members from ALO had preregistered for our October statistics minicourse but had to cancel due to budget problems.)

Mr. Waldrop and I will maintain an ongoing exchange of information regarding course offerings and training needs. Contrary to NRC's training program, courses presented by ALO are open to licensees and other interested parties.

Training Programs for CY 1979

The Education Committee requests guidance from the Executive Committee regarding specific instructional programs for the coming year. Possibly, the recent INMM membership questionnaire will identify certain training needs.

At this point the Education Committee is looking at an overall training and course schedule for the coming year. Our plans call for continuing Jaech's statistics courses and expanding the dissemination of course offerings, workshops, and topical meetings to the general membership. We are presently negotiating with **Walt Strohm** at Mound Laboratory to co-sponsor a measurements course in calorimetry sometime in the first half of 1979. We are still attemtping to tie down the proposed Supervisor Guard Training course. At the present time, DOE, NRC, and the American Security Association are proposing their own individual courses. Even though physical security is not a strong suit within INMM, we still feel we could contribute organizational and management expertise to presenting physical security courses.

Workshop on the Impact of IAEA Safeguards

The Education Committee assisted the Ad Hoc Committee in formulating plans and the agenda for the INMM Workshop held December 7-8, 1978. I attended a planning meeting hosted by **Russ Weber** on October 17, 1978, in which plans were finalized for the December workshop.

Mr. Strohm

UPCOMING SAFEGUARDS TRAINING

INMM-Sponsored Safeguards
Training Courses in Spring, 1979
Batelle Columbus Laboratories

"Introductory Statistics with Applications to Special Nuclear Material Control."	March 13-15, 1979 20 Attendees
"Selected Topics in Statistical Methods for Special Nuclear Material Control."	May 7-11, 1979 20 Attendees

Brochures on INMM-Sponsored Safeguards courses are sent to the INMM members. Brochures are available from the INMM Publications Office, 20 Seaton Hall, Kansas State University, Manhattan, Kansas 66506. Both courses will be offered at Battelle Columbus Laboratories and taught by John L. Jaech, Staff Consultant with Exxon Nuclear Co., Inc., Richland, Washington.

DOE SAFEGUARDS TECHNOLOGY TRAINING PROGRAM
Los Alamos Scientific Laboratory
Schedule of 1979 Courses

Listed below are the dates for the US DOE Safeguards Technology Training Program courses for 1979.

"Measurement and Accounting Systems For Safeguarding Nuclear Materials"	March 19-22, 1979 40 Attendees
"Gamma-Ray Spectroscopy for Nuclear Material Accountability"	May 14-18, 1979 25 Attendees
"Fundamentals of Nondestructive Assay of Fissionable Material Using Portable Instrumentation"	October 1-5, 1979 30 Attendees
"In-Plant Nondestructive Assay Instrumentation"	December 3-7, 1979 20 Attendees

Brochures on LASL Safeguards Courses are sent to members of the INMM as well as past attendees. The mailing list numbers about 800. This year the course announcements also were listed in *Physics Today* and *Nuclear News.*

Short Courses, Conferences, and Workshops

In the last issue of the Journal we mentioned that future issues would expand on available courses, conferences, and workshops. The following information was compiled by the Education Committee. Course information for the two upcoming Statistics courses and Safeguards courses being presented by LASL are listed separately in this issue.

- AIF INFO '79, February 25-28, 1979, Crown Center, Kansas City, MO, Telephone AIF: 301-654-9260
- AIF Conference on Special Environmental Issues, April 1-4, 1979, Mayflower Hotel, Washington, DC, Telephone AIF: 301-654-9260
- AIF Workshop on Reactor Licensing and Safety, May 13-16, 1979, Waldorf Astoria, New York, NY, Telephone AIF: 301-654-9260
- Nuclear Criticality Safety Short Course, May 14-18, 1979, Department of Chemical and Nuclear Engineering, The University of New Mexico, Albuquerque, NM 87131, Telephone: 505-277-5431
- Nuclear Criticality Safety Specialists' Update, May 21-25, 1979, Department of Chemical and Nuclear Engineering, the University of New Mexico, Albuquerque, NM 87131, Telephone: 505-277-5431
- Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP), March 14-15, 1979, Washington, DC, Contact: W.R. Ney, NCRP, 7910 Woodmont Avenue, Suite 1016, Washington, DC 20014

Certification Examination Available Soon

By Dr. Francis A. O'Hara
Battelle Columbus Laboratories

and

By Dr. Frederick Forscher
Energy Management Consultant
Pittsburgh, Pennsylvania

As one element of emphasizing his goal of improved INMM communications and professionalism, Chairman **Bob Keepin** has recently set up an ad hoc committee to consider the certification process and to formulate a new examination to be utilized in the certification process. Dr. **Frank O'Hara,** Executive Committee member cognizant in the area of certification, is Chairman of this committee with Dr. **Frederick Forscher,** Chairman of the standing committee of certification assisting him.

A two-step process has been proposed which will culminate in full certification. A general examination covering the areas of nuclear materials accountability, measurements, materials control and protection will be required at the entry level. Prerequisites for this level are a bachelor's degree in an appropriate discipline or a minimum of five years experience in the field (or an equivalent combination of the two). Following successful completion of the entry level examination, the applicant will be designated a **Qualified Safeguards Intern.** After the completion of three years of applicable professional experience and peer recommendation, the individual will be eligible to take a series of in-depth written and oral examinations in one of the major areas and become a **Certified Safeguards Specialist.**

Two sub-committees have presently been established. The first, under Forscher, will formulate objective examination questions in each of the topic areas. These questions will then be reviewed by a committee under O'Hara. It is anticipated that these actions will result in a new certification examination which will be available in the Spring of 1979. The new examination should be available for qualified applicants at the 20th annual meeting of INMM next July 16-18 in Albuquerque, New Mexico. This will also allow for the administration of such examinations following completion of a series of safeguards courses sponsored by the Education Committee. It should also be possible to make the entry-level examination available to those who have completed curricula in Safeguards and Materials Management, such as that recently established by Dr. **Fred Tingey** at the Idaho Nuclear Engineering Laboratory in conjunction with the University of Idaho.

If there are any suggestions or comments regarding the certification examination process, or if anyone wishes to participate in the formulation or review of questions, they should contact Dr. O'Hara, [(614) 424-4018]. Anyone who desires further information on the examination or who might wish to make application to take the entry level examination should contact Dr. Forscher, [(412) 521-7340].

Dr. O'Hara

Dr. Forscher

Deadline for Nominations Extended to April 1, 1979

By Samuel C.T. McDowell, Chairman
INMM Awards Committee
Washington, D.C.

The Institute of Nuclear Materials Management is pleased to announce its second annual student competitive award, consisting of a $500 stipend for the best paper submitted by a college or university student, for presentation at its next Annual Meeting, to be held in Albuquerque, New Mexico, July 16-19, 1979. In addition, all reasonable travel expenses and per diem will be paid by the Institute of Nuclear Materials Management.

The subject areas for entries are:

- Nuclear Materials Accountability
- Nuclear Materials Control
- Data Processing and Analysis
- Measurements Technology
- Measurement Control
- Physical Protection
- National and Multinational Safeguards
- International Safeguards
- Alternative Fuel Cycles
- Transportation Safeguards

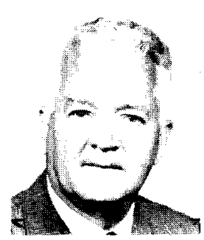
Applicants for this award should prepare an informative summary of the proposed paper. The summary must be a minimum of 400 words but not exceed 600 words in length, and must be accompanied by a 100 word Abstract. A summary is not a complete paper, but must furnish sufficient detail to permit a selective review. The submission should include: the title of the paper, author(s), university/college affiliation, mailing address, telephone number (commercial and/or FTS), references to related work. Summaries are to be submitted by April 1, 1979 to:

Dr. Samuel C.T. McDowell, Chairman
Awards Committee, INMM
U.S. Department of Energy
Office of Safeguards and Security
Washington, D.C. 20545

The winning paper will be presented by the author at the 20th Annual INMM Meeting in Albuquerque, New Mexico, and published in the INMM Proceedings. Notification of the winning paper will be made during April 1979.

For the first time, this student competition is extended to include entries from foreign universities and colleges. The INMM Student Awards Committee encourages and looks forward to the submission of a significant number of high-quality papers from which a selection can be made for the 1979 award. INMM members in the U.S. and particularly abroad are encouraged to bring this award to the attention of their colleges and universities.

The winner of the first annual Student Award was Dr. Carolyn Heising from Stanford University, whose paper titled "Analyzing the Reprocessing Decision: Plutonium Recycle and Nuclear Proliferation" was presented by her at the INMM 19th Annual Meeting in Cincinnati, Ohio, June 1978.



Dr. McDowell

Dr. Heising

Kurihara to Japanese Embassy In Washington, D.C.

The INMM Chairman in conference with Professor Sumiji Fujii, Dean of the Faculty of Engineering at the University of Tokyo.

Dr. **G. Robert Keepin,** Chairman of INMM, visited Japan in September at the invitation of the Japan Chapter of INMM. Dr. Keepin gave a lecture, "Safeguards Technology and Implementation," on Sept. 12 in which he presented an excellent review of recent technological developments in fissile material analysis and accounting. Most members of the Japan Chapter were in attendance at the meeting and Dr. Keepin's detailed description of safeguards technologies was well accepted. A party followed and active informal contacts were established between Dr. Keepin and the chapter members.

The INMM Chairman visited at the University of Tokyo on Sept. 11 at the invitation of Prof. **Ryohei Kiyose.** Dr. Keepin presented a lecture there as well.

He also visited the Japan Atomic Energy Research Institute, Power Reactor and Nuclear Fuel Development Corp., and Osaka University for discussions on safeguards technology and established close contacts with Japanese specialists working in the field.

Dr. Keepin and several chapters' members participated actively in the Second Pacific Basin Conference on Atomic Energy held in Tokyo Sept. 25-29. Dr. Keepin presented a technical paper, "Safeguards Implementation in the Nuclear Fuel Cycle" which was well accepted at the conference. That paper was published in the Fall 1978 Issue of the Journal, Vol. 7, No. 3, pp. 44-58.

Herman Miller, President of National Nuclear Corp., Redwood City, Calif., and Chairman of the INMM Public Information Committee, met with Chairman Kawashima, Vice Chairman Kiyose, and Treasurer R. Hara of the chapter and reviewed recent INMM activities. It was concluded that close relationships should be maintained between INMM and the Japan Chapter and that INMM members traveling to Japan should take part in activities of the chapter whenever possible.

H. Kurihara, an officer of the chapter who was in charge of the National Safeguards Projects at the Science and Technology Agency, was assigned to the counselor for scientific affairs at the Japanese Embassy, Washington, D.C. He plans to help strengthen relationships between INMM and the Japan Chapter.

This report was compiled by **Y. Kawashima, M. Hirata,** and **R. Hara,** officers of the Japan Chapter.

Dr. Keepin met with Officers of the Japan Chapter of INMM while in Japan. First row (l. to r.): Prof. Kiyose, University of Tokyo; Dr. Keepin; and Yoshio Kawashima, Nuclear Material Control Center. Second row (from left): Tsuyoshi Mishima, PNC; Takaaki Shibata, PNC; Toshiyuki Matsuura, Nippon Electronics Co.; Eizo Sugimoto, NMCC; Takeshi Osabe, Japan Nuclear Fuel Co.; and Noboru Kaseda, NMCC, Tokyo.

Safeguards Public Information Program Underway

By Herman Miller, Chairman
INMM Public Information Committee
National Nuclear Corp.
Redwood City, California

Can the INMM provide an effective Public Information program of interest and use to the public and the nuclear industry? The efforts of the INMM Public Information committee will be directed to obtain an unequivocal yes.

In the development and application of central station nuclear power, the major questions unanswered to the public's satisfaction have been boiled down to the few. One of these is Safeguards. Can nuclear material be carefully monitored, measured and protected? As the technical society with the preponderance of personnel dedicated to this effort, the INMM can and must provide the information needed by the public to make these judgments.

Accordingly, the program for the coming year will have as its objective: "Inform public (in broadest definition) that there are effective systems, personnel, and equipment in place for safeguarding nuclear materials and these are being constantly improved by well-planned and well-funded program, both in the U.S. and worldwide."

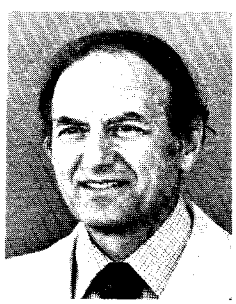
To carry out this program, INMM News Bureau members will be appointed in key areas throughout the U.S. The INMM News Bureau member in each key U.S. city will be responsible for monitoring local news for items favorable or unfavorable, and will supply local news media with nuclear safeguards information. The emphasis will be on continual information flow, but information will also be provided in response to negative media coverage.

The information to be disseminated will be obtained from several sources. A primary source will be the INMM Safeguards Committee. Other information will be obtained from other societies such as ANS, AIF, etc. Information releases from government and industry will also be utilized. Annual and topical meetings, speeches and other events will provide further information. Special projects will be undertaken where necessary.

INMM information will be disseminated only by the News Bureau, and designated INMM spokesmen.

Initial response to the program has been favorable and valuable information and cooperation is being achieved from and with other societies. The first News Bureau members appointed include **Elroy Diatikar, Jr., E.R. Johnson** and **William W. Talley II. Fred Olds** and **Tom Collopy** have also agreed to help.

This is an opportunity for others who want to participate more fully in INMM activities. We need your help. If you have any suggestions or wish to participate in this activity, please contact me at (415) 364-2880, or at National Nuclear Corp., 3150 Spring St., Redwood City, Ca. 94063.



Mr. Miller

HERMAN MILLER (B.S., M.S., A.E., Calif. Inst. of Tech.) is Chairman of the Board, National Nuclear Corp. He left his position as a General Manager in the General Electric Nuclear Division after over ten years to help found National Nuclear Corp. In the following ten years, he has worked on the development and manufacture of nuclear material NDA and safeguards equipment. During recent years, he has been an active INMM member, serving as Exhibits Chairman and, currently, as Chairman, Public Information. Author of over 30 published papers, Miller is a long-time participant in the development of nuclear power and in nuclear safeguards.

First Annual Listing

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Edward Owings
James P. Patterson

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Program (Annual Meeting)
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A. William DeMerschman

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D.W. Wilson

8.3. Nondestructive Assay Calibration
Darryl B. Smith, Chairman
Dennis M. Bishop
Richard N. Chanda

European Safeguards R&D Association

ESARDA

First Symposium on Safeguards and Nuclear Material Management April 25-26, 1979

Brussels, Belgium

The JOINT RESEARCH CENTRE of the Commission of the European Communities is responsible for the organization of the European Communities will be responsible for the organization of the Symposium.

Albert E. Evans
Sydney R. Gaardner
Robert O. Ginaven
Joerg H. Menzel
Merle Parker
Thomas E. Shea

8.4. Nuclear Carimetry Calibration

Francis A. O'Hara, Chairman
David A. Ditimars
John E. Glancy
Ken C. Jordan
Wilfrid M. Mann
Frank L. Oetting
William A. Rodenburg
Walter W. Strohm

9. Nondestructive Assay

Darryl Smith, Chairman

9.1. Material Categorization

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Richard L. Bramblett
Albert E. Evans
John Gray
Francis X. Haas
Michael J. Jump
Hergert E. Smith
Stanley Turel

9.2. Container Standardization

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W.S. Cowan
John H. Gray
Ron Hawkins
James Rushton
Thomas E. Shea
Kale Smay
Charles N. Tesitor

9.3. Physical Standards

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S. Carpenter
P.A. Harlon
M.J. Jump
T. L. McDaniel
W.P. Reed
D. Reilley
W. Rodenburg
P. Ting
N.M. Trahey

9.4. Measurement Controls

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Richard J. Brouns
Willard Brown
John M. Crawford
Edward Eckfeld
Richard Hagenauer
Robert M. Hellen
J. Lechner
Gavin Mallet
Robert B. McCord
Charles M. Vaughn

9.5. Techniques

John P. Stewart, Chairman
Norman S. Beyer
James Griggs
Thomas Crane
Lynn K. Hurst
Keith O. Johson
Herman Miller
Merle A Parker
Hans Weber

9.6. Automation

Walter W. Strohm, Chairman
Ronald W. Brandenburg
Larry East
Kennith Johnson
Norman E. Hall
James L. Lawless
Nicholas J. Roberts
David E. Rundquist
Phillip Ting

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M.J. Cooney
H.M. Dixon
Mark Elliott
W.E. Gilbert
Edward F. Kurtz
E.L. Musselwhite
H.C. Paxton
James Prell
Don Six
A.E. Winblad

IAEA International Symposium On Nuclear Material Safeguards

By James E. Lovett, Past Chairman
Institute of Nuclear Materials Management
Vienna, Austria

The safeguarding of nuclear materials to provide assurance that the clandestine proliferation of nuclear weapon capabilities has not occurred is a highly complex subject. It involves questions of politics, and it involves questions of technology. Moreover, as with many other topics of world interest, the questions of politics and the questions of technology are closely coupled. Political discussions, for example concerning desired quantitative detection goals or timeliness of detection, are influenced by opinions as to what is reasonably possible, and technical investigations are influenced by opinions as to what goals have been or should be agreed to, by a desire not to imply acceptance of a goal by investigating its feasiblity, or by a desire to demonstrate feasibility as a means of gaining support for a proposed goal.

Against this background the IAEA, during the week of 2-6 October, convened a symposium on nuclear material safeguards, titled, "International Safeguards Technology—1978." The symposium was attended by 276 participants from 35 Member States or international organizations. A total of 111 technical papers were presented in 10 technical sessions.

The meeting covered a broad range of topics related to the international safeguarding of nuclear materials. In terms of numbers of papers presented, the majority of the meeting dealt with destructive or nondestructive measurement and verification technology. Audience interest and participation, however, clearly related more to design criteria, safeguards systems development, and advanced material control concepts.

Several papers at the symposium stressed the importance of design criteria and design features, while others discussed design features which had been incorporated into specific facilities and which the authors felt would improve the safeguardability of those facilities. Cost was a factor often mentioned, but those who described actual safeguards design features usually argued that costs were in fact reasonable or even insignificant.

It is striking to compare the four safeguards symposia with regard to the non-destructive measurement of nuclear material quantities. NDA (non-destructive assay) procedures in 1965 discussed sodium iodide detectors coupled to single channel analyzers. Read-out was direct and visual and data manipulation was manual, limited primarily to background subtraction followed by comparison to calibration curves drawn empirically from prepared standards. By 1970 the concept of active interrogation had appeared, and data manipulation, while often still limited in scope, had begun to disappear within the confines of data processors. By 1975 this trend to computerized data processing had become firmly entrenched, and in the present symposium a number of highly sophisticated concepts of data manipulation were discussed.

As data manipulations become more complex, active interrogation has declined, and interest during the symposium seemed to center around two major problems, the NDA determination of burnup and thence residual uranium and plutonium content in spent fuel assemblies, and the measurement of plutonium by neutron coincidence. The notable survivor of active interrogation is the K-edge densitometer, in which a differentiation between atomic species occurs by the use of two gamma energies, one immediately above and one immediately below the K-edge absorption line of the element in question.

Accuracy of NDA measurement has also improved over the years. Systems described during the present symposium of plus or minus 1% or sometimes even a bit better. Modern systems also are remarkably less sensitive to common interfering elements, or are capable of measuring and adjusting for the effect of such interferences.

Advanced or dynamic materials control systems have been developed in a significant number of nuclear facilities, and audience interest in the papers discussing this concept and its applications was high.

The symposium ended with almost a full day of papers on international safeguards during the reprocessing of spent fuels. Most of the papers discussed only further refinements of existing technology, but a Japanese presentation of early material control experience at their newly commissioned reprocessing facility at Tokai, Japan contained encouraging data. It cannot be claimed that the basic problem of safeguarding a large scale reprocessing facility has been solved, but the papers presented at the symposium clearly showed that the technology of the early facilities no longer represents the state of the art.

Mr. Lovett

Should We Spike Nuclear Fuel?

By Herbert J.C. Kouts
Brookhaven National Laboratory
Upton, New York

For several years, there have been repeated proposals for "spiking" of fresh fuel for nuclear reactors. Several concepts of denaturing have been proposed. Some have suggested that highly radioactive isotopes such as cobalt-60 be added to fresh fuel. Others have suggested that fresh fuel might be preirradiated in a nuclear reactor to build in the activity from fission products. Others have proposed that recycle fuel for breeders or other reactors, containing typically plutonium and uranium oxides in varying ratios, might be prepared using a chemical process that leaves some of the long-lived fission products which are hard gamma-ray emitters in with the plutonium. This is one feature of the recently proposed Civex process.

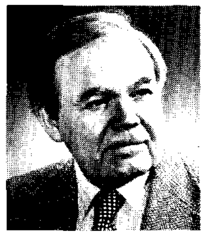
Ideas for spiking are directed at protecting the fissionable material from illicit use, through diversion or theft. Some schemes would protect only the more sensitive material such as fresh plutonium-bearing fuel. Others would protect even less sensitive material such as slightly enriched uranium for light water reactors.

In any case, it is clear that denaturing would in itself do little to inhibit a nation from clandestine production of nuclear weapons using fissionable material in its possession. Any nation with the ability to build a nuclear weapon will have the know-how to shield or remove the activity from a nuclear fuel with relative ease.

Any benefit from spiking must be seen in its value as a deterrent against conceivable subnational threats, such as theft to construct a nuclear device for blackmail or revolutionary objectives. Paradoxically, deterrence could only be accomplished if the use of spiking were widely publicized, and this would be a signal to any possible thieves of precisely what kinds of protective measures they would have to use.

One of the principal disadvantages of spiking is the effect on materials accountability. Even such simple operations as weighing and chemical sampling would be more difficult, more time-consuming, more expensive, and less accurate if they could only be done under hot cell conditions. Methods of assay that depend on measurement of radioactivity would become completely impossible; the background radiation from the denaturant would swamp the desired signal. Since IAEA depends heavily on these methods for its independent verification, IAEA safeguards would suffer substantially.

The price that would be paid for spiking would be heavy, indeed. No steps should be taken in this direction without careful weighing of the damage to safeguards through accountability.



Dr. Kouts

City of Alburquerque

Albuquerque: 1979 Annual Meeting Site, Much to Do and See

By Roy B. Crouch, Chairman
INMM Local Arrangements Committee (1979)
Albuquerque, New Mexico

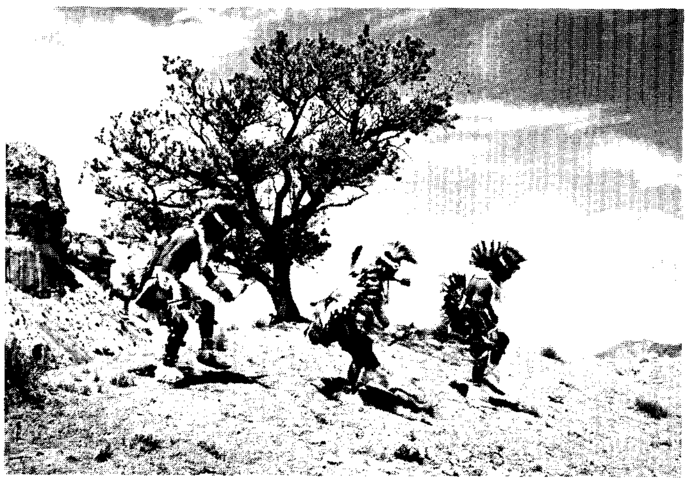
The twentieth annual meeting of the Institute of Nuclear Materials Management will be held in Albuquerque, New Mexico, July 16-19, 1979. Albuquerque besides being one of the most beautiful cities in the world is headquarters of the U.S. Atomic Weapons program. Two of the primary Weapons Laboratories, Sandia (Albuquerque) and LASL (Los Alamos) are also research lead laboratories for the U.S. Safeguards Program. Tours of portions of both these laboratories are planned for July 19th and 20th at the conclusion of the institute meeting.

Albuquerque is one of the oldest cities in the United States (70 years older than the American Revolution). It is a unique blending of three major cultures—Indian, Spanish and Anglo-American. Each has left its mark in food, music, religion, art, architecture, customs, traditions and attitude toward life. It is centrally located to numerous areas of interest, all within an easy day's drive—Carlsbad Caverns and Juarez, Mexico to the south, Grand Canyon to the west and Santa Fe, Taos, the Rocky Mountains, Colorado Springs and Denver, Colorado to the north.

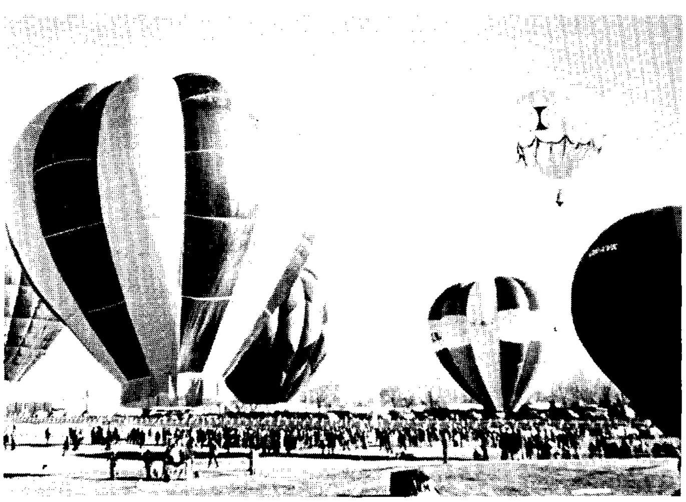
You may wish to plan your vacation around the institute meeting. An extensive women's program is planned with tours of Indian Culture Center and Pueblos, Albuquerque Old Town and the Sandia Mountains, 10,680 ft. via the longest tram in North America. Tickets to the world famous Santa Fe Opera will be available. Transportation will be available at night to Old Town and the Tram.

The meeting will be held in the Albuquerque Hilton. Informality is the unwritten law. This year's annual bash will be an evening buffet, poolside with Mariache Band and Flamenco Dancers.

San Augustin Church at Isleta Indian Pueblo, 13 miles south of Albuquerque, dates back to the early 1600s. Its massive elemental style characterizes 'Pueblo Architecture', a legacy of early Franciscan missionaries.



Spectacular Indian dances occur in the pueblos and on the reservations of New Mexico throughout the year. In the spring and summer, the dances pertain to planting and crops; in the fall, they are ceremonies of gratitude for a bountiful harvest; and in the wintertime, they are usually animal or hunting dances—a wish for good hunting and much meat on the table. Photo courtesy of Dick Kent.



Albuquerque is a center of ballooning activity. The balloonists who crossed the Atlantic Ocean this past year hail from New Mexico's largest city.

The longest tramway in North America whisks visitors to the top of the 10,378 foot high Sandia Peak, *just minutes from downtown* Albuquerque. A summer playground among tall pines and alpine flowers, a winter playground for snow enthusiasts, Sandia Peak offers a spectacular panorama of 11,000 sq. miles.

TRADITIONAL PUEBLO DRESS—The dark colored "manta" (one shouldered over dress) covers a lacy underdress worn by this lovely Pueblo Indian woman. The traditional dress includes handmade moccasins, a woven belt and of course, the handcrafted turquoise and silver *Indian jewelry. Photo: Courtesy of Indian Pueblo Cultural Center.*

BOOK REVIEW

Review of "Nuclear Power and Nuclear Weapons Proliferation," report of the Atlantic Council's Nuclear Fuels Working Group, Westview Press, Boulder, Colorado (Vols. I and II, $6 each).

By Eugene V. Weinstock
INMM Book Review Editor
Brookhaven National Laboratory
Upton, New York

There are, roughly speaking, two different schools of thought in the U.S. concerning nuclear proliferation policy. One is that the international regime developed laboriously since President Eisenhower's 1953 Atoms-for-Peace proposal has, by and large, worked pretty well but, as more nations approach the threshold of nuclear capability, is in need of strengthening, expansion, and the development of new, cooperative institutional and political forms. This approach is sometimes termed "incrementalist," presumably because of its belief in the gradual evolution of policy, building on what has gone before.

The second school of thought, given great impetus by the Indian explosion in 1974, holds that the past policy is, at the very least, outmoded and will become increasingly so if nuclear power with its full range of fuel-cycle activities is allowed to spread world-wide. This latter school is represented most heavily in the State Department and Arms Control and Disarmament Agency and has been in the ascendancy in the present Administration. It views nuclear power not so much as a promise of abundant energy in an energy-hungry world as a problem in arms control. In fact, the former role is acknowledged only grudgingly, if at all, as demonstrated by President Carter's opening speech before the organizing conference of the International Nuclear Fuel Cycle Evaluation in October, 1977. One senses, underneath the bland assurances of support for the "once-through" light-water-reactor fuel cycle, at best an indifference to nuclear power as an energy source and, at worst, a deep-seated hostility to it. Perhaps it is no accident that many of the leaders of this school come from the universities, where the anti-nuclear movement is strongest.

The views of this second school have been set forth most fully in the recent Ford-Mitre study, "Nuclear Power Issues and Choices" and in the Pan Heuristics report, "Moving Towards Life in a Nuclear-Armed Crowd?" both of which have had great influence in the present Administration. In essence, this school would rely much more strongly on a policy of technological denial and the coercive use of the near monopoly the U.S. still enjoys in the commercial enrichment of uranium to impose stricter controls on nuclear energy than the international community has hitherto been willing to accept.

Dr. Weinstock

Now comes a forceful and concise exposition of the views of the opposing camp, in the form of a policy paper by the Nuclear Fuels Working group of the Atlantic Council, entitled "Nuclear Power and Nuclear Weapons Proliferation." (The Atlantic Council is a non-profit, bipartisan citizens' organization dedicated to the study of and the fostering of public debate on major issues of international security, economics, and politics). In 135 well-written pages it identifies the issues, presents the history of non-proliferation policy, analyzes the contending arguments, and proposes a spectrum of measures for coping with the potential dangers of unrestrained nuclear power while preserving its promise of energy.

Actually, to describe the proponents of the two different points of view as forming "opposing camps" is a considerable oversimplification. Despite the difference in attitude, already noted, they share many similar concerns, and there is a great deal of common ground in their positions. Nevertheless, the differences are genuine and important, as a reading of the Atlantic Council report makes clear.

The report is issued in two volumes, the first containing the analysis and conclusions and the second consisting mostly of appendices containing much useful reference material and some dissenting opinions or amplifications.

We shall skip over the first of the eight chapters in Vol. I, since it is only an executive summary, for the headline readers. The second chapter, an introduction to the issues, gives the background of the change in domestic attitudes and policies towards the non-proliferation issue, summarizes the Carter policy and its implications, and discusses the criticisms and doubts of other nations towards it and the relationship between the developing countries and proliferation. Concerning the last, it warns that "there should be no **a priori** judgment that a permanent class of 'third world' countries has no need for nuclear energy," and points out that "the most likely candidates for proliferation are precisely those developing countries that are already substantially industrialized . . ." So much for the absurd fears of **Idi Amin** and **Colonel Qaddafi** that anti-nuclear extremists love to invoke.

Of startling import in this chapter is the suggestion it cites by Dr. **Fred C. Ikle,** past director of ACDA, that the U.S. may be developing a new concept of proliferation, under which the acquisition by a country (Pakistan was the specific example) of a commercially unjustifiable reprocessing plant would, in itself, be an act of proliferation. This view is in almost flat contradiction of the earlier U.S. interpretation of the NPT, offered by another past director of ACDA, Dr. **William C. Foster,** in testimony before Congress during the negotiation of the Treaty, that it "clearly permitted . . . the development, under safeguards, of plutonium-fueled power reactors, including research on the properties of metallic plutonium . . . and fast breeder reactors . . ." (see p. 93 of **Mason Willrich's** book, "The Non-Proliferation Treaty: Framework for Nuclear Arms Control").

The report also distinguishes between the short-term and the long-term proliferation threats. The short-term threat involves the 10 or 20 "threshold" countries capable of developing nuclear weapons now, while the long-term threat is the emergence of new threshold countries. The former threat requires a case-by-case approach, while the latter, toward which the Administration's policy seems primarily to be directed, permits a more general and abstract approach.

The issues raised by the development of the plutonium-fueled breeder reactor are explored in the next chapter. A number of important points are made, among them that the long lead times for development and deployment require starting now; that the development of advanced converters and other types of breeders will take at least as long and cost at least as much; that development and demonstration are different from actual deployment and that the former does not **have** to be followed by the latter if it turns out to be uneconomical or unnecessary; that global uranium resources are less important to most countries than their own energy supply and demand situation; and that even with the present uncertainty in costs, it is highly likely that the breeder will be competitive with conventional sources of energy some time around the turn of the century. Efforts to inhibit the development of the breeder in another country are likely to be regarded as intrusive and threatening, while unilateral controls or conditions on export could weaken assurances of supply and might actually lead to a more rapid development of the breeder, especially since in the eyes of many nations the safeguards problems of the "plutonium economy" are subordinate to those of assuring adequate energy. Alternative fuel cycles are considered worthwhile exploring, but are probably less important or promising than developing institutional controls.

To this reader, the high point of the report is Chapter III, entitled "How We Got Where We Are," a vivid and fascinating account of the evolution of American non-proliferation policy, written by someone who, judging from the intimate knowledge of negotiations revealed in the chapter, must have been personally involved in many of them.

The account begins with the background of the first attempts to control the spread of nuclear technology. After the rejection of the Baruch plan, these were based on a policy of secrecy and denial. The great emphasis at this time was on the difficulties of the production of fissile material because, the authors suggest, the vast majority of the effort during World War II was on this aspect while, by contrast, the actual design of the weapon had been made to appear easy by the brilliant assemblage of scientists who worked on it.

The American atom-bomb monopoly was broken in 1949 by the Russians, and in 1952 the British exploded their first weapon. By 1953 there were reactors in France, Canada and Norway, as well as in the U.S., U.K., and U.S.S.R. It was obvious that the policy of secrecy and non-cooperation was not working, and in 1953, in a dramatic reversal of the earlier policy, President Eisenhower proposed his Atoms-for-Peace plan, calling for an accelerated development of nuclear energy and worldwide cooperation in this endeavor. It is fashionable in some quarters today to blame Atoms-for-Peace for greatly increasing the risk of proliferation; indeed, one such critic recently attacked the plan as "the stupidest thing the United States ever did." This attitude, however, betrays an ignorance of both the history of the policy, which was prompted by a failure of the policy of denial, and of the complex motives behind the change, which were not entirely altruistic. Two of these were the desire to generate a more receptive attitude internationally towards the U.S. possession of nuclear weapons, by demonstrating that it had certain peaceful side benefits, and to draw the U.S.S.R. into a dialogue on nuclear matters.

"Atoms for Peace" was followed, in rapid succession, by the Atomic Energy Act of 1954, the first Geneva Conference on the Peaceful Use of Atomic Energy, the first U.S. bilateral agreements for nuclear cooperation with a number of countries, and the founding of the International Atomic Energy Agency. The chapter provides some interesting and, to this reviewer, new insights into these developments. For example, in the beginning many nations were distrustful of international safeguards, preferring to deal directly with the U.S. The reason was a fear of unpredictable political pressures from an international organization which might become the captive of some hostile bloc. (South Africa and Israel are two countries today that might have such reservations.) Another example is an explanation of the peculiar way in which the continuous presence of inspectors is recognized as a legitimate safeguards measure in one of the fundamental safeguards documents of the IAEA, INFCIRC/66. Acceptance of this important principle appears only as an easily overlooked footnote to an annex on bulk processing plants. The explanation, according to the author, is that all the other countries except the U.S. were opposed to the idea, but finally agreed to it on condition that the provision be expressed in the most inconspicuous possible manner. Of such stuff is diplomacy made.

The chapter makes some important points based on this history, points that are also often ignored by the critics. One is that the language relating to reprocessing in the various IAEA statutes and the U.S. bilaterals on which they were based makes it clear that exercise of the right of approval of this activity was to be for the sole purpose of ensuring that adequate safeguards were employed. The restriction was therefore not on reprocessing but on the **means** of reprocessing. In other words, at the outset reprocessing and the re-use of plutonium were viewed by both the U.S. and the IAEA as natural and desirable, contrary to present claims made in some quarters that the non-proliferation regime established then was never intended to cope with the widespread use of plutonium.

A second, more fundamental, point is that, as the history of negotiations for the NPT makes clear, nations might accept the principle of non-proliferation but not that of interference in the peaceful uses of nuclear energy. One was a **quid pro quo** for the other, and the ability of the U.S. to get strong safeguards depends on its ability and willingness to contribute to these peaceful uses.

Serious reconsideration of the policy of nuclear cooperation began in the 1970s, as a result of the confluence of five major events or movements: the Indian explosion, the rise of terrorism, Nixon's offer of reactors to Egypt and Israel, the rise of the environmental movement and the increasing mistrust of the establishment, and the threat of a rapid spread of nuclear power, stimulated by the quadrupling of oil prices and resulting in offers to sell reprocessing plants to Brazil, Pakistan, Iran, and Korea.

In Chap. IV, the institutional obstacles to proliferation are reviewed. Topics included are the role of the NPT, safeguards, the IAEA, export controls, agreements for cooperation, etc. The effectiveness of these institutional controls is demonstrated by contrasting the relatively rapid spread of nuclear technology with the slow spread of nuclear weapons. "Cooperation in peaceful uses under controls," it is suggested, "has made it possible to remove the cloak of legitimacy from uncontrolled national nuclear efforts, and has contributed to the development of a world consensus that the acquisition of nuclear weapons is an undesirable and illegitimate goal." It follows that severe restraints on such cooperation may actually help legitimize unsafeguarded efforts.

The cooperation included the transfer of reprocessing technology, which the Atoms-for Peace program required and for which it got Congressional authorization. In a telling thrust at those who would put their faith in the denial of technology, it is remarked that "this action was consistent with the long-held attitude that the control of information (unless classified) not only presented enormous administrative problems but is inconsistent with U.S. traditions with respect to the transmission of ideas." Since the spread of technology is inevitable, at most one would gain only a few years by a policy of denial, a time which would be better spent developing a long-lasting multinational system containing the most likely proliferators.

In three subsequent chapters, the relationship between nuclear power and proliferation, possible institutional innovations, and the elements of a nonproliferation strategy are analyzed and discussed. One of the more interesting questions considered in these chapters is that of the role of sanctions. It is proposed that these be of two kinds: automatic, predetermined sanctions for clear violations, and a presumption of sanctions for ambiguous violations. A variety of specific sanctions, not all nuclear, is considered. Not raised are the prickly questions of how long sanctions should be applied following a violation and under what conditions they would be lifted.

The central importance of political security to a decision to acquire nuclear weapons is addressed. Measures of relief that are proposed include security assurances and the promotion of regional security agreements. Again, however, a key question is not asked: Is the U.S. in any mood or position to offer such assurances? The example of the withdrawal from South Korea does not offer grounds for optimism.

An intriguing suggestion is made in connection with an international fuel cycle authority as one institutional alternative for the control of sensitive nuclear facilities. It "may be possible to develop arrangements . . . for genuine international **jurisdiction**—not simply **inspection rights**—over [such facilities] and their product . . ." The actual management and non-safeguards operations could then be under either national or multinational control. A potential variation is to locate such a center in an international enclave, which would strengthen the inhibition against seizure by the host nation.

The role of both suppliers and recipients of nuclear technology is scrutinized. "Nuclear-weapons states" must accept the role of nuclear power as an alternative energy source, recognize the importance of economic and security incentives instead of downplaying them, and acknowledge that the possession of nuclear weapons itself constitutes a threat to non-proliferation. Actions such as those taken by the London Suppliers Group and unilaterally by the U.S. and Canada are only temporary and stop-gap in their effectiveness, since they are imposed by one group on the other, instead of being a mutual undertaking. Indeed, from the point of view of the Third-World recipients, non-proliferation policy as practiced by the U.S. and U.S.S.R. is but one more instance of paternalism and is offensive to their sovereignty. This view is fortified by the nature of the remedies being proposed: the embargo of fuel-cycle facilities or the elimination of nuclear power altogether. There is also a one-sidedness with respect to trust—recipients are expected to trust the weapons states not to use nuclear weapons, but the latter are not required to trust the former's non-proliferation undertakings.

The report concludes with seventeen recommendations for strengthening the non-proliferation regime, which I won't try to list here. Some of them are already being pursued by the present Administration. The emphasis here, however, is on recognition of the importance of nuclear energy to the world and on cooperation in both its development and use and in its control, without arbitrary restrictions on peaceful activities.

To conclude, this is a sensible, well-written, persuasive, and, at times, provocative report. I have only a few minor criticisms. At one point it is suggested that almost as many research reactors as power reactors, worldwide, are producing plutonium. This is an exaggeration, since many research reactors use highly enriched or medium enriched uranium fuel and produce very little plutonium. On several occasions it is proposed that steps be taken to improve the safeguards of spent-fuel shipments, a problem which anyone familiar with safeguards would recognize as deserving the lowest priority. More serious and somewhat disquieting is the recommendation that foreign and domestic policy, especially with respect to nonproliferation and energy, be more closely integrated. The development of nuclear energy in the U.S. has already been badly damaged by an unwarranted intrusion of foreign policy into domestic affairs, and there is good reason to fear that any further "integration" of the two would soon actually degenerate into a subordination of the latter to the former.

However, these are minor quibbles indeed, hardly enough to detract from the general excellence of this report, which can be recommended wholeheartedly to the readership of the INMM Journal.

Variation on the Theme Of Small-Sample Comparisons

By **Yvonne M. Ferris**
Rockwell International
Golden, Colorado

Still smarting from missing the deadline for the "INMM Member Interest Questionnaire," I was naturally delighted when **Tom Gerdis** requested that I write a guest editorial for the Journal. I was being offered another chance for MY VIEWPOINT to be heard.

My glee and pride in this task lasted until I sat pen in hand before a blank sheet of quadrille paper (metric, of course). The keen wit and poignant observations with which I had planned to dazzle my readers faded faster than the acidification of solutions in the presence of a phenolphthalein indicator. Glancing desperately around my office in hopes that the random thoughts in my head would gel eventually, I noticed a recent statistical publication entitled "Small-Sample Comparisons." The thought occurred to me that that is exactly what a guest editorial is—a sample of one (1), with which others compare their opinions. The remainder of this article, therefore, is concerned with a single viewpoint about a subject known to us all—professional societies.

Soon after I located in Vienna to begin my tenure with the International Atomic Energy Agency, I suddenly realized I no longer had any professional society meetings to attend. In assessing this fact there was a strange mixture of panic, depression and relief. Panic because the people whom I once could call for professional advice were now an expensive and timewise inconvenient phone call away. Depression because finding out what was new in the world of statistics, nuclear materials control, and management would have to come through the literature or chance meetings with long known professional acquaintances. Relief because now I had a few more days out of every month to call my own. I soon discovered this was too great a price to pay for "free time."

Lacking a monthly, quarterly or annual contact with my professional associates, I created a surrogate contact out of paper—the newsletters, the journals, the pamphlets. I was starved for news of what my colleagues were proposing, evaluating or accomplishing. Reading their articles was akin to carrying on a one way conversation with a time delay of 6 to 12 months, but it was better than encouraging a personal, mental vacuum. In addition to the journal articles I read the advertisements, the summaries of local programs in Dayton, New Orleans or wherever, and the personal news. Believe me, the pictures as well as the featured articles in the INMM Journal have not gone unnoticed or unread by me.

Y.M. Ferris

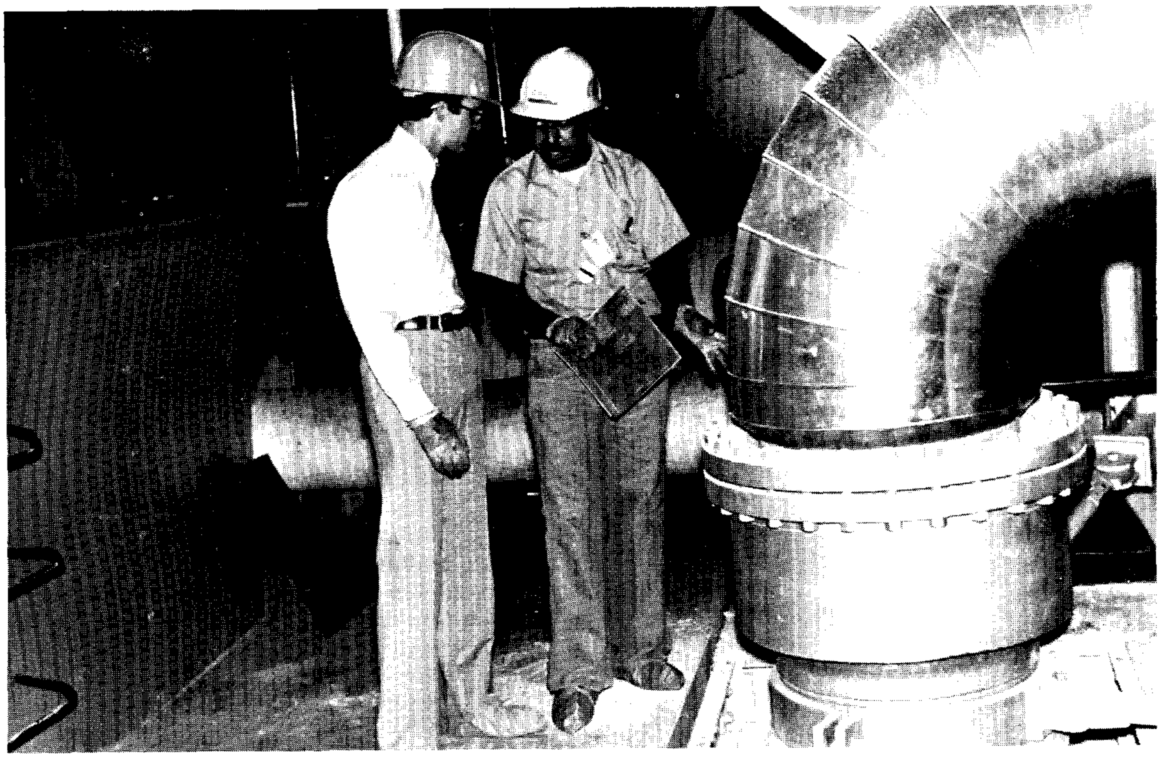
In November the citizens of Austria voted on a referendum which was to decide the future of their nuclear industry. I longed for an organization other than industry or the government which could counter the extremely effective campaign conducted by the "Atomkraft? Nein, Danke" group. We needed an organization which could educate the unscientifically inclined, assure the frightened, and explain the issues clearly so that the voters could make a decision based on facts and not emotion. A Speaker's Bureau with a ready reserve of informed citizens (neighbours) which normally exists within a professional society was definitely needed—one that might have existed in a local body of the INMM, for example.

Admittedly, the above reflects a rather passive relationship between myself and professional societies—enjoying or gaining from what they do for me but doing or offering nothing in return. This relationship results from a current lack of professional societies to which I can tangibly contribute my time and energy. I actually have found that now I miss such inane activities as updating and rectifying membership lists, publishing newsletters to inform the membership of its society's activities, and many other bits of trivia on which I spent my time and by which all organizations are kept alive. Although I do not thrive on such menial tasks as licking envelopes, I do thrive on the results of improved attendance, a well informed membership and effective organization.

For me, therefore, professional organizations fulfill a need for keeping up with what's current, meeting the "new blood" of the profession, expressing a professional opinion, and socializing with those whom I otherwise see only in a business or industrial setting.

The INMM lives up to all of the above and I con-

(Continued on Page 40)



Carolina Power & Light Company officials discuss the function of a Barco Type N 24-inch ball joint at the Brunswick nuclear power plant. (Note the protective booties, gloves and hardhats being worn.)

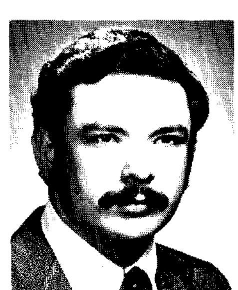
Security: A Way of Life In a Nuclear Power Plant

By Wayne D. Thomas
Public Relations Manager
Aeroquip Corporation
Jackson, Michigan

Editor's Note: The following article is reprinted with permission from the September 1978 issue of THE FLYING A magazine. Mr. Thomas holds a B.S. degree in journalism from Bowling Green State University and a M.A. degree in journalism/public relations from Ball State University. Prior to joining Aeroquip Corporation in 1977, he was a senior staff writer for Libbey-Owens-Ford Company.

A recent FLYING A visit to the Brunswick Nuclear Power Plant was a unique experience; and we came away with a greater respect for the elaborate security precautions attendant to the safe operation of a nuclear facility. Once past the plant's attractive reception area, we were issued visitor badges and were escorted into a stark, almost antiseptic environment manned by uniformed, armed contract security guards.

Mr. Thomas



The security precautions at the Brunswick plant are required by the Nuclear Regulatory Commission for all nuclear plants.

The first order of business was to fill out detailed report forms indicating our nationality, social security number, reason for visit, past history of radiation exposure and numerous other questions.

Next came a scene straight from the old "Dragnet" TV series. Three of us, myself, the photographer and even our CP&L host from company headquarters in Raleigh, were lined up and frisked by a security guard.

Our photography equipment was then checked before we were allowed to proceed to the next security area, entering through doors controlled electronically by a guard sitting behind a bullet-resistant glass enclosure.

Here too, uniformed, armed security guards were very much in evidence, monitoring the flow of people going into and exiting the generating plant. More forms were required to be filled out and another badge was issued to us (which later would be checked for exposure

RESIGNATION AT LASL EFFECTIVE MARCH 1

Dr. Agnew Accepts General Atomic Presidency

Editor's Note: Dr. Agnew has been a special friend to INMM in recent years. The Staff of the Journal extends him its very best wishes in his new position as President of General Atomic Company, San Diego, Calif.

LOS ALAMOS, N.M.—In a letter dated October 27, 1978, to University of California President Dr. **David S. Saxon,** Los Alamos Scientific Laboratory Director Dr. **Harold M. Agnew** stated his intention to resign his position as Director effective March 1, 1979.

A successor to Dr. Agnew will be named by the University of California, which operates the Laboratory under contract to the Department of Energy.

Dr. Agnew, 57, was a member of Enrico Fermi's team which worked on the first nuclear fission chain reaction at the University of Chicago in 1942. He came to Los Alamos in 1943 as a physicist and flew with the 509th Bombardment Group as a member of the scientific team on the first nuclear weapon strike against Hiroshima.

Dr. Agnew earned his Ph.D. at the University of Chicago in 1949 and returned to Los Alamos. From 1961 to 1964 he was Scientific Advisor to the Supreme Allied Commander in Europe at NATO headquarters in Paris. He returned to Los Alamos in 1964 as head of the Weapons Physics Division.

On September 1, 1970, Dr. Agnew became Director of the Laboratory. He received the **E.O. Lawrence Award** from the U.S. Atomic Energy Commission in 1966. He is a Fellow of the American Physical Society, a Fellow of the American Association for the Advancement of Science, and a member of the National Academy of Engineering.

Dr. Agnew is only the third Director LASL has had since the Laboratory was established in 1943. He succeeded Dr. **Norris E. Bradbury** in 1970 who had succeeded the late Dr. **J. Robert Oppenheimer** as Director in mid-October, 1945.

Dr. Agnew

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to radiation).

From this point, we left the "real" world behind, and entered a maze of corridors filled with helmeted, bright orange uniformed plant workers wearing badges indicating which areas they were authorized to enter.

After issuing us hardhats, surgical-type booties and plastic gloves, we proceeded through a futuristic science-fiction environment where we fully expected that Agent 007—James Bond—would appear at any moment.

To gain access to the areas which we wished to photograph, our plant guide was issued a set of keys which unlocked massive steel doors set into four-foot thick concrete walls.

Before entering the area where Barco ball joints are used to compensate for pipe movement on massive steam turbines, we were required to don our gloves and booties as a precaution against coming into contact with radioactive dust or other material. A ball-point pen accidentally dropped on the metal grating floor had to be discarded in a nearby waste bin.

Finishing that portion of our photography assignment, we each in turn stood on a rubber mat at the exit door. Lifting one foot at a time we pulled our booties off with our rubber gloves. We used our right hand to remove the left glove and then with our left we carefully worked our fingers underneath the protective plastic to peel off the right glove, without touching the exposed portion of the glove. The same procedure was duplicated as we entered a second area to photograph on-the-job use of Aeroquip products.

At the end of each photo session we were required to stand on a platform and insert our feet and hands into a machine which gave a radiation reading. A series of flashing colored lights, moving from left to right culminated in an "all clear" green signal light.

When we finished our photography and interview work it was back to the point of entry again to turn in our hardhats and badges. Our cameras were given a thorough check with a hand-held geiger counter and our guide took a sight reading from a small instrument resembling a pen-light flashlight which he had carried clipped to his shirt throughout the day.

To our collective relief, the instrument indicated that we had not been exposed to any radiation. Despite this fact, before our final exit we each had to enter a small isolation chamber where once again a series of flashing lights, finishing with a green signal, indicated that we were "clean."

We all left the plant with a new perspective about security precautions which exist in a modern nuclear-powered electrical generating plant. We can all be thankful safety is considered to be the most important job in the entire operation.

INMM Chairman Visits Austria, Japan

By Tom Gerdis, Editor
Nuclear Materials Management
Manhattan, Kansas

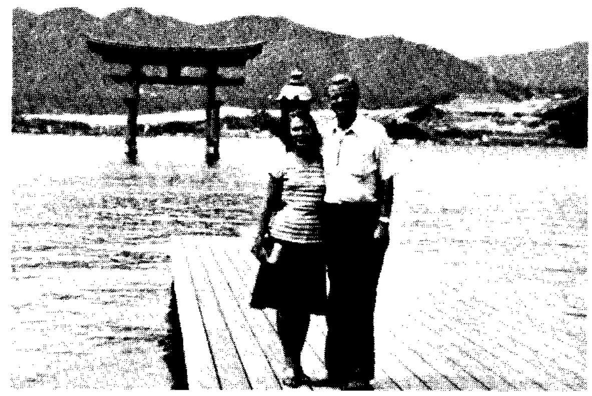
INMM chairman **Bob Keepin** recently visited Japan and Austria on a round-the-world trip that included lectures, tours, and briefings on safeguards technology at various nuclear establishments and universities in Japan and the International Atomic Energy Agency in Vienna.

At a meeting of the Japan Chapter of the INMM, chairman Keepin delivered an address on "Recent Developments in Safeguards Technology" and later met personally with officers and Executive Committee members of the Japan Chapter in the Japan Nuclear Materials Control Center in Tokyo. At the Tokai Mura nuclear complex he lectured and participated in discussions on safeguards technology and in-plant application of advanced safeguards systems with staff members of the JAERI (Japan Atomic Energy Research Institute) and PNC (Power Reactor and Nuclear Fuel Development Corp.) facilities. He received extensive briefings and tours of various installations at JAERI and PNC—including the Tokai Mura Reprocessing Plant and the highly automated Mixed-oxide Fuel Fabrication Facility at PNC.

Later Keepin presented an invited paper "Safeguards Implementation in the Nuclear Fuel Cycle" at the Second Pacific Basin Fuel Cycle Conference, September 25-29, in Tokyo. (This paper was reprinted in the Fall, 1978 issue of the INMM Journal.) At the invitation of the University of Tokyo and Osaka University, he conducted seminars in the Nuclear and Chemical Engineering Departments, and was given briefings and tours of the various research and development facilities in the respective Universities.

Bob Keepin's extensive visit to Japan was, in his own words "extremely informative, worthwhile and enjoyable" and the experience left him "greatly impressed with the long-range commitment Japan is making to nuclear power and the nuclear fuel cycle, as well as a commensurately strong commitment to international nuclear trade under effective international safeguards." He adds that Japan, as one of the first major industrial nations to ratify and implement the NPT, is a recognized leader in international safeguards, and is likewise a leading proponent of international cooperation in nearly all areas of the nuclear fuel cycle including resource exploration, reliable fuel supply, nuclear trade, and safeguards technology implementation and evaluation.

At the IAEA Symposium on Safeguarding Nuclear Materials in Vienna, Oct. 2-6, Keepin chaired Technical Session VIII, "Advanced Material Control Systems," and co-authored an IAEA/US joint paper with **Jim Lovett** of IAEA entitled "The Potential Value of Dynamic Materials Control in International Safeguards." (Reports on the Vienna Safeguards symposium have been prepared for the Journal by Jim Lovett, a former INMM Chairman, and **Vince DeVito,** INMM Secretary, and are published elsewhere in this issue.)



Taking time out for some sightseeing in Western Japan, Bob and Madge Keepin visit Itsukushima Shrine at Miyajima, an island near Hiroshima, Japan.

In summarizing the overall impression of his world trip, Chairman Keepin cited the increasing and widespread awareness and appreciation of the global nature of safeguards and nonproliferation issues, and the corresponding need for international consensus and cooperation in achieving a workable, effective international safeguards system, which is so important to the future of nuclear power worldwide.

It may be added as a timely postscript, that these observations by the INMM Chairman fit in very well indeed with the "International Safeguards" theme of the Institute's 1979 Annual Meeting next July in Albuquerque, N.M.

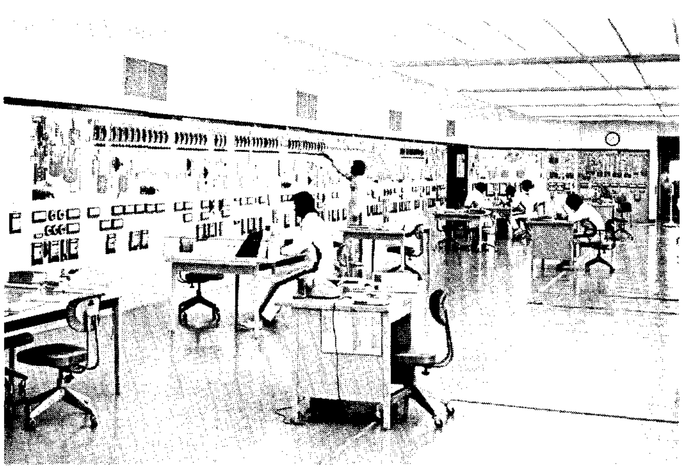
Mr. Gerdis

Bob Keepin addressing the Second Pacific Basin Fuel Cycle Conference in Tokyo on the topic "Safeguards Implementation in the Nuclear Fuel Cycle."

Bob Keepin discusses absorption edge densitometry in a lecture on "Recent Developments in Safeguards Technology" to the Japan chapter of the INMM on September 12 in Tokyo.

Bob Keepin and Yutaka Yamamoto, Commissioner, Japan Atomic Energy Commission, co-chairing Session IV, "The Nuclear Fuel Cycle," at the Second Pacific Basin Fuel Cycle Conference, September 25-29 in Tokyo.

Jim Lovett, Scientific Secretary and Bob Keepin, Session Chairman (Session VIII, "Advanced Material Control Systems") at the IAEA International Symposium on Nuclear Materials Safeguards, Vienna, Austria, October 2-6, 1978.



Central Control Room of the Tokai Spent Fuel Reprocessing Plant. Completed in 1974, the plant uses the Purex process and has a capacity of 700 Kg/day; product is UO_3 and $Pu(NO_3)_4$.

At the Pacific Basin Conference, banquet reception, l to r: INMM Chairman, Bob Keepin; Edward Hennelly, President-elect of the American Nuclear Society; and Akira Oyama (Director, PNC, and General Chairman of the Pacific Basin Conference).

Small-Sample Comparisons: Ferris

(Continued from Page 35)

tinue to enjoy my relationship with it. In today's vernacular, however, that's the good news. The bad news is that the Institute in my opinion suffers from two distinct but related weaknesses. The first is its extremely low profile. I believe the Institute should take on the responsibility of educating the public concerning the nuclear industry. We do a fantastic job of teaching each other about statistics, nuclear material accounting, states' systems, and on and on. in addition to this I would like to see a program aimed at informing the non-nuclear community. This program would include but not be limited to reinitiating a Speaker's Bureau, offering special programs for students from junior high school through college, preparing and distributing literature in areas dominated by anti-nuclear forces. The bumper sticker which refers to THEM "freezing to death in the dark" is unfortunately referring to all of us. The membership of the Institute must help the general public understand that its current attitude toward nuclear power will result in a slow, torturous death.

The second area of weakness, again in my opinion, is in the political arena. I realize the Institute is probably not yet strong enough and affluent enough to lobby in the strictest sense, but we are in a position to strengthen our friendly persuasion. Conceding the point that some of our members are active in this area, they nevertheless are clearly acting as individuals and not as spokesmen for the INMM. The Institute needs greater visibility through resolutions, letters, delegations, etc. These techniques cost little in money and time when compared to the cost of inaction. Even a voice crying in the wilderness is better than an inaudible whisper in the city.

The INMM recently celebrated its 20th anniversary. Its history and accomplishments are well known to most of us. It is a firmly established organization and beginning to expand internationally. Survival is no longer the issue it might have been during the Institute's infancy. Realizing that the INMM is dedicated to the advancement of Nuclear Materials Management as a profession, let us also realize that if the nuclear industry is not given a chance to develop fully and be utilized in a safe and profitable manner for all of us, there will be no need for the profession of Nuclear Materials Management.

(Continued from Page 13)

that no long-term technical reasons exist to forestall adoption of the nuclear option where practical. It is for this reason that it is important that the Institute continue to aggressively pursue the complete definition of professional methods through consensus standarization.

Many public-minded members of the nuclear community have been telling Congress that it is time to stop studying and take action to solve today's energy needs. The same challenge can be posed to each Institute member. Get involved in the new wave of Institute activity. Participate on a N15 Standards Committee writing group or one of the other standing committees which are organized to funnel Institute energies into constructive and affinitive public action. It is hypocritical to accuse the public of apathy and not contribute our own technical energies to replacing such attitudes with assurance. Your help is needed now, not after public opinion is even more negatively set by so called environmental groups. **Please take action now.**

SUBCOMMITTEE	SCOPE	NUMBER OF STANDARDS		
		Issued	Under Development	Proposed
INMM-1	Accountability and Control Systems	6	1	2
INMM-3	Statistics	4	1	3
INMM-4	Records and Reports	1	1	
INMM-5	Measurement Controls (Proposed)			1
INMM-6	Inventory Techniques	1	1	
INMM-7	Audit Techniques	1	1	
INMM-8	Calibration	4		
INMM-9	Nondestructive Assay	1	6	
INMM-10	Physical Security	1	1	1
INMM-11	Certification		1	
INMM-12	International Safeguards (Proposed)			1
INMM-13	Transportation (Proposed)			1
	TOTAL:	19	13	9

IAEA Funding

By **E.R. Johnson**
E.R. Johnson Associates, Inc.
Vienna, Virginia

In the light of the current worldwide concern over nuclear proliferation, the International Safeguards Program of the International Atomic Energy Agency assumes particular importance. One would, however, not immediately recognize the importance of this program if the level of funding of the program in recent years is used as a guideline. In 1976, the total safeguards portion of the IAEA budget was slightly under $6.5 million and represented only about 19% of the total budget of the IAEA. In 1977, the IAEA safeguards budget was $7.9 million and, in 1978, was increased to $12 million. In addition to these budgeted funds, the Agency receives some support in the way of studies in safeguards technology by member states, particularly the U.S.

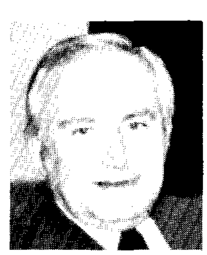
In view of the widespread belief that a potentially attractive way for a non-weapons state to acquire a nuclear weapon capability is through diversion of special nuclear material from facilities intended to serve peaceful applications of nuclear energy, the Agency's facility inspection program in member states becomes an especially important part of the overall safeguards program. When one recalls that in 1970, Congressman **Craig Hosmer** stated that the Agency needed a safeguards budget amounting to $100 million annually, it is clear that the recently increased funding for the safeguards program falls far short of being adequate to establish and operate an effective worldwide safeguards inspectorate, and it is equally clear that as the number of nuclear facilities increases in the world, the disparity between available funding and needed funding will become even greater. This problem is further exacerbated by the inclusion under the Agency's inspection program of a vast number of facilities in nuclear weapons states.

In the light of these observations, the agreement by the U.S. government to place selected nuclear facilities which are not directly related to national security under the Agency's inspection program raises some serious questions involving the dilution of Agency efforts under an already strained budget as well as the imposition on the U.S. industry of increased costs for dubious benefits. In the U.S., all facilities which would be subject to the Agency's inspection program are either licensees of the Nuclear Regulatory Commission or contractors to the Department of Energy, and as such are subject to the full scope of the U.S. safeguards program through the regulations of the NRC or administrative and contract requirements of the DOE. It seems doubtful, therefore, that the imposition of Agency safeguards on U.S. facilities will result in any more effective control over strategic nuclear materials than that provided currently through these instruments. Agency inspectors are not able to revoke licenses or contracts, impose fines, or to take other actions necessary to force the correction of deficiencies. Agency safeguards also do not cover physical protection of plants and facilities.

It appears that, although the Agency's safeguards program will involve a larger number of U.S. facilities, "full scope safeguards" will apply to only about 10 U.S. facilities at any one time. All facilities under the purview of the Agency program will be required to submit reports, design information and procedural materials related to the nuclear material accountancy program; those under the "full scope safeguards" will in addition be routinely inspected by Agency teams. Amongst the facilities covered by the Agency program in the U.S. will be those processing natural and depleted uranium and thorium—which are not now subject to the safeguards regulations of the NRC or to DOE contractual safeguards requirements. Therefore, the application of Agency safeguards in the U.S. will involve coverage of more material types and more facilities than are now covered by domestic safeguards activity and will involve additional (or different) reports and record keeping systems.

The principal rationale for subjecting weapons states facilities to Agency safeguards is to provide these facilities with the same exposure to cost, inconvenience, and the disclosure of process and design information as

(Continued on Page 44)



Mr. Johnson

To Cope with Proliferation

By Dr. Frederick Forscher
Energy Management Consultant
Pittsburgh, Pennsylvania

In an energy-short world we must pay special attention to any material that promises to meet the growing demand for kilowatt hours. Fissile isotopes are such materials. The unique properties of these isotopes make them useful for power production and to create—note "create"—additional fissile materials from fertile stock of uranium and thorium. By utilizing available resources and present day technology, mankind has at its disposal today several thousand years' supply of energy, more than enough to fuel the transition from energy-capital intensive economies of today to the energy-income intensive economies of the future.

So what's the problem? Fertile material must be converted to fissile material during a reactor cycle. It must then be removed from the reactor and separated in a reprocessing plant. That process and that plant constitute hazards with respect to health, safety, and proliferation. Until these risks are satisfactorily resolved—this tremendous and cheap energy resource will remain beyond our reach.

The health and safety problems are primarily of a technical nature and can be solved predictably, within probability limits. However, the proliferation problem is primarily of a political nature, depending on domestic and foreign institutions controlled by decision makers whose game plan is beyond prediction. In general, decision makers are faced with a list of options of which they are expected to select the optimum one that serves their goals and objectives. However, as Nobel prize winner Herbert Simon discovered long ago, **decision makers don't optimize, they "satisfice"**; they select any option that keeps them out of unacceptable difficulties (risks), or that promises overwhelming advantages (benefits).

Leaders around the world begin to realize that we are faced with a world security problem of unprecedented proportions. So far, we have made only a feeble beginning with national and international safeguards. Commissioner Gilinsky summarized the situation in a recent speech in London, England, September 27.

> "We have in place certain instrumentalities for control which took at least 25 years to build up: a frail system of international safeguards in the IAEA, the NPT pledges to refrain from nuclear weapons manufacture, not yet universal, and the rough ground rules agreed to among the nuclear suppliers at London . . .
>
> "What I have tried to say here today, is that nuclear explosive materials cannot be handled within the normal rules of commerce—their control is beyond the present capacities of our international institutions—and that time is running out.

It is important to distinguish between non-proliferation and safeguards. The goal of non-proliferation includes all the objectives of safeguards and more. Briefly, non-proliferation aims to deter and detect overt actions to build and deliver nuclear weapons; safeguards aims to deter and detect diversion of SNM (and to protect against sabotage). The INMM can be proud of its history and the part it has played in safeguarding SNM. But, in our efforts to manage and control nuclear materials, we should never forget the overriding goal of non-proliferation.

Reconciling a growing demand for fissile energy with satisficing of decision makers leads one to expect the establishment of a new *international institution*—for example, the International Nuclear Fuel Authority (INFA) as proposed in the Nuclear Non-Proliferation Act of 1978—that would become the sole decision maker regarding fissile isotopes for power use. Low enriched oxide fuel (LEO), the presently preferred reactor fuel, may be temporarily exempt from its control. Developments in separation technology may eventually force even LEO under the control of this international institution.

I visualize three types of facilities under INFA control: isotope separation plants, reprocessing plants and fuel refabrication plants. Some or all of these facilities may be located in multi-national (or international) fuel cycle centers. These centers may also house breeders, providing power for the other facilities, and possibly some excess power for the surrounding countries.

The fuel refabrication facility will be capable of manufacturing all types of reactor fuel, including

Dr. Forscher

breeder fuel. The consolidated refabrication facilities can be viewed as a shopping-mart for all nuclear fuel except LEO. The combination of fissile and fertile oxides that will be ordered by a utility will depend on three considerations. 1. Technical consideration involving the type and design of the reactor. 2. Political considerations regarding signator to the NPT or other agreements; and 3. Economic considerations regarding national resources (thorium, uranium) and the accumulated plutonium credits. Proliferation resistant elements would be shipped from this remotely operated and remotely maintained facility under international supervision.

Clearly, the major problem is not technical. The political issues of how to manage and control such an international fuel cycle center have barely been raised. We are looking to INFCE to make the first giant step in this direction. Unless we are able, within a few years, to establish fool-proof control over fissile isotopes, the world will not be able to take advantage of the enormous energy content of fertile materials so essential to a smooth transition to the solar age.

An unexpected benefit of a viable INFA could be its effect on currency stabilization. Fissile isotopes, primarily plutonium, could very well become the next internationally accepted basis to which all national currencies could be pegged. It would greatly help in stabilizing the world monetary markets, a function that gold, a less useful element for human development, has not been able to fill.


DeVito


Murrell

Goodyear Atomic Promotes Three

PIKETON, Ohio—A new Division, Safeguards and Security, was established at Goodyear Atomic Corp. effective Sept. 1. Named to head the newly-created division as Manager was **Vincent J. DeVito.** Mr. DeVito, INMM Secretary the past several years, reports to **Gerald D. Althouse,** Assistant General Manager, Operations.

Jonathan S. Murrell was promoted to Superintendent, Nuclear Materials Control, replacing DeVito. Also promoted in the creation of the new Division is **Kenneth D. Baldwin** to Superintendent, Security. Murrell and Baldwin are active INMM members.

Mr. DeVito was one of the original Goodyear start-up team members as he transferred to Southern Ohio in June, 1953 as an S.F. Materials Accountability Engineer. He started with The Goodyear Tire and Rubber Company in August, 1950 in Akron. He was a member of the Squadron Program there, receiving the Litchfield Award as its outstanding member.

He was named Uranium Control Assistant in 1962 and in May, 1970 was promoted to Superintendent of Nuclear Materials Control.

Mr. DeVito is a graduate of Ohio State University with a B.S. degree in business administration. He is a Certified Nuclear Materials Manager.

Mr. Murrell joined Goodyear Atomic in September, 1957 as an engineer. In January, 1967 he was named Staff Engineer. In May, 1970 he was promoted to Supervisor of Nuclear Materials Engineering.

Originally from Huntington, W. Va., Mr. Murrell received his B.S. degree in general engineering at Marshall University. He, too, is a Certified Nuclear Materials Manager and a member of the American Nuclear Society.

Mr. Baldwin is originally from Fairfield, Ohio. He joined Goodyear Atomic in April, 1972 as an engineer. Previous to that time, he was employed by Standard Oil of California and Chevron Chemical in Louisiana. Mr. Baldwin is a graduate of the University of California with a B.S. degree in chemical engineering.

IAEA Funding

(Continued from Page 41)

is experienced by commercial activities in non-nuclear weapons states in order that the commercial activities in weapons states and non-weapons states are on the same competitive basis. Added benefits to an inspection program in weapons states may come from the training Agency inspectors would receive and the possible early development of realistic and effective techniques through inspections in the U.S. and other weapons states. It seems questionable, however, that over the long-term, these benefits offset the disadvantage of the resulting extensive diversion of the Agency's efforts from the more important job of policing facilities in non-nuclear weapons states.

The Atoms for Peace Program, under which the U.S. agreed to cooperate with other countries in the peaceful uses of nuclear energy, was first initiated by the U.S. over 22 years ago. In the interim, the U.S. has accomplished only two basic results from its diplomatic efforts: the establishment of the IAEA and the ratification of the Non-Proliferation Treaty by a large number of nations (but not all). The Carter Administration at the outset of its organization identified proliferation concerns to be so great as to necessitate the indefinite deferral of reprocessing of spent nuclear fuel and the development of the breeder reactor in the U.S. The Agency's safeguards program and the NPT are the only available tools for the international control of nuclear proliferation. The President has determined that major sacrifices are required to reduce the prospects of proliferation. It therefore would appear that the U.S. should be more heavily involved in effecting an immediate large increase in funding for the Agency's safeguards program, even if the U.S. has to pay for the bulk of the increase. Certainly the U.S. diplomatic community should be able to sell the idea of increased contributions to the Agency from the various nations of the world, if it has any confidence in its ability to sell these same nations on the prospect of abstaining from reprocessing and the development of the breeder reactor.

Reflects on 20 Years As An INMM Member

By F.H. Tingey
Idaho Falls, Idaho

Recently the officers of the Institute distributed to the membership a questionnaire relative to the functioning of the Institute. Such action is appropriate at any time, but particularly so now as we contemplate the next 20 years.

In responding to the questionnaire I had occasion to reflect on the 20 years and identify strengths and weaknesses of the Institute as I perceive them. Anyone doing this cannot help but be impressed with the N-15 standards work, the annual meetings, and the birth and careful nurturing of the Journal. Undoubtedly there are other activities of merit, but these are the most visible and consequently the ones most easily judged. Unfortunately these activities have provided opportunity for professional development for relatively few of the membership. If the Institute is to realize its full potential as a professional organization, programs must be adopted that will increase membership involvement and participation. Simultaneously improved visibility and credibility will result. Consequently, I propose the following ten-point program:

1. Organize the Institute membership into regional chapters.
2. Define and organize subsections of the Institute as to areas of interest, i.e. materials accountability, materials control, instrumentation, physical security, etc. and designate chairpersons and committees.
3. Sponsor region and subsection meetings on a more frequent basis than annually.
4. Sponsor topical meetings.
5. Prepare and distribute to the membership monthly newsletters which would identify the important activities and decisions relative to safeguards.
6. Increase the technical content of the Journal and move the bulk of the non-technical to the newsletter.
7. Stimulate within the academic community (both high school and college) curricula focusing on safeguards.
8. Implement a system of graded membership according to recognition, accomplishments and contributions to the field. Four possible levels might be: student, associate, member, and fellow.
9. Provide an annual award (recognition) for particularly meritorious service to the Institute and the field of safeguards.
10. Become more involved and visible as an organization in the policy formulation and decision process relative to safeguards. This can be done through participation by the membership on national committees, through Institute-sponsored reviews of papers and studies, and publications of such reviews in the Journal.

None of the suggestions are particularly new or novel. Many have been implemented successfully by other professional organizations and some in part by the Institute. Several depend upon sufficient membership to be meaningful. Particularly the first four are of that nature. It would appear to me, however, that we now have the numbers for regional chapters to function. At least this would be the case in regions housing major DOE or NRC installations or organizations.

I note with enthusiasm Bob Keepin's announced intent to expand the Institute programs and professional activities. The meeting in Washington, D.C. in December relative to the impact of IAEA Safeguards is, I hope, only one of a series of topicals sponsored by the Institute.

Items 5 and 6 focus upon ways and means to accommodate expression by the membership and promote professional development. I strongly believe that more avenues are needed for that expression, hence the newsletter. Also it would appear to me that the inclusion of both technical and non-technical articles in the same publication dilutes the effectiveness of the publication either with regard to affecting policy or establishing technical credibility, since the audiences for such articles are so different.

With regard to items 8 and 9, I believe it important that the Institute itself provide a mechanism for motivating the membership to service to the Institute and to the profession. In a way the certification program was an attempt to provide some recognition. However, many in the profession do not recognize a need for certification; consequently, alternatives should be considered. Admittedly, graded membership and recognition

Dr. Tingey

Dircks, Martin Promoted By NMSS at U.S. NRC

William J. Dircks has been appointed Director of the Nuclear Regulatory Commission's Office of Nuclear Material Safety and Safeguards (NMSS), and John B. Martin will head the NRC's new Division of Waste Management, Chairman Joseph M. Hendrie announced on December 26.

Mr. Dircks, who has been Deputy Executive Director for Operations at NRC, succeeds Clifford V. Smith, who resigned to become Vice President of Oregon State University. Mr. Martin has been Assistant Director for Fuel Cycle Safety and Licensing in NMSS.

The office which Mr. Dircks now heads is responsible for licensing and regulating the handling of nuclear materials, construction and operation of nuclear fuel cycle facilities, waste management, and the safeguarding of nuclear facilities against sabotage and nuclear materials against theft.

The new Division of Waste Management was created by the Commission in October 1978 within the Office of Nuclear Material Safety and Safeguards. It is responsible for licensing and regulating the long-term management and disposal of high level and other long lived radioactive wastes, and low level wastes.

INMM TO PRESENT DISTINGUISHED SERVICE AWARD

The Institute of Nuclear Materials Management (INMM) announces its Distinguished Service Award to be presented to a selected outstanding candidate at its next annual meeting to be held in Albuquerque, New Mexico, July 16-19, 1979.

Final selection for this award will be based on the significance of the individual's contributions and dedication to the field of nuclear materials management and safeguards. The candidates do not have to be members of INMM.

Each INMM member is requested to carefully consider candidates for this prestigious award and submit a name along with the supporting basis, for consideration by the Awards Committee. Submissions must be made by April 1, 1979, to:

Dr. Samuel C.T. McDowell
Chairman, Awards Committee
c/o U.S. Department of Energy
Office of Safeguards and Security
Room A2 1016
Washington, DC 20545

In recognition of this award the selected candidate will be presented with a Distinguished Service Award plaque at the Albuquerque meeting.

awards may not be the total answer, but at least they are relevant.

Finally, I believe the Institute must become a more significant factor as an organization in the major nuclear (and particularly safeguards) policy decisions being generated within the DOE/NRC/IAEA complex. This requires the Institute to take a position on controversial issues and become visible in those positions. It requires competent and objective reviews and evaluations and credibility as an organization. It may be the biggest challenge of all.

The program focuses on professional development, credibility, and involvement. It will require a commitment to the Institute and its purposes on the part of many of us which heretofore has been lacking. I have no doubt that we can meet the challenge.

INMM Chairman's Workshop Report Sent to Key Individuals

Editor's Note: The above letter from the INMM Chairman, Dr. G. Robert Keepin of Los Alamos Scientific Laboratory, to the Honorable Joseph M. Hendrie, Chairman of the U.S. Nuclear Regulatory Commission, provides a timely overview of the thrust of the recent special INMM Workshop on the Impact of IAEA Safeguards in the U.S. held December 7-8, 1978, in Washington, D.C. Similar letters were sent to Dr. Sigvard Eklund, Director General of the IAEA; U.S. Senator John Glenn, D-Ohio; Ambassador Gerard C. Smith, U.S. Representative to the IAEA; Dr. John F. O'Leary, Deputy Secretary of the U.S. Department of Energy; Mr. Charles Van Doren, Assistant Director for Nonproliferation, U.S. Arms Control and Disarmament Agency; and to Ambassador Roger Kirk, U.S. Resident Ambassador to the IAEA. The above key persons have direct interest in the results of the recent workshop and major responsibilities in international safeguards. Each is also receiving a copy of this issue of the Journal which contains the longer summary article on the workshop by Russell E. Weber, Senior Technical Associate, NUSAC, Inc., McLean, Virginia.

The Honorable Joseph M. Hendrie
Chairman, U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Joe:

Pursuant to our brief chat in Washington last month, I wanted to give you an overall impression of the recent INMM Workshop on the Impact of IAEA Safeguards, held in Washington, D.C., December 7 and 8. As you know, Paul Morrow and James Wolf of the NRC staff were invited speakers at the workshop, and reflecting the key role that NRC will play in the application of IAEA Safeguards in the U.S., their remarks and viewpoints were of particular relevance and concern to all workshop participants. Judging from all reactions and responses of attendees, the workshop clearly provided an extremely timely forum for discussions between nuclear industry/plant people and government/safeguards people.

In his opening remarks, Ambassador Gerard Smith, U.S. Representative to the IAEA, emphasized the key importance of the U.S. offer in relation to overall nonproliferation goals by stating bluntly that "if the U.S. does not fulfill its part of the bargain, then it could have a very detrimental effect on U.S. efforts to implement safeguards and achieve nonproliferation goals around the world."

The implementation of IAEA Safeguards under the pending US/IAEA Agreement has, as you know, been a matter of growing interest and concern among U.S. licensee facilities that will come under the new 10 CFR Part 75 rules and IAEA safeguards records and reporting requirements, accounting, and control procedures as set forth in detail in individual facility attachments that are yet to be negotiated between the IAEA and the U.S. in consultation with the licensee. The details of this process of drafting, reviewing, and approving the facility attachments (as developed from the design information questionnaires to be completed by licensees) were clearly an area of major concern at the workshop. In particular, licensees are seeking a more active role in the entire rulemaking process, including rule formulation, facility attachments, and subsequent implementation—whether a given facility is to be under full Agency safeguards, including inspections, or under the Protocol to the Agreement (i.e., excluding only inspections). In response, NRC officials at the workshop stressed the use of "informal channels of communication" and "consultation" with licensees throughout the negotiation phase of developing facility attachments rather than relying on more formalized procedures.

Many other areas of concern were touched upon, including strengthening provisions for protection of proprietary information, frequency and cost of inspections, who will pay, etc. On balance, the consensus of the workshop seemed to be that such questions and concerns, although quite real, did not raise insurmountable problems and that these could be resolved in due course; thus, despite the many uncertainties about implementation and difficulties to be overcome, a generally positive and constructive attitude of "getting on with the job" seemed to prevail throughout the workshop. Likewise, the goal of a smooth and rapid transition to the effective implementation of IAEA safeguards as being in the best overall interests of a viable nuclear industry, worldwide, was emphasized repeatedly in all three sessions of the workshop.

Workshop participants, both at the Washington meeting and in subsequent communications, have expressed their appreciation for the opportunity to hear, firsthand, the experience of plant operators (from the U.S., Canada, and Japan) under operating IAEA safeguards conditions. Similarly, the viewpoints of NRC and IAEA officials regarding inspection experience in operating production facilities provided further valuable insight and perspective for Workshop attendees. The intense question and answer periods, as well as extended after-hours discussions, clearly testified to the usefulness of this type of forum for direct communication on an impartial, professional basis between all parties concerned with the application of effective safeguards on both the national and the international level. Some workshop participants expressed the opinion that such a forum was "long overdue" and that another similar workshop should be held in 1979—e.g., following Senate consideration (and possible modification) of the US/IAEA Agreement

We in the Institute believe this kind of direct professional interaction between the parties involved provides a distinctly positive contribution, and can only help to improve the prospects for an orderly transition to the implementation of effective IAEA safeguards in the United States. Workshop Chairman Russell Weber of NUSAC Inc. has prepared a summary report on the workshop which will be published in the Winter issue of the INMM Journal (**Nuclear Materials Management,** Vol. VII, No. 4). I have arranged for you to receive a copy of this issue of the Journal as soon as it is published.

On behalf of the Institute, I want to thank you for the NRC's important contributions to and participation in the workshop (some 18-20 NRC attendees). We would welcome any comments, constructive criticism, suggestions, etc. that you or any of your staff may have on the workshop per se, as well as your views on other services or functions the Institute, as a professional organization, could provide in support of international safeguards and nonproliferation goals generally.

In closing, I would note that the INMM 1979 Annual Meeting to be held at the Hilton Inn in Albuquerque, NM July 16-19, 1979 carries the theme "International Safeguards," and we are expecting many of the timely issues and questions taken up at the recent workshop will be pursued further at the Albuquerque meeting.

Best wishes for a Happy and Prosperous New Year.

Cordially yours,

G. ROBERT Keepin

International Training Course On Physical Protection Of Nuclear Facilities and Materials

An International Training Course on the Physical Protection of Nuclear Facilities and Nuclear Materials has been conducted for representatives of foreign countries by the Department of Energy's Sandia Laboratories in Albuquerque, New Mexico, from November 1 to 15, 1978.

The two-week course was offered under the direction of DOE, in consultation with the Nuclear Regulatory Commission (NRC) and under the general auspices of the International Atomic Energy Agency (IAEA). In attendance were representatives from developing countries who are responsible for preparing regulations and designing and assessing physical protection systems.

The course was designed to be responsive to the requirements of the Nuclear Non-Proliferation Act of 1978, and emphasized total systems concepts of physical protection for facilities and nuclear materials. Discussions on the international threat to nuclear installations were presented by a panel of guest speakers.

Participants were provided basic background information on nuclear materials, radiation hazards, reactor systems and reactor operations. Transportation of nuclear materials was addressed with emphasis on regulations.

The elements of a physical protection system, including protective forces, intrusion detection systems, communication and entry control systems, were discussed. In addition to practical exercises during which participants solved problems, attendees participated in the conceptual design of a physical protection system for hypothetical nuclear facility.

It is anticipated that this course will be repeated in the future.

INMM Chairman Invites Feedback On International Safeguards Workshop

By Russell E. Weber, Workshop Chairman
Senior Technical Associate
NUSAC, Inc.
McLean, Virginia

The handout materials related to the implementation of IAEA safeguards in the U.S. drew considerable interest at the INMM Workshop. Plans to make available these materials to registrants at the 1979 Annual Meeting July 16-19 in Albuquerque have been made.

On May 25, 1978 the Nuclear Regulatory Commission published a proposed rule in the Federal Register. Nothing new or different in that, and yet, this one **was** different. It was 10 CFR Part 75—the proposed new rules that will introduce the International Atomic Energy Agency's safeguards requirements to U.S. nuclear industry. Many people, mostly in the government agencies concerned, have for years been aware of impending IAEA safeguards inspection in the U.S., and have been working to prepare the way, but it is very clear that much still remains to be done before IAEA safeguards can be effectively applied in the United States.

Accordingly, at the Institute's Annual Meeting in June 1978, INMM Chairman **Bob Keepin,** after several discussions with others having strong interests in this area, announced that the Institute would sponsor a Workshop in late 1978 on the Impact of IAEA Safeguards in order to provide INMM membership with as much insight as possible into the subject. A Program Chairman for the Workshop was designated, and the plan went into action. As this was the first workshop of its type that the Institute had undertaken, there were many unknowns, but with the fine support and encouragement of many INMM members and the enthusiasm of everyone contacted to be a speaker, the Workshop program and plans evolved rapidly.

So it was on December 7 and 8, 1978 the INMM Workshop took place at the Washington Hilton Hotel, Washington, D.C. Over 160 representatives of industry and government attended the day and a half meeting, which was truly a workshop with all the informality and effective communication that the term workshop implies. Portfolios had been provided, and most were well used by the close of the Workshop on Friday, December 8. And seldom had the coffee provided been as essential to gird participants for the flood of new information being presented.

Although the Workshop attendance was twice the number contemplated back in June, the Institute recognized that there are many who will be affected by the implementation of IAEA safeguards but who could not be at the meeting. Thus, for those and all who have interest in this timely subject, we have prepared this brief synopsis of the Workshop for the Journal. The program consisted of three sessions, each moderated by a session chairman. The invited speakers were selected for their experience and special qualifications to address a specific area of responsibility or knowledge in the safeguards field.

The Institute strongly supports the goal of a smooth and rapid transition to the new IAEA safeguards requirements as being in the best overall interests of a viable nuclear energy industry, worldwide, and this theme was emphasized over and over again during the three sessions. The speakers from various Government agencies, in addition to explaining many of the new safeguards criteria and concepts, were uniformly positive and supportive in their assurances to the industry regarding practical implementation of the new provisions. Representatives from the private sector, and notable experts from outside the U.S., were extremely helpful in describing "how things really were" under operating IAEA safeguards conditions.

The Program started with brief welcomes by **Russ**

Some 162 registrants took part in the workshop. There was considerable question-and-answer activity both in the sessions and during coffee breaks and free time. The Washington Hilton Hotel served as a first class meeting site for the INMM Workshop.

Weber, Workshop Chairman, and Bob Keepin, Institute Chairman. Bob Keepin then introduced Ambassador **Gerard C. Smith,** President Carter's Representative for Non-Proliferation Matters and U.S. Representative to the International Atomic Energy Agency. Ambassador Smith set the tone for the meeting by stressing the importance to the world of strong and effective safeguards. President Johnson expressed this in December 1967, when he announced that the United States would voluntarily permit the IAEA to apply its safeguards to non-defense-related nuclear activities in the U.S., and each President since Johnson has repeated the offer. Ambassador Smith noted that the time is approaching to make good on the proposal. The U.S. Senate is expected to consider ratification of the Agreement early in 1979. When the Senate gives its advice and consent to ratification, the Agreement will go into effect and the Subsidiary Arrangements, Transitional Subsidiary Arrangements, and Facility Attachments, as they are implemented by the NRC and DOE will soon become very real and very important to a major portion of the U.S. nuclear industry.

In recognition of the need for timely reporting on the Workshop, and given the limitations on full reporting that this type of informal meeting entails, the three sessions can only be summarized in this report. I am indebted to the Session Chairmen who were asked to encapsulate their parts of the agenda, on a very compressed time scale in order to meet our stringent deadline for publication in this issue of the Journal.

Mr. Weber

Session I — Summary

Chairman: **Harley L. Toy,** Battelle Columbus Laboratories

Topic: "Governmental Implementation of the Agreement"

Speakers: **James R. Wolf,** U.S Nuclear Regulatory Commission
Paul K. Morrow, U.S. Nuclear Regulatory Commission
Harvey E. Lyon, U.S. Department of Energy
H. Allen Rose, Atomic Energy Control Board, Canada

Governmental Implementation of the US/IAEA Agreement provided the opening springboard for the workshop discussions on the provisions of the Agreement to apply Agency safeguards to certain sectors of the U.S. Nuclear Program.

The mission of the opening session was to present the governmental approach and proposals to meeting the commitments as set forth in the Agreement. **Paul Morrow** and **James R. Wolf,** representing NRC, brought forth an overview of proposed 10CFR Part 75, while **Harvey Lyon,** Director of DOE's Office of Safeguards and Security presented a briefing on DOE's plan for implementation. Rounding out the first session, **H. Allen Rose** of the Atomic Energy Control Board of Canada related first hand experience under NPT safeguards.

Outlines and highlight excerpts of the remarks presented by the four panelists included the following:

Paul Morrow, NRC

Without dwelling on the details of their development or content, a brief overview of the program for the implementation of the US/IAEA Safeguards Agreement appears appropriate. I will then focus on the new and revised regulations which NRC intends to promulgate to

Among key participants and speakers at the recent INMM Workshop on IAEA Safeguards (from left) were Harley L. Toy, Battelle Columbus Laboratories; Paul K. Morrow, U.S. NRC; James Wolf, U.S. NRC legal staff; Admiral Harvey E. Lyon, formerly director of U.S. DOE's Office of Safeguards and Security; and H. Allen Rose, Atomic Energy Control Board of Canada.

implement IAEA safeguards in the licensed industry. Some of the detailed aspects of the implementation program will be addressed in other sessions of this Workshop.

As most of you know, in 1967 the U.S., via a Presidential offer, pledged to place its non-military nuclear operations under IAEA safeguards.

To fulfill the commitments associated with this offer, an Agreement between the U.S. and the IAEA was negotiated, approved by the IAEA Board of Governors and on February 8, 1978, forwarded to the U.S. Senate for consent to ratification as a treaty. The document spells out the commitments of both parties in applying full agency safeguards, including inspections, in those eligible facilities selected by the IAEA, and a Protocol to the Agreement which spells out the commitments made by the U.S. and the IAEA for safeguards in those facilities selected by the IAEA under the terms of this Protocol. Safeguards under the Protocol are generally the same as under the agreement itself except for inspections. To specify the methods for implementing IAEA safeguards in the U.S. as required by Article 39 of the Agreement and Article 3 of the Protocol, a Subsidiary Arrangement and a Transitional Subsidiary Arrangement have been negotiated to apply the IAEA program in U.S. licensed facilities, the NRC intends to promulgate a new Code of Federal Regulation Part 75 and conforming amendments to Parts 40, 50, 70, and 150. Proposed rules published on May 25 include background and authority for the U.S. offer and an analysis of the provisions of the proposed rules as related to the Articles of the Agreement and Protocol.

An outline of the steps involved in establishing IAEA safeguards in licensed facilities would be:

I. 10CFR Part 75 and appropriate revisions to other Parts will be made effective

A. This will occur only after affirmative action by the U.S. Senate

II. After Senate confirmation, U.S. will provide the IAEA with a list of those facilities eligible for safeguards under the Agreement

A. From this list, IAEA will select those facilities in which it wishes to apply safeguards under the terms of the Agreement **and** those in which it wishes to apply safeguards under the Protocol to the Agreement

III. NRC will request from these selected facilities the installation information required under 75.11 utilizing a "Design Information Questionnaire" for this purpose

A. Detailed instructions for the completion of this questionnaire will be provided at the time this information is requested

B. Following a review by NRC for completeness and accuracy, this information is turned over to the IAEA for the preparation of their procedures for applying safeguards in that specific facility

C. In accord with 75.13 the Agency will be given an opportunity to visit the facility for the purpose of verifying the installation information

IV. Utilizing the information provided, and in **consultation** with the licensee, the U.S. and the IAEA will negotiate a "facility attachment" or a "transitional facility attachment" which spells out the details of the IAEA safeguards program for that facility

Covered above is the general program for applying IAEA safeguards in licensed facilities. 10CFR Part 75 and conforming revisions to other regulations are still in the formative stages. The proposed rules published in May of this year are currently out for additional public comments. The comments received to date are now being considered by the NRC staff. Additional comments received, continuing internal staff reviews, and Senate evaluation during their consideration of the Agreement will effect a modification of the rules as now proposed.

James R. Wolf, NRC

Mr. Wolf has been with the Office of the Executive Legal Director of the U.S. Regulatory Commission since 1976. One of his principal activities at NRC has been participation in the development of regulations to implement the US/IAEA Safeguards Agreement. Mr. Wolf's remarks are outlined as follows:

Topic I: NRC Rulemaking Process

A. Requests for Comments
1. 43 FR 22365 (5/28/78)—approximately 20 comments
2. 43 FR 54255 (11/21/78)—comment period expires 12/21/78

B. Thrust of Comments
1. Licensees desire an active role in the entire process
   a. Rulemaking
   b. Facility attachments
   c. Subsequent implementation
2. Licensees are concerned about the protection of proprietary information
3. Licensees are concerned about potential burdens
   a. Additional effort
   b. Additional cost
   c. Delay

C. General Analysis of Comments
1. No comments in the nature of objection to the President's offer as a whole
2. Comments related to implementation of the President's offer
   a. Types of comments which would not result in changes in proposed rules
      (1) Policy issues beyond the scope of NRC responsibility and jurisdiction
      (2) Issues involving distinctions between US/IAEA relationship and NRC-licensee relationship
      (3) Issues involving failure to recognize the balancing provisions of the Agreement
      (4) Issues involving matters inadequately explained by NRC
   b. Types of comments which may result in changes in proposed rules
      (1) Formal recital of certain activities of NRC that were intended but which had not been stated expressly (e.g., consultation on facility attachments)
      (2) Clarification of procedures
      (3) Relaxation of substantive requirements, where compatible with the Agreement

Topic II: Steps in Implementation (simplified)

A. Prior to Entry into Force
1. Senate advice and consent
2. Final rulemaking
3. Effective date of rules

4. Collection of installation information, transmittal of nonconfidential portions to IAEA—to enable 90-day limit of Article 40 of the Agreement to be met

B. Entry into Force

C. After Entry into Force

1. Eligible list to Agency
2. Identifications by Agency
3. Collection of installation information
4. Transmittal of installation information to Agency
5. Preparation of facility attachments in consultation with licensee; verification
6. Requirements document from NRC
7. Notice to implement Paragraph 75.21(e) of 10 CFR 75.
8. Items out of above sequence 30-60 days after entry into force
   a. Reporting initial report
   b. Designation Paragraph 75.41 [see Article 40(c)]

Harvey E. Lyon, DOE

DOE REPORT ON APPLICATION OF IAEA SAFEGUARDS TO FACILITIES OF THE U.S. DEPARTMENT OF ENERGY—The implementation of the US Voluntary Offer to accept the application of safeguards by the International Atomic Energy Agency, the IAEA, on peaceful nuclear activities within the U.S. awaits only U.S. Senate approval. I want to give you some information as to actions the Department of Energy is taking in readying for implementation and would like to start with these fundamentals:

1. The IAEA and United States safeguards systems are inherently compatible. The two systems are founded upon the same basic principles of nuclear materials accountability including the periodic determination of book-physical inventory differences.

2. The US Voluntary Offer included eligible government facilities from the beginning. These facilities sometimes incorporate advanced technology and the ongoing R&D may lead to new technology, competitive with other technologies. DOE has worked with NRC, industry and the IAEA to include IAEA requirements in the DOE/NRC nuclear materials accountability reporting system used by both Government facilities and licensees.

3. DOE expects that the U.S. implementation of IAEA safeguards will have some programmatic impact. We expect to work closely with the NRC and the nuclear industry in minimizing this impact.

4. Some DOE and DOE contractor facilities are excluded from the US Offer by the provision which excludes activities of direct national security significance.

DOE shares a responsibility with NRC, State and ACDA for implementation of the US/IAEA agreement. I am confident that the US can meet its responsibilities without undue burden or interference with the activities underway as is done in the other nations subject to IAEA safeguards.

Our planning assumes that eventually all eligible DOE facilities will be required to submit accounting reports for the IAEA. In addition, the IAEA is to receive design information for any eligible facility that the IAEA chooses and some eligible DOE facilities probably will be selected for full implementation of IAEA safeguards, perhaps for intervals of time running for one or two years.

As to the decision-making process for exclusions of some DOE and DOE contractor facilities due to activities of direct national security significance, facilities normally engaged in activities of direct national security significance are to be excluded and IAEA safeguards are to be applied at included facilities only when containing materials which do not have direct national security significance.

In the United States, some facilities have been inspected by the IAEA from time to time over the past 15 years. Under a trilateral safeguards Agreement with Japan, 46 kilograms of plutonium are now under IAEA safeguards at the Argonne National Laboratory. IAEA verification done in connection with scheduled physical inventories involved minimal interferences to ANL and DOE.

When the IAEA chooses specific DOE facilities for inspection, we will cooperate with their safeguards activities and help them to complete their assigned responsibilities. The DOE safeguards program is dedicated to cooperation with contractors faced with these additional responsibilities and will help them to meet their needs to develop and implement systems, equipment and instrumentation for IAEA safeguards.

H. Allen Rose, Atomic Energy Control Board, Canada

REFLECTIONS ON IAEA/INDUSTRY INTERACTIONS BASED ON CANADIAN EXPERIENCE UNDER THE NPT—I would like to express my pleasure at being here as a participant in this workshop considering a critical phase, perhaps even a turning point, in the development of IAEA safeguards under the Nuclear Non-Proliferation Treaty of 1970.

I might say that there are two aspects of the non-proliferation issue which impinge on the industry. The major aspect is, of course, national policy with regard to exports of nuclear materials, equipment and technology. The second, and in comparison, minor aspect, is the implementation of safeguards inspections by the IAEA. IAEA inspection is certainly the lesser of the two evils from the industrial point of view because its economic implications are smaller. It does, however, involve direct contact between IAEA inspection teams and facility operating personnel and the conflicting objectives of these two groups can sometimes be difficult to reconcile.

Canada has supported both the NPT objectives and the Agency as its operative agent from the beginning and has consistently vested all safeguards implementation rights under bilateral agreements in the Agency. Canada is, therefore, totally committed to the further development of an effective and efficient Agency inspectorate.

The Agreement between the Agency and the United States is based on the Agency guideline INFCIRC 153 commonly known as the "Blue Book," with which you must all be familiar. This document was drafted in 1970 by a committee set up by the Agency and was the result of deliberations by 48 member states over a period of two years. It was intended to protect the state and the industry while at the same time guaranteeing the right of the Agency to conduct adequate inspections. This it does admirably well. Article 2 of the IAEA Statute of 1956 reads, "The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose."

Clearly the facility, the state and the Agency all wish to establish the legitimacy of the operation for the assurance of the rest of the world. Article 4 of the Blue Book reads,

"The Agreement should provide that safeguards shall be completed in a manner designed:

(a) To avoid hampering the economic and technological development of the State or international cooperation in the field of peaceful nuclear activities, including international exchange of nuclear material;

(b) To avoid undue interference in the State's peaceful nuclear activities, and in particular in the operation of facilities; and

(c) To be consistent with prudent management practices required for the economic and safe conduct of nuclear activities."

Clearly no conflict of interest here. Finally Article 7 of the Blue Book reads,

"The Agreement should provide that the State shall establish and maintain a system of accounting for and control of all nuclear material subject to safeguards under the Agreement, and that such safeguards shall be applied in such a manner as to enable the Agency to verify, in ascertaining that there has been no diversion of nuclear material from peaceful uses to nuclear weapons or other nuclear explosive devices, findings of the State's system. The Agency's verification shall include, inter alia, independent measurements and observations conducted by the Agency in accordance with the procedures specified in Part II below. The Agency, in its verification, shall take due account of the technical effectiveness of the State's system."

I would not have considered it worthwhile to take up your time today with motherhood statements about non-proliferation, Agency benevolence and living happily ever after if everything was smooth going. In fact, you may find this marriage a bit prickly at times, and I would like to suggest some ways of reducing the friction to everyone's benefit.

In view of what I have already said, why should problems arise? In fact, they arise from the paragraphs I have already quoted from the Blue Book.

To begin with, the Agency has not only a right but an obligation under its agreement with the U.S. to apply safeguards. There is little use bargaining with such an organization because it has nothing to gain in making concessions and nothing to lose in insisting on meeting its obligations. This is as it should be if the Agency is to fulfill its role.

While the Agency's selection procedures do ensure a high caliber of inspector, the requirement to enlist staff from member States with due regard to equitable geographical representation eliminates the possibility of selecting only inspectors with relevant experience such as operations, material accounting and control or nuclear regulatory service. Only a few member states have highly developed nuclear industries and nuclear regulatory agencies. Inspectors generally have high academic qualifications but direct industrial or regulatory experience is not a common factor among them. This is not to criticize but only to point out an unavoidable fact of life. This is also not to say that an academic will make a less effective inspector than an engineer or a shift foreman. What it does say is that Agency personnel are not necessarily well qualified under Article 4 of the Agreement, to judge what constitutes "undue interference" in the operation of your specific facility. The Agency's ability to judge what is consistent with "prudent management practices" is similarly dependent upon outside advice.

To a lesser degree I would say the same is true of your own DOE and NRC. When it is a question of operation of the facility and management of the facility which includes accounting practices, the ability to judge consequences of actions affecting the facility operation rests largely with the personnel of the facility.

Whether IAEA safeguards work smoothly in your plant or create difficulties is, I believe, largely in your hands. Considering that you already operate under an extensive and sophisticated regulatory program it may not be obvious why this should be the case. I would like to approach this point now from a different direction.

Article 7 of your Agreement deals, as I have noted earlier, with the State System of Accounting and Control and stipulates that the Agency should verify the findings of the State System. There is, however, a Catch 22; the Agency's verification shall include "independent measurements."

Ten years from now it is possible that all of this will be cut and dried. At present, however, in spite of extensive efforts on the part of industry, states and the Agency, no complete set of routine procedures yet exist for carrying out the type of verification the Agency is supposed to provide. Industry does not easily appreciate the role in which the Agency is cast. It is after all an instrument created by the members of a club to which we all belong and acting according to the dictates of the members through the Board of Governors. It has been directed to act as though member States are in collusion with industry to divert nuclear material to explosive use and hide the fact from the Agency. Under analysis it will be seen that perfectly adequate nuclear material control from the operator's point of view is of little value to the Agency unless the Agency duplicates what the facility does. The same is true of the State control system. A smoothly operating system might provide an effective cover for a clandestine weapons program through a sophisticated material embezzlement scheme. The Agency is supposed to be able to detect such an activity.

In addition to independent auditing then, the Agency must analyze each facility to determine a system of checks, inventory measurements and containment and surveillance devices that will detect any attempt at diversion.

Recognizing that for most cases the Agency possesses only rudimentary knowledge of your operation, the proposals that will be put forward will undoubtedly conflict with your operation to some degree. Anecdotes are too lengthy to include here but I can assure you that there are a few in the Canadian experience. What can you do to minimize the impact of these conflicts?

Your first defense is, I suggest, offense. This is not to recommend resistance to Agency safeguards because we are after all trying to promote them on a global scale. You can, however, devote some manpower to an analysis of your own plant. The place to start is with the Blue Book to try to see the problem from the Agency's point of view. A quality control program, for instance, is of use to the Agency only if the Agency has some way of verifying its conclusions that is independent of operator generated data. I suggest that you are in a better position to analyze such a situation and propose an efficient system than is the Agency. At least you could be in a position to comment constructively on Agency proposals.

The next on your list should be your particular facility attachment. This is a part of the total Agreement but is subject to amendment at any time. The facility attachment should set out in detail the inspection regime to be applied to your plant. Again, if we were at a stage when such things were standardized there would be little room for maneuvering. We are not at that stage and, consequently, you can have an influence on your own fate. The entry into force of a facility attachment has to come, unfortunately, prior to a complete safeguards approach being in place. This is so because at this time techniques for many types of plants are not yet fully developed. It is prudent, therefore, to be sure that the facility attachment does not commit you to procedures or goals which are impossible or highly impractical to achieve.

The basic goal is, of course, obvious. Even a means of achieving it may be theoretically obvious. However, safeguards approaches invariably require measurements. Destructive and non-destructive assay methods certainly exist, but can they be applied in a manner which will actually provide the Agency with a positive conclusion without either seriously affecting plant procedure or being prohibitively expensive. Again I suggest that you, particularly as members of a highly sophisticated and integrated nuclear fuel cycle, and operating in a country which is responsible for much of the advanced technology in the world, are in an excellent position to play a positive role in designing safeguards systems in collaboration with the Agency which can be applied to similar plants throughout the world in an effective, efficient and hopefully painless manner.

Don't be upset if the Agency treats your advances with suspicion. They are paid to be suspicious and it's nothing personal. On the other hand, you can decide to either accept blindly or actively resist attempts by the Agency to apply safeguards. Either one is a losing proposition. Time and the Government are on the Agency's side and you won't beat that combination. Better to jump in with both feet and create a situation that everyone, including the somewhat uncertain public, will be happy to live with.

Session II — Summary

Chairman: **Sylvester Suda,** Brookhaven National Laboratory

Topic: "Reporting Experiences and Inspection Application"

Speakers: **Ronald Oberholtzer,** Eldorado Nuclear, Limited, Canada
Charles Vaughan, General Electric Company, Wilmington
Alan Bieber, Brookhaven National Laboratory
Takeshi Osabe, Japan Nuclear Fuel Company, Limited, Japan
Marco Ferraris, International Atomic Energy Agency

Ronald Oberholtzer, Eldorado Nuclear

The first speaker, **Ronald Oberholtzer,** Eldorado Nuclear Limited, Port Hope, Ontario, Canada, reported on the experiences of the refining and conversion facility under the Non Proliferation Treaty. Mr. Oberholtzer is the plant superintendent for Nuclear Materials Control and has been involved in the development and implementation of safeguards for the conversion plant since 1972 when Canadian facilities came under IAEA safeguards.

The Port Hope facility consists of chemical processing to convert mine concentrates to sinterable uranium dioxide powder for subsequent fabrication into heavy water reactor fuel and to uranium hexafluoride as feed for isotopic separation plants; and of metallurgical reduction, melting, alloying, and casting on a custom basis. All commercially available isotopic levels are handled.

Implementation of IAEA safeguards was carried out under the terms of the Facility Attachment which divides the plant into three Material Balance Areas (MBA) according to the enrichment of the Uranium: MBA-1—natural uranium as UF_6, UO_2 and metal, and depleted uranium metal; MBA-2—less than 5% enriched uranium; and, MBA-3—greater than 5% enriched uranium. The two areas which have been most problematic are the examination of records and the obtaining of independent measurements by the Agency inspectors.

In his presentation Mr. Oberholtzer observed that inspections are, on occasion, made on a committee basis rather than with assigned individual duties. That is, three inspectors may be involved in verifying the content of a can; one checking the labeled content, another doing the weighing and the third checking the inventory listing. Because no formal safeguards existed at the Port Hope plant prior to its coming under the NPT, the initial inventory listings consisted of a handwritten array of identification numbers without any descriptive information. This complicated the physical inventory and verification. Since then there has been an evolution from a primitive, awkward and unsatisfactory system to one which not only transmits the inventory information more readily but also operates with improved ease.

Charles Vaughan, General Electric

Charles Vaughan, who is the manager of the Nuclear Materials Management section in the fuel fabrication facility, spoke on the involvement by the General Electric Company plant in Wilmington, N.C. in a series of US/IAEA integrated safeguards exercises starting in 1973.

This series has covered the preparation of the Design Information Questionnaire and the Facility Attachment for the Wilmington plant. Mr Vaughan served as the GE Coordinator for these US/IAEA integrated safeguards exercises. The GE Wilmington fuel fabrication facility is engaged in the manufacturing of low enriched uranium fuel for boiling water reactors.

In 1977, an integrated safeguards exercise on reporting and inspection was conducted at the Wilmington plant as part of the U.S. program for technical assistance to the IAEA. Mr. Vaughan's presentation was from the viewpoint of a manager of nuclear materials management whose responsibilities include the installation measurement, and full implementation of a plant's safeguards program.

It was pointed out that most presentations made regarding IAEA Safeguards implementation have indicated that there is no significant impact on plant operations. This is based on the fact that the U.S. currently has a strong safeguards program and that there are only a few new requirements in the Agreement. These are true statements but very superficial. The statement of "no significant impact" was challenged in Mr. Vaughan's presentation and he made the following comments.

Consider for a moment the U.S. Government—the amount of money already spent to support international safeguards and develop the implementing agreements. Also recognize the fact that the U.S. will have to modify systems, make new reports, administer new licensing and monitor conformance . . . a significant percentage impact to our national budget—No . . . a significant amount of money—Yes. In the private sector, consider administrative time, nonrecurring engineering, potential investments and/or new people, new programs for assurance, new procedures and routines to maintain and a new impedance to the regulatory process . . . a significant percentage impact on your corporate budget—probably not . . . a significant investment and ongoing expense,—most likely.

The impact of IAEA Safeguards on a low enriched uranium fuel fabrication facility, in the Wilmington experience, is summarized in Table I.

Table I
IAEA Safeguards Impact Summary
(GE Wilmington Experience)

1. **Design Information Questionnaire**
   - One time nonrecurring safeguards engineering effort like FNMCP
   - Ongoing change control effort similar to FNMCP
   - Protection of company sensitive information
2. **Facility Attachment**
   - One time safeguards engineering effort to review and critique new implementing procedure and controls
   - New audits to ensure compliance
3. **New Reporting**
   - System design and implementation for batch naming (investment and expense)
   - Apply batch requirements to all transfers and physical inventory lists
   - Reporting of measurement basis for each transfer and inventory batch
   - Reporting of new transactions (blending, measured discards, classification)
4. **Inspections**
   - A third independent party
   - Additional flow and record verifications
   - Sealing and surveillance
   - Potential disputes
5. **Regulatory Process**
   - New considerations for exemptions (added safeguards engineering)
   - Increased cycle time and impedance

Alan Bieber, Brookhaven National Laboratory

Alan Bieber, Brookhaven National Laboratory, working under an ongoing DOE task was a participant in the GE Wilmington reporting and inspection exercise. The first phase of the exercise consisted of preparing a model Design Information Questionnaire and a model Facility Attachment for a low enriched uranium facility.

The next major phase of the overall exercise was conducting of a reporting exercise. The objective of this phase was to evaluate methods for transmission of safeguards data from a U.S. facility to the IAEA. In particular, the reporting exercise allowed testing of a new flexible format for providing data to the IAEA on computer-readable magnetic tape suitable for direct input to the IAEA Safeguards Information System.

During the course of the reporting exercise, which covered the six-month period from March through August 1977, the facility submitted all data and reports which would have been submitted had the facility actually been under IAEA safeguards. Since IAEA safeguards agreements are with countries rather than individual facilities, all data were transmitted from the facility to the IAEA via the U.S. Nuclear Materials Management and Safeguards System (NMMSS), located at Oak Ridge, Tennessee.

Two basic points should be kept in mind during the following discussion of the reporting exercise. First, every attempt was made to minimize the impact on the facility of compliance with IAEA reporting requirements. Thus, for example, rather than constructing new formats for reporting transactions, the few additional data elements required by the IAEA were simply added to the standard 741 already in use. Similarly, rather than require the facility to adopt new reporting codes or formats, it was decided to use the existing facility codes and formats with the minimum number of changes required to comply with IAEA requirements.

The facility uses a near real-time computer system to store and update the facility book inventory. Because of this fact and the volume of data which had to be reported, all data were transferred from the facility to the NMMSS on computer tape. This required preparation of two sets of computer programs for data conversion: one set ot convert facility data to U.S. NMMSS codes and formats; and a second set for conversion from NMMSS codes and formats to those specified by the Agency for input to its computerized safeguards information system.

The most difficult problem faced in the conversion process was that of converting the facility's data, which are kept on an item basis, to batch data, as required by the IAEA. The definition of batch, given in INFCIRC/153 (the basic document describing IAEA safeguards under the NPT), while precise, was not helpful in this effort. Eventually, items were grouped into a batch if they satisfied the following conditions:

1) all items in the same MBA and KMP

2) all items have the same facility and NMMSS material type codes

3) all items have the same measurement basis, and

4) all items have about the same measurement error.

The impact of IAEA safeguards on a low enriched uranium facility, in the Brookhaven view, are summarized in Table II.

The costs of implementation for the Wilmington exercise were:

a) Computer software for the conversion from the GE computer format to the NMMSS computer format: $40,000.

b) Computer software for the conversion from the NMMSS computer format to the IAEA computer format: $50,000.

These figures do not include the considerable cost for manpower used in the overall planning and design and are based on the fact that the facility already had in place a computerized accountability system.

Takeshi Osabe, Japan Nuclear Fuel

Takeshi Osabe, Manager of the Nuclear Materials Management Section, Japan Nuclear Fuel Company Limited, Yokosuka, Japan, reported on Japanese experience with IAEA Safeguards at a LEU fuel fabrication facility. Mr. Osabe was instrumental in the development of the safeguards and nuclear materials accountability system for the fuel fabrication facility.

Table II
Major Impacts of Implementation of IAEA Safeguards in the U.S.

1) Facility information (one-time effort plus updates or revisions as required)
   * Design Information Questionnaire (DIQ) (prepared by facility)
   * Facility Attachment (reviewed by facility)
2) New Reporting Requirements
   * Reporting of all data by batch
   * Records and reporting of measurement basis of each batch
   * Reporting of transfers between IAEA MBAs at one facility
   * Reporting of physical inventory by batch
   * Reporting on 741s of new types of inventory changes (e.g., blending or measured discards)
   * For facilities not under 10CFR70, a completely new set of accountability records and reports
3) Inspection (only for a very limited number of facilities)
   * Records audits
   * Sampling and/or NDA for flow and inventory verification
   * Installation of seals, cameras, etc., for containment and surveillance

The JNF facility manufactures boiling water reactor nuclear fuel for commercial nuclear power plants under license to the General Electric Company of the United States. The feed material to the facility is uranium dioxide powder and its maximum permitted enrichment is 4% U-235. The plant consists of three material balance areas, with nine flow key measurement points and 26 inventory key measurement points.

The presentation by Mr. Osabe was extremely informative and of great interest to the Workshop attendees. Because of the extensiveness of the Japanese experience and the careful detail with which it was presented, a short summary of the scope and content of the paper is not possible here. Mr. Osabe's full paper, including the extensive and informative illustrations used, is tentatively scheduled to be published in the Spring 1979 issue of the Journal (Vol. VIII, No. 1). Copies of the paper are available from: INMM Publications Office, 20 Seaton Hall, Kansas State University, Manhattan, KS 66506.

Marco Ferraris, IAEA

Marco Ferraris, Head, North American Section, of the Division of Operations A, Department of Safeguards, International Atomic Energy Agency, Vienna, presented his views on the range of safeguards activities as identified in the Subsidiary Arrangements to the US/IAEA Agreement and more specifically in the Facility Attachments. As the Section Head of the North American Section, Division of Operations A, he was well acquainted with the unique status of the United States in the size of plants and in the sophistication of the U.S. Safeguards system.

It was his opinion that, from the point of view of the facility operator, safeguards is a burden which shows little or no operational advantage. However, safeguards already exist in the U.S., and there is no reason to believe that the extension of the existing system to accommodate IAEA Safeguards should significantly increase this burden. Indeed, as might be expected, the IAEA has its own cost effectiveness objectives and it is in our mutual interest to minimize this impact of IAEA Safeguards.

It is Dr. Ferraris' view that at any individual facility the IAEA Safeguards effort and impact is inversely proportional to the quality of the records system, the adequacy of the preparation for physical inventory verification and the degree of cooperation afforded by the facility operator.

Session III — Summary

Chairman: **Thomas B. Bowie,** Combustion Engineering

Topic: "Facility Attachments and Negotiations"

Speakers: **Allan M. Labowitz,** U.S. Department of State
Joerg H. Menzel, U.S. Arms Control and Disarmament Agency
Edward L. Cohen, LeBoeuf, Lamb, Leiby, and MacRae
Darrell A. Hyde, Union Carbide Corporation
Paul K. Morrow, U.S. Nuclear Regulatory Commission

Allan M. Labowitz, U.S. Department of State

The State Department and Arms Control and Disarmament Agency have been instrumental in the planning and implementation of the Treaty. These agencies will continue to play key roles in this matter. The NRC and DOE, respectively, will be the licensee and contractor contact for fully implementing the Treaty. The licensee/contractor participation may involve areas wherein the full legal impact may or may not have been considered. This session attempted to describe and discuss all these ramifications.

Mr. **Allan M. Labowitz,** whose assignment in the Department of State concerns policy formulation and implementation with respect to international peaceful atomic energy activities, highlighted, from the State Department viewpoint, the Treaty and its ramifications. He stressed that in Article 3C of the Agreement it states that the safeguards to be applied by the Agency under this agreement to source or special fissionable material in facilities in the United States shall be implemented by the same procedures followed by the Agency in applying its safeguards to similar material in similar facilities in non-nuclear-weapon states under agreements pursuant to paragraph I of Article III of the Treaty.

He further noted that the U.S. is represented by Dr. **Carl Bennett** on the Agency Policies Group which formulates the safeguards procedures. Article 2(c) states that the U.S. and the Agency will have a mutual agreement wherein discrimination between U.S. facilities will be avoided. In addition, the United States has already established the list of facilities from which the Agency will select appropriate facilities for inspection. The State Department is the contact with IAEA and will take an active part in the initial negotiations of the facility attachments; however, the facility responsibility to the agency will be through the NRC/DOE as applicable. Mr. Labowitz discussed in specific detail various concerns that participants raised concerning the facility attachments, the Agreement articles, terminology and interpretation.

Joerg H. Menzel, ACDA

Dr. Menzel in his remarks described the U.S. Arms Control and Disarmament Agency (ACDA) and what role it will play in respect to the functions of the Department of State, DOE, and NRC in implementing IAEA safeguards in the U.S.

ACDA was created in 1961 as an independent agency whose director serves as the principal advisor on arms control and disarmament matters to the Secretary of State and to the President. Since ACDA also has responsibilities for ensuring the effective implementation and verification of arms control treaties, ACDA continues to have a key role in:

- promoting the widest possible adherence to these treaties;
- seeking the widest possible safeguards coverage with respect to countries that have not joined these treaties;
- ensuring that the resulting safeguards agreements and implementation of safeguards thereunder are as effective as possible;
- supporting nuclear fuel cycle materials, facilities, and arrangements which enhance the effective application of safeguards and minimize proliferation risks; and
- implementing agreements for cooperation and export control measures commensurate with reliable supply as well as effective non-proliferation policies.

Specifically, ACDA will strive for implementation of a safeguards regime in the United States that is consistent with the Agreement and that will reinforce the ability of the IAEA to meet its safeguards objectives in an efficient and effective manner. Since a successful international safeguards system relies on the cooperation of the State, the facility operator, and the IAEA, the search for an increasingly effective and efficient system will involve all parties.

Edward L. Cohen

Mr. Cohen, an attorney with the Washington, D.C. office of LeBoeuf, Lamb, Leiby and MacRae, addressed his remarks to some of the legal and practical difficulties with the proposed implementing regulations that were published for comment in the *Federal Register* on May 25, 1978, and the November 21, 1978 publication which extended the comment period until December 21, 1978.

Concern was expressed over the speed by which the proposed rules would be implemented after Senate ratification. It was proposed that after the Senate has approved the Agreement there be an opportunity for further public comment on the proposed regulations in light of any Senate discussion. A subject as important as the safeguarding of our nuclear facilities should be considered carefully. If speed is necessary then a second round of proposed regulations incorporating as appropriate any comments already received from interested persons as well as reflections of the various administrative agencies concerned could be published in the *Federal Register* prior to Congressional consideration.

Mr. Cohen also expressed concern over the following:

a) Proposed Part 75.12 introduces a confusing double standard for protecting commercial and financial information. The proposed regulation should include an enumeration of the factors NRC will consider in review of a request for withholding information. Further, 75.12 should be revised to allow requests for protection of sensitive information.

b) The inspection provision of the regulations should be more specific. The limits in 75.13 and 75.42(a) on IAEA inspections to "all reasonable times" does not accurately inform licensees of the limits on IAEA inspection rights included in the Agreement. He is of the opinion that the regulation should be modified to reference appropriate provisions from the Agreement defining the different IAEA inspection rights in articles 69-82.

c) IAEA inspectors should be accompanied by the applicable NRC/DOE regulatory agency.

d) 75.42(d) should include a procedure whereby a licensee can obtain help in resolving conflicts between IAEA inspection requests or other requirements.

e) The regulations should afford the licensee adequate opportunity to obtain reimbursement or other payment from the IAEA for certain categories of special or additional expenses as provided in Article 14 of the Agreement.

f) The regulations should provide the mechanism for the licensee to consult directly with the NRC during negotiations of the Facility Attachment.

g) The methods for selection of the facilities to be monitored should be made known. In addition, a mechanism for voicing an applicant's disagreement with the selection should be provided.

Mr. Cohen further recommended interested persons and companies not only to submit comment on the proposed regulations to the NRC as requested in the November 21, 1978 *Federal Register* but also to submit testimony and statements to Congress underscoring not only potential difficulties in the proposed Agreement or regulations but also constructive ways to remedy these difficulties.

Darrell A. Hyde, Union Carbide Corporation

Mr. Hyde was instrumental in the development of a computer-based information support system on nuclear materials and is currently providing IAEA/NRC with computer supported information. These activities can be summarized as follows:

The application of safeguards in the United States by the IAEA will place some additional requirements on the eligible U.S. facilities.

Many of the U.S. facilities that will be exempted from Agency safeguards ship material to and receive material from eligible facilities, and reporting by exempt facilities may be impacted indirectly by the reporting requirements placed on eligible facilities.

Much of the data that is to be reported to the Agency is now being reported to the U.S. Government by U.S. facilities for current national needs, but the draft Safeguards Agreement calls for additional data to be reported.

The United States plans to modify the domestic reporting system with only the changes that are needed to produce the additional data and minimize the total reporting burden on U.S. facilities.

An automated data interface will be constructed on the national system for reporting information to the Agency.

Computer programmed procedures will be implemented to retrieve the applicable information from the central data base and transform the information to the codes and formats required for processing by the Agency's system.

The general provisions of the Safeguards Agreement and the Subsidiary Arrangements become specific for a given facility in the Facility Attachments that are yet to be completed for each of the eligible facilities.

In addition to the provisions for inspections, inventory verification, and other arrangements, contents of the Facility Attachments include significant material accounting and reporting details for the facility. These details will become a part of the specifications for the reporting and the processing of safeguards accounting data for that facility.

Paul K. Morrow, U.S. Nuclear Regulatory Commission

Mr. Morrow has, as one of his responsibilities in NRC, been working with the licensees and the IAEA in development of appropriate Facilities Attachments. He described what the Facility Attachments consist of and explained what each Code entails.

The format of a Facility Attachment is shown in Table III.

Table III
Facility Attachment Format

Code 1	Identification of the Facility
Code 2	Information on the Facility
Code 3	Safeguard Measures
Code 4	Specifications for Key Measurement Points (KMP's)
Code 5	Records System
Code 6	Report System
Code 7	Inspection
Code 8	Agency Statements

More complete and detailed descriptions of each of the Codes listed in Table III were presented at the Workshop and copies are available on request from the office of Paul K. Morrow, U.S. NRC Headquarters, Washington, D.C.

* * * * *

Summary Statement

All in all, the general consensus among Workshop participants was that the December Workshop in Washington, D.C., provided both a timely and a valuable contribution to better understanding of International Safeguards and the significance and impact of forthcoming IAEA requirements under the terms of the US/IAEA Agreement.

It may be noted in closing that this entire broad subject will be further developed as a major topic area at the Institute's 1979 Annual Meeting in Albuquerque, New Mexico, July 16-19—for which the theme is, very appropriately, "International Safeguards."

INMM Chairman Bob Keepin relaxes after the highly successful Workshop on the Impact of IAEA Safeguards, December 7-8, in Washington, D.C. Dr. Keepin is the Associate Group Leader of the Nuclear Safeguards and Technology Division at Los Alamos Scientific Laboratory.

Titles and Abstracts Of Recent Safeguards R&D Publications and Reports

Editor's Note—This is the fifth in a series of listings of titles and abstracts of recent safeguards R&D publications and reports from agencies and R&D laboratories. It has been compiled by Sandia Laboratories, Albuquerque, New Mexico. The Spring Issue (Volume VIII, No. 1) will have a similar listing from New Brunswick Laboratory, Argonne, Illinois. If your agency or R&D laboratory is interested in being included in this series, please contact the editors (William A. Higinbotham (516-345-2908) at Brookhaven National Laboratory or Thomas A. Gerdis (913-532-5837) at Kansas State University, Manhattan).

1. **Advanced Physical Protection Systems for Facilities and Transportation,** O.E. Jones. Proceedings of the Institute of Nuclear Materials Management Inc., 17th Annual Meeting pp. 211-225, 1976.
   Abstract:
   Sandia Laboratories is developing advanced physical protection safeguards in order to improve the security of special nuclear materials, facilities, and transportation. Computer models are being used to assess the cost-effectiveness of alternative systems for protecting the facilities. Physical protection elements are being evaluated, adapted, and where required, developed. New facilities safeguards concepts which involve (control loops) between physical protection and materials control elements are being evolved jointly between Sandia Laboratories and Los Alamos Scientific Laboratory. Special vehicles and digital communications equipment have been developed for the ERDA safe-secure transportation system. The current status and direction of these activities are surveyed.
2. SAND77-0116C** **Protection of Nuclear Power Plants Against Sabotage,** October 1977, D.J. McCloskey, S.V. Asselin, J.W. Hickman, G.B. Varnado, J.A. Milloy.
   Abstract:
   Sandia Laboratories has conducted several studies to identify the vulnerabilities of nuclear power plants to sabotage, determine possible consequences of reactor sabotage, recommend means by which sabotage can be prevented, and develop a framework for the evaluation of reactor safeguards system effectiveness. This paper summarizes the methodology, results, and conclusions of these studies.
3. SAND77-0400* **A Structure for the Decomposition of Safeguards Responsibilities,** August 1977, V.L. Dugan, L.D. Chapman. Proceedings of the 18th Annual Meeting of the INMM, pp. 218-226, 1977.
   Abstract:
   A major mission of safeguards is to protect against the use of nuclear materials by adversaries to harm society. A hierarchical structure of safeguards responsibilities and activities to assist in this mission is defined.
4. SAND77-0715* **An Overview of the SECOM II Communications System,** April 1977, W.D. Olson.
   Abstract:
   This report describes the requirements and capabilities of the SECOM Communications system.
5. SAND77-1033** **Entry Control Systems Handbook,** September 1977.
   Abstract:
   This handbook provides information concerning philosophy, operating principles, and hardware descriptions of entry control components as well as complete portal systems.
6. SAND76-0554** **Intrusion Detection System Handbook,** October 1977.
   Abstract:
   This handbook provides information pertinent to the selection, procurement, installation, test, and maintenance of elements of an intrusion detection system.
7. HCP/D6540-01* **Nuclear Safeguards Technology Handbook,** December 1977, Prepared by International Energy Associated Limited for Sandia Laboratories.
   Abstract:
   The purpose of this handbook is to present to United States industrial organizations the Department of Energy's Safeguards Technology Program. The handbook may also be of interest to international organizations and energy development and regulatory units of U.S. and foreign governments.
8. SAND77-0777** **Barrier Technology Handbook,** April 1978.
   Abstract:
   This handbook reviews the historical and philosophical aspects of adversary deterrence and delay through the use of barriers. It discusses barrier test results, new insights on barrier usage, dispensable barriers, and advanced concepts for increasing barrier penetration delay.

9. SAND78-0356J** **DOE/SS Handbooks-A Means of Disseminating Physical Security Equipment Information,** J.D. Williams, Journal of the Institute of Nuclear Management, VII, No. 1 Spring 1978, pp. 65-76.

Abstract:

In this article, a series of handbooks which are used to disseminate physical security equipment information is described. They contain data obtained from evaluation programs conducted at various laboratories supported by DOE, the Department of Defense (DOD), other government agencies, and information provided by commercial security equipment suppliers. Handbooks in the area of intrusion detection systems, entry-control systems, and barrier technology presently exist and an overview of their contents is given. Handbooks in the areas of locks, seals, and safeguards central control systems are being prepared and outlines of their anticipated contents are also given.

10. SAND77-1505C* **DOE Sponsored Evaluations of Interior Intrusion Detection Systems,** D.L. Mangan, 1978 Carnahan Conference on Crime Countermeasures Proceedings May 15-19, 1978.

Abstract:

This paper discusses the techniques which have been developed to evaluate various interior intrusion detection sensors. The technological types of sensors considered include boundary penetration sensors (vibration, balanced magnetic, infrared, and capacitance), motion or volume sensors (ultrasonic, microwave, infrared, and audio), and proximity sensors (capacitance).

11. SAND78-0644** **Intrusion Detection Sensors,** Session 24, WESCON, Los Angeles, CA, J.D. Williams, September 12-14, 1978.

Abstract:

Sandia Laboratories has conducted a survey of available intrusion detection sensors and has tested a number of different sensors. An overview of these sensors is provided which includes (1) the operating principles of each type of sensor, (2) unique sensor characteristics, (3) desired sensor improvements which must be considered in planning an intrusion detection system, and (4) the site characteristics which affect the performance of both exterior and interior sensors. Techniques which have been developed to evaluate various intrusion detection sensors are also discussed.

12. SAND76-0428* **Safeguards System Effectiveness Modeling,** September 1976, H.A. Bennett, D.D. Boozer, L.D. Chapman, S.L. Daniel, D. Engi, B.L. Hulme, G.B. Varnado. Proceedings of the 17th Annual Meeting of the INMM, pp. 239-247, 1976.

Abstract:

A general methodology for the comparative evaluation of physical protection system effectiveness at nuclear facilities is presently under development. The approach is applicable to problems of sabotage or theft at fuel cycle facilities. In this paper, the overall methodology and the primary analytic techniques used to assess system effectiveness are briefly outlined.

13. SAND77-0082* **Users' Guide for Evaluating Physical Security Capabilities of Nuclear Facilities by the EASI Method,** June 1977, H.A. Bennett.

Abstract:

The objective of this handbook is to provide a guide for evaluating physical security of nuclear facilities using the "Estimate of Adversary Sequence Interruption (EASI)" method and a hand-held programmable calculator. The handbook is intended for use by personnel at facilities where special nuclear materials (SNM) are used, processed, or stored. It may also be used as a design aid for such facilities by potential licensees.

14. SAND78-0506* **EASI Program Improvements for HP-67 and TI-59 Calculators,** July 1978, H.A. Bennett, D.W. Sasser.

Abstract:

EASI (Estimate of Adversary Sequence Interruption) is an effective, simple method which has been developed for use in evaluating physical security systems. The usefulness of the method is enhanced by the fact that it can be implemented on a programmable pocket calculator. New EASI programs for the Hewlett-Packard HP-67 and the Texas Instruments TI-59 calculators are provided. These new programs store the input data for subsequent recall or change.

15. SAND78-0112** **User's Guide for EASI Graphics,** March 1978, D.W. Sasser.

Abstract:

EASI (Estimate of Adversary Sequence Interruption) is an analytical technique for measuring the effectiveness of physical protection systems. EASI Graphics is a computer graphics extension of EASI which provides a capability for performing sensitivity and trade-off analyses of the parameters of a physical protection system. This document reports on the implementation of EASI Graphics and illustrates its applications with some examples.

16. SAND77-0043* **Insider Safeguards Effectiveness Model (ISEM) User's Guide,** November 1977, D.D. Boozer, D. Engi.

Abstract:

This report provides a comprehensive presentation of the ISEM computer program. ISEM was designed to evaluate the effectiveness of a fixed-site facility safeguards system in coping with the theft, sabotage, or dispersal of radiological material by a single person who has authorized access to the facility. This insider may be aided by a group of insiders who covertly degrade sensor systems.

17. SAND77-1367** **Users' Guide for Evaluating Alternative Fixed-Site Physical Protection Systems Using "FESEM,"** November 1977, L.D. Chapman, G.A. Kinemond, D.W. Sasser.

Abstract:

This manual will provide a guide for evaluating physical protection systems using FESEM. It is intended for use by personnel involved in evaluating fixed-site security systems, modification of existing protection systems or the implementation of new systems. This users' guide has been written for an audience which has some previous computer experience.

18. SAND77-2039* **MINDPT: A Code for Minimizing Detection Probability up to a Given Time Away From a Sabotage Target,** December 1977, B.L. Hulme.

Abstract:

This report documents a subroutine designed for use by safeguards analysts in determining good physical routes for a saboteur to follow in a fixed-site facility. The mathematical criterion used in MINDPT is based on the idea that a saboteur should minimize his probability of detection until he is so close to the target that it is too late for defensive forces to respond to an alarm and interrupt the adversary's activities.

19. SAND78-0378* **Safeguards Automatic Facility Evaluation (SAFE) Methodology,** August 1978, L.D. Chapman, L.M. Grady, H.A. Bennett, D.W. Sasser, D. Engi.

Abstract:

An automated approach to facility safeguards effectiveness evaluation called Safeguards Automated Facility Evaluation (SAFE), has been developed. This automated process consists of a collection of a continuous stream of operational modules for facility characterization, the selection of critical paths, and the evaluation of safeguards effectiveness along these paths. The technique has been implemented on an interactive computer time-sharing system and makes use of computer graphics for the processing and presentation of information.

20. SAND77-1916C** **A Method for Determining the Susceptibility of a Facility to Sensor System Nullification by Insiders,** February 1978, D.D. Boozer, R.B. Worrell.

Abstract:

One strategy for insiders attempting the theft of special nuclear material (SNM) from a nuclear facility, is to attempt to nullify a sufficient set of sensor system elements to create an unprotected exit path through the personnel control system. A qualitative method for determining the susceptibility of a nuclear facility to this strategy is described.

21. SAND77-8254* **A Survey of Threat Studies Related to the Nuclear Power Industry,** August 1977, N.R. Wagner.

Abstract:

This report summarizes several major studies directed toward the determination of threat characteristics. This summary includes only studies involving attacks on nuclear material, plus those incidents which because of their objectives, resources, or motivations may lend insight into potential threat against nuclear facilities or material.

22. SAND77-8625** **The Configuration of Road Convoys: A Simulation Study,** July 1977, R.J. Gallagher, K.G. Stimmell, N.R. Wagner. Proceedings of the 18th Annual Meeting of the INMM, pp. 348-355, 1977.

Abstract:

An important element in the evaluation of transportation safeguards systems is the analysis of convoy configurations. A computerized model, SOURCE, has been developed which simulates the initial interaction between a convoy and an adversary force. This paper briefly describes the model and presents example results for several vehicle convoy configurations.

23. SAND77-8626** **Estimating the Availability of LLEA Officers,** July 1977, K.P. Berkbigler. Proceedings of the 18th Annual Meeting of the INMM, pp. 618-624, 1977.

Abstract:

An important element in the analysis of transportation safeguards systems is the determination of the availability of local law enforcement agents. A computerized model, COPS, has been developed which rapidly estimates the total number of officers along a highway route. This paper briefly describes the model and presents example results for several routes in California and Nevada.

24. SAND77-8624** **Conflict Simulation for Surface Transport Systems,** July 1977, S.C. Keeton, P. DeLaquil, III.

Abstract:

An important element in the analysis of transportation safeguards systems is the determination of the outcome of an armed attack against the system. A battle model, SABRES, which can simulate safeguards engagements is under development. This paper briefly describes the first phase of SABRES and presents some examples of its capabilities.

25. SAND77-0644** **Reactor Safeguards System Assessment and Design, Volume 1,** June 1978, G.B. Varnado, D.M. Ericson, Jr., S.L. Daniel, H.A. Bennett, B.L. Hulme.

Abstract:

A methodology for assessing the effectiveness of safeguards systems was developed in this study and was applied to a nuclear power plant. The methodology combines fault free analysis, graph-theoretic modeling, and simulation modeling to produce a quantitative measure of the effectiveness of reactor safeguards systems in repelling forcible attacks.

26. SAND77-0890C** **Safeguards System Design Methodology,** November 1977, M.N. Cravens, A.E. Winblad. Proceedings of the 18th Annual Meeting of the INMM, pp. 101-110, 1977.

Abstract:

Sandia Laboratories is developing methods for the design of physical protection systems to safeguard special nuclear material and vital equipment at fixed sites. One method is outlined and illustrated with simplified examples drawn from current programs. The use of an adversary sequence diagram as an analysis tool is discussed.

27. SAND78-1017* **The Design of Integrated Safeguards Systems for Nuclear Facilities,** June 1978, J.M. deMontmollin (SLA) and R.B. Walton (LASL)

Abstract:

This paper describes a facilities safeguards system suitable for a production plant, in which the traditional elements of physical protection and periodic material-balance accounting are extended and augmented to provide close control of material flows.

28. SAND77-0996** **Perimeter Intrusion Detection and Assessment System,** November 1977, M.J. Eaton, J. Jacobs, D.E. McGovern. Proceedings of the 18th Annual Meeting of the INMM, pp. 380-410, 1977.

Abstract:
This is a block of three papers which were devoted to discussing how detection and assessment concepts, techniques, and hardware were used to upgrade one aspect of physical security at a particular site.

29. SAND78-1243C* **Containment and Surveillance Systems for International Safeguards,** June 1978, J.F. Ney.

Abstract:
Important criteria in measuring the effectiveness of IAEA safeguards include timeliness of detection of diversion, timeliness of reporting such detections, and confidence in determining the amount of material diverted. System studies are being carried out for different types of facilities that may come under IAEA safeguards to determine the proper balance between inspector's efforts and the use of safeguards instrumentation. A description of a typical study is presented.

30. SAND77-0980C** **Surveillance and Containment Instrumentation-International Safeguards,** June 1977, J.F. Ney, J.W. Campbell. Proceedings of the 18th Annual Meeting of the INMM, pp. 332-347, 1977.

Abstract:
The objective of IAEA safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful activities to the manufacture of nuclear explosive devices or for purposes unknown, and deterrence of such diversion by risk of early detection. Techniques utilized to provide this detection capability include material accountancy, containment, and surveillance. Sandia Laboratories has developed a number of unattended, tamper-indicating instruments that can be used as part of a containment and surveillance system.

31. SAND75-0390* **An Irradiated Fuel Bundle Counter,** J.W. Campbell, J.L. Todd, July 1975. Proceedings of the 16th Annual Meeting of the INMM, pp. 508-515, 1975.

Abstract:
The design of a prototype safeguards instrument for determining the number of irradiated fuel assemblies leaving an on-power refueled reactor is described. Design details include radiation detection techniques, data processing and display, unattended operation capabilities and data security methods. Development and operating history of the bundle counter is reported.

32. SAND78-1242C* **Electronic Self-Monitoring Seal,** August 1978, J.W. Campbell. Presented at the 19th Annual INMM Meeting, 1978.

Abstract:
The Electronic Self-Monitoring Seal is a new type of security seal which distributes its identity information through time. The identity information is a function of the individual seal, time and seal integrity. A description of this seal and its characteristics are presented. Also described are the use cycle for the seal and the support equipment for programming and verifying the seal.

33. SAND75-0439* **Pickering Safeguards—a Preliminary Analysis,** May 1977, J.L. Todd, (SLA) and J.G. Hodgkinson (AECB Canada).

Abstract:
This report presents a summary of thoughts relative to a systems approach for implementing international safeguards. Included is a preliminary analysis of the Pickering Generating Station followed by a suggested safeguards system for the facility.

34. **Tamper-Indicating Radiation Surveillance Instrumentation,** W.H. Chambers (LASL), and J.F. Ney (SLA), Volume II International Atomic Energy Agency, Vienna, 1976, pp. 297-304.

Abstract:
Prototype personnel and shipping-dock portal monitors suitable for unattended use were fabricated and tested. The requirement for continuous operation with only periodic inspection along with a desire for minimum costs and minimum interference with normal plant operation imposed unique design constraints. This paper describes the design, operation, and performance of the detection and data-recording instrumentation, as well as the tamper-indicating techniques required to protect the collected data. The techniques for joining major subassemblies and providing unique seals as well as some differences in signal conditioning and processing are also described.

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* Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161

** Available from Sandia Laboratories, Technical Library Division 3141-1, P.O. Box 5800, Albuquerque, NM 87185

New Accident-Resistant Plutonium Package

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A new package for the air transport of plutonium has been certified (licensed) by the USNRC (Nuclear Regulatory Commission), in response to United States Public Law 94-79 (August, 1975), which restricted the U.S. air transport of plutonium except for small medical devices. This new package, called PAT-1 for Plutonium Air Transportable package model 1, was the result of the NRC-sponsored PARC (plutonium accident-resistant container) project at Sandia Laboratories, Albuquerque.

The events leading up to the criteria for and the existence of the PARC program and the PAT-1 package, and the likely future impact on U.S. and international nuclear material managers, are considered. Several IAEA-member nations involved in the development of a plutonium economy are planning a dependence on the air transport of SNM, especially including plutonium. IAEA regulations are now being considered for revision in this regard, and the PAT-1 package is one of the influencing factors.

The PAT-1 package is designed to meet or exceed the new criteria specified in NUREG-0360. These new criteria specify a very severe accident-modeling test sequence of impact [>250 KTS (129m/s) perpendicular to an unyielding target, in most damaging orientation], crush, puncture, slash, fire [>1010°C (1850°F) large JP-4 fire for >1 hour], and water immersion, with very stringent acceptance standards of plutonium release, nuclear shielding, and nuclear criticality.

The PAT-1 package utilizes redwood, with embedded metal shells, for shock mitigation and fire retardation. The innermost structural element is a precipitation-hardened, martensitic stainless steel pressure vessel, with high sealing integrity under hydrostatic, crush, thermal, ballistic, and corrosive attack. The package is 62 cm (22-1/2 in.) O.D., 108 cm (42-1/2 in.) in length, and weighs approximately 227 kg (500 lb) when loaded with 2 kg PuO_2, 25 watts maximum thermal activity.

INTRODUCTION

Plutonium is shipped by air, especially for long distances or for international movements, as a result of a perceived measure of safety, security, and reliability afforded to this high-value accountable material, when compared to other shipping methods. U.S. civilian applications for plutonium that have utilized air shipment in the past include medical isotopes, medical application power sources (artificial heart; heart pacemakers), safeguards analytical laboratory evaluation samples, reactor analysis samples, and mixed-oxide fuel elements and assemblies in connection with research and development for LWR recycle and LMFBR's.

International research, development, and commerce in light water reactors, spent fuel processing, reactor fuel rod fabrication, and reactor refueling has resulted in air cargo movements of plutonium oxide, mixed oxides, and mixed oxide fuel assemblies. Such movements will increase substantially when plutonium recycle becomes operational. Nations involved with the use of plutonium in conjunction with commercial power generation or research leading toward breeder reactors or plutonium burners include France, the United Kingdom, the Federal Republic of Germany, Japan, and the Commission of the European Communities ("EURATOM"). Many of these states or groups designate air shipment as the most desirable transportation method, especially in regard to physical security and in-transit accountability.

The risk of transporting plutonium by air was assessed (1,2)* and was found to be small, as a result of the excellent safety record of commercial aviation, the small number of plutonium shipments, and the integrity of previously-required packagings.

However, legislation calling for a still higher level of packaging and transport safety regarding air shipment of plutonium was passed by the U.S. Congress (3). Since the U.S. is a member of the IAEA (International Atomic Energy Agency), and international plutonium shipments were crossing the U.S., the new developments in the U.S. soon came to the attention of other participating countries. Current activities may impact the international regulations for the air transport of plutonium. New proposals, which do not at this time have uniform agreement among the concerned nations, tend to increase the severity of package qualification testing to assure a higher level of crashworthiness.

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*Numbers in parentheses designate references at the end of this paper.

U.S. LEGISLATIVE ACTION AND NRC RESPONSE

An amendment to United States Public Law 94-79, August 9, 1975, (the Scheuer Amendment) (3) restricted the air shipment of plutonium, except for very small quantities of material in medical devices, until the NRC (U.S. Nuclear Regulatory Commission) "... has certified that a safe container has been developed and tested which will not rupture under crash and blast testing equivalent to the crash and explosion of a high-flying aircraft...."

The NRC response to this law included NUREG-0360, Qualification Criteria to Certify a Package for Air Transport of Plutonium (1). This document describes new qualification criteria (a test program) to certify a package for air transport of plutonium; it includes a discussion of aircraft accident conditions and a rationale for the technical basis of the newly required tests; it includes stringent post-test acceptance of standards of release, criticality, and shielding; and it includes certain operational controls to be exercised during transport. The rationale embodies a maximum credible accident approach, with severe single-event accident elements all applied sequentially to the same package. Certain individual tests are included as well as a requirement to conform to the existing regulations of 10 CFR 71 (4) and 49 CFR 173 (5).

Parallel to developing the new criteria, the NRC engaged Sandia Laboratories in the development of a new plutonium transportation package that would meet the evolving criteria. Sandia dubbed this project PARC for Plutonium Accident Resistant Container (6). The PARC project resulted in the development of the PAT-1 (Plutonium Air Transportable Model 1) package. The package was designed concurrently with, and in response to, the Qualification Criteria, and is the first design to meet the new legislative requirements. It survives the sequential and individual tests of both the new and old criteria and meets the applicable acceptance standards in each case. The 227 kg (500 lb) package is licensed to accommodate 2 kg of PuO_2 or PuO_2 mixed with natural or depleted uranium, in any solid form, with a limitation of 25 watt decay heat, in a small internal can.

Both the new criteria and the new package were approved by the ACRS (Advisory Committee for Reactor Safeguards), the National Academy of Engineering's Ad-hoc Committee on the Air Transport of Plutonium, and by the NRC at the Commissioner level.

The NRC then certified to Congress that the conditions of PL94-79 had been satisfied, and on August 4, 1978, the NRC rescinded their order of August 15, 1975, reestablishing permission for air transport of plutonium under the new conditions.

On September 1, 1978, the NRC advised licensees by letter that Certificate of Compliance #0361 (7) (the "license") for the PAT-1 package is issued, permitting the air transport of plutonium, under specified conditions, in this type of package.

OUTLOOK FOR U.S. AND INTERNATIONAL (IAEA) Pu SHIPPERS

The domestic air transport of plutonium* by U.S. licensees is now regulated to utilization of a PAT-1 type package. The NRC has provided a few PAT-1 packages (excess from the engineering and development program) to the DOE; these packages have been distributed to pertinent DOE agencies for their use. Additional U.S. applications, such as in the commercial sector, would probably require that an applicant provide additional newly-obtained PAT-1 packages, built to the conditions of NUREG-0361, the PAT-1 Safety Analysis Report (SAR) (8). It is possible that this package will come into use for a wider variety of radio-isotopes and may also become used for surface-only transport, rather than the present orientations toward plutonium and air transport.

Internationally, there is some agreement that qualification test levels for plutonium air transport packages may require some increased stringency (9). The IAEA SAGSTRAM (Safety Advisory Group on the Safe Transport of Radioactive Material) group is considering revisions to Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6 (10). Some debate also exists (11) as to whether any changes at all are necessary, and there is definite disagreement (11) with the new unilateral high-level U.S. criteria.

The probable outcome is that IAEA regulations will change, but not to the level of conformance to the U.S. regulations. This would result in an imbalance of requirements within IAEA member states, at least for the air shipment of plutonium. It can be predicted that the PAT-1 package will meet or exceed upgraded IAEA requirements, enabling U.S. shippers to operate nationally and internationally. A problem remains for international shippers attempting to utilize U.S. air routes with the older packages currently in use.

PARC/PAT-1 PROJECT

It may be of interest to nuclear materials managers to gain some insight into the severity of the new qualification criteria, and also to gain some insight into the extensiveness of the PARC engineering and development program that ensued to meet these criteria. Complete details are available in Reference 6, PARC (Plutonium Accident Resistant Container) Program Research, Design, and Development. The following is a summary of the criteria and the engineering development program.

The Qualification Criteria are summarized in the next two tables; Table 1 defines the test program of new sequential and individual tests, and also summarizes the tests of the existing regulations 10 CFR 71. Table 2 summarizes the acceptance criteria, essentially, comprising three requirements: containment, shielding, and criticality.

*Only uranium oxide or plutonium oxide, and their daughter products, in solid form, are presently covered by USNRC Certificate of Compliance #0361.

TABLE 1

QUALIFICATION CRITERIA TO CERTIFY
A PACKAGE FOR AIR TRANSPORTATION OF PLUTONIUM
(NUREG-0360)

Sequential Tests		
Impact	--	129 m/s (422 fps; 250 KTS) perpendicular to flat unyielding target; most severe orientation
Crush	--	310 kN (70,000 lb) through 5.1 cm (2 in.) wide steel bar; most severe location
Puncture	--	227 kg (500 lb) steel probe with .4 cm (1 in) dia. blunt end cone dropped 3 m (10 ft) onto package at most vulnerable point
Slash	--	45 kg (100 lb) steel angle dropped 46 m (150 ft); twice onto package tilted at 45°
Fire	--	Engulfed in large JP-4 fire for one hour; left to self-extinguish or cooled by water, whichever results in maximum damage to package.
Submersion	--	Under 1 m (3 ft) water for 8 hours
Individual Tests		
Hydrostatic	--	4.1 MPa (600 psi) for 8 hours [equivalent to 411 m (1350 ft) immersion depth]
Terminal Velocity Free Fall	--	Impact test at terminal velocity required if terminal velocity is more than 250 KTS
10 CFR 71 Tests		
Normal	--	Heat, cold, pressure, vibration, water spray, 1.2 m (4 ft) drop, penetration, compression
Accident	--	9 m (30 ft) drop, puncture, fire, submersion

TABLE 2

ACCEPTANCE CRITERIA

Containment of Plutonium

-- Release must be less than IAEA A2 weekly quantity following test sequence of new criteria

-- "No release" from double containment following 10 CFR 71 normal or accident conditions

Shielding

-- Normal transport - 49 CFR 173 requires that external radiation be limited to:

10 mrem/hr @ 1 m (3 ft), and
200 mrem/hr @ surface

-- Post-accident - 10 CFR 71 requires that external radiation, following the more severe tests of the new criteria, be limited to:

1000 mrem/hr @ 10 m (3 ft)

Criticality

-- Undamaged single packages and large arrays must be subcritical per 10 CFR 71

-- Arrays of damaged packages must be subcritical per 10 CFR 71, following the more severe tests of the new criteria

When the qualification test levels for the PAT-1 package are compared to the severities of aircraft accidents (12), it is conservatively predicted that the PAT-1 test levels are greater than the conditions encountered in more than 99.5% of all aircraft accidents. In general (13), major aircraft accidents occur once every 10^8 air miles. Therefore, the expectation that an air accident will occur which will exceed the qualified capabilities of the PAT-1 package is less than once for every 10^{10} miles of plutonium air transport. Additionally, the PAT-1 package has a reserve margin beyond these figures, deriving from several factors including the severe double slash test (which increased the fire vulnerability of the tested packages) in the qualification criteria, and from the fact that the PAT-1 package did not fail at test levels higher than the qualification criteria (6) and in fact never was tested to failure.

Package Description

The PAT-1 package is externally similar in appearance to a 65-gallon stainless steel process vessel, except that it appears to have two "top" ends. The package, 62 cm (24-1/2 in) O.D., 108 cm (42-1/2 in) in length, and approximately 227 kg (500 lb) when loaded, is shown during aircraft loading in Figure 1. It consists of three separate items: an AQ-1 (Air Qualified Model 1) overpack, a TB-1 containment vessel, and a PC-1 product can. These items and other details of design and construction are shown in the cutaway (Fig. 2).

Air Qualified Overpack (AQ-1) -- The AQ-1 consists of a bonded double-wall outside drum of 16 gauge 304 stainless steel, an outer and inner grain-oriented redwood assembly with an interstitial load spreader assembly, and a heat conductor element. The double outside drum ends, both top and bottom, are secured in a unique manner to permit relatively simple access to the container (through one end only) and yet retain the removable parts when subjected to a violent impact.

High specific energy absorption capability parallel to the grain coupled with good characteristics were the factors leading to the selection of redwood as the shock mitigator/thermal barrier. These capabilities were examined relative to absorber density to constrain the final package size and weight while maintaining utility as an industrial air transportable package with a practical (although small) internal payload.

The interstitial load spreader was found to be essential to distribute dynamic compressive loading from the relatively small surface area loading of the containment vessel to a larger area of the shock-absorbing material. In a side or lateral impact, the tube is the principal load spreader; in an end or longitudinal impact, the discs are the principal load spreaders. Referring to Figure 2, the region of the tube which extends beyond the discs acts both as a load spreader and also deforms inward in a severe corner impact, which constricts possible passage of the discs and containment vessel in an outward direction. This deformation/construction action also occurs in side and end impacts.

Figure 3 indicates the resulting package cross-section, showing the double-walled outside drum, the radial grain orientation of the outer and inner annuli of redwood, the load spreader tube, and the containment vessel. The non-removable elements of this assembly are permanently bonded together with a polyester-flexibilized epoxy adhesive which has resilience over a wide temperature range. When impact forces cause deformations, this bond acts to join the wooden elements and their adjacent metal elements, affording resistance to impact deformation. This same bonding material joins the two walls of the stainless steel drum, adding to the drum's resistance to ripping and tearing.

Containment Vessel (TB-1) -- The TB-1 containment vessel (Fig. 4) consists of a body, a lid secured by bolts, a copper gasket, and an O-ring. The vessel body and lid are fabricated from PH13-8Mo precipitation hardened stainless steel. The H1075 temper enhances ductility while preserving high strength from low to high temperatures. The body and lid are designed with approximately hemispherical end shapes and cylindrical side wall shapes to resist deformation from either external or internal loads or pressures. The lid is hermetically sealed to the body by the use of a ductile copper gasket in conjunction with knife-edge sealing beads on both the body and lid, and by a pattern of bolts. The lid has a pilot diameter region of great structural shear strength which fits closely into the mating internal diameter of the body. This closely limits any possible radial motion between these parts, especially motion that would be induced by deformations resulting from accidental crash, crush, or puncture loads. This pilot diameter is also equipped with an O-ring in a groove, which acts as a secondary seal to supplement the upper copper gasket and double knife edges, to maintain contents within the containment vessel.

Twelve closure bolts, 1.27 cm (1/2 in) in diameter, (Fig. 4) are forged from A-286 stainless steel, and provide over 133 kN (30,000 lb) ultimate tensile strength per bolt. This material resists contact corrosion with the stainless steel body and lid, and provides high temperature strength to maintain the seal at elevated temperatures. The bolts are silver plated to prevent galling of the stainless steel bolt in the stainless steel vessel.

An aluminum honeycomb spacer prevents the flat end of the internal product can from entering into the hollow hemispheric lid in the event of severe impact loads in the axial directions. This spacer also serves as a thermal conductor for heat generated by radioactive decay of the PuO_2 contents.

The containment vessel mass/strength tradeoff was optimized to reduce the vessel's kinetic energy (an internal threat to the surrounding shock mitigation material) while keeping the vessel strong enough to survive direct impact and puncture threat, including armor piercing projectile attack.

Product Can (PC-1) -- The PC-1 product can, shown on the right side of Figure 4, is fabricated from 304 stainless steel. It is closed by crimping in a canning machine and is also sealed with an epoxy material. The close fit of the TB-1 containment vessel limits product can deflection or permanent change of shape under severe impact loads. The product can provides double containment under the normal and accident conditions of transport performance tests as specified by 10 CFR 71.42. This product can may be loaded to a maximum weight of 2 kg PuO_2 contents, in plastic bags, not to exceed a maximum of 25 watts thermal activity, of PuO_2 of various isotopic compositions. The product can is approximately 10.3 cm (4.06 in) in diameter and 16.3 cm (6.42 in) high, with one rounded end.

Thermal Analysis

Thermal analyses of the PAT-1 package included finite difference modeling for internal heat load capacity. This analysis led to the 25 watt limitation on thermally active radioisotopic contents; the limiting consideration here was long-term protection of the redwood to preserve known performance factors. Finite difference thermal modeling was also used for analysis of externally applied heat such as standard hot day conditions, and to predict package performance in the 1010°C (1850°F) large JP-4 fuel fire environment.

Shielding and Criticality

The PAT-1 package exceeds the radioactive materials shielding and criticality requirements of 10 CFR 71 and 49 CFR 173. These results are given in extensive detail in Reference 6 and are summarized in Table 3.

Test and Evaluation Program

A large number of engineering development tests were necessary during the derivation of the package design. After firm design definition, the qualification tests were conducted. Before the tests, each sealed containment vessel was loaded with a finely divided surrogate UO_2 powder, helium gas, and an excess of internal water content. Table 4 summarizes the qualification tests and indicates results. This table shows that five PAT-1 packages were subjected to similar sequential test series, except that the initial impact test was oriented so as to encompass the five different principle threat orientations of top, top corner, side, bottom corner, and bottom. Figure 5 shows the PAT-1 package following a side impact with the unyielding target at 136 m/s (445 fps). This test is conducted from a high horizontal aerial cable by a vertical pull-down apparatus that utilizes a rocket-powered sled. The crush, puncture, slash, fire, and immersion tests that followed were essentially identical for all packages, with the application point of each test being chosen to produce the most damaging cumulative effect on each package. Table 4 also includes the individual hydrostatic test required by the Qualification Criteria, the high and low temperature engineering development impact tests, applied as the first in a sequence of tests, and the required 10 CFR 71 tests.

Fluorimetric instrumentation with a sensitivity $\gtrsim 10^{-8}$g U indicated that no UO_2 powder escaped. A mass spectrometer-type helium leak detector showed that only very small helium leak rates were induced in the containment vessel seals.

Experimental work with actual PuO_2 was conducted under NRC sponsorship at another laboratory (14), to correlate the observed helium leak rates with conservative bounding estimates of worst-case possible plutonium loss. These conservative bounding assessments of plutonium loss were compared to IAEA "A2" quantities (10).

These assessments demonstrated successful performance of the PAT-1 package, satisfying the criteria for plutonium containment.

TABLE 3

SHIELDING AND CRITICALITY

Shielding

Normal Transport:

-- PAT-1 Package provides sufficient shielding (40 CFR 173)

Required -- < 10 mrem/hr 3 ft from surface
Calculated -- 4 mrem/hr* 3 ft from AQ-1 -- horizontally
1 mrem/hr* 3 ft from AQ-1 -- vertically

Required -- < 200 mrem/hr at surface
Calculated -- 30 mrem/hr* at surface of AQ-1 -- horizontally
15 mrem/hr* at surface of AQ-1 -- vertically

Post-Accident:

-- Containment Vessel (TB-1) Provides Sufficient Shielding (10 CFR 71) - This permits AQ-1 overpack to be discounted

Required -- < 1000 mrem/hr 3 ft from surface
Calculated -- 8 mrem/hr* 3 ft from surface of TB-1 -- horizontal or vertical

*Using most radioactive recycled plutonium as conservative source model.

Criticality

Normal Transport:

-- Undamaged infinite array
$K_{eff} \sim 0.22$

Post-Accident:

-- Damaged infinite array (full consequence of qualification criteria)
$K_{eff} \sim 0.34$

Single water-flooded and reflected TB-1
$K_{eff} \sim 0.62$

(K_{eff} = effective neutron multiplication factor)

Table 4

SUMMARY OF NRC QUALIFICATION TESTS, PAT-1 PACKAGE

Impact Orientation	Impact Vel. ⊥ to Unyielding Target, fps	Crush 70,000 lb	Puncture 5000 ft-lb	Slash 15,000 ft-lb	Fire 2200°F 60 Minutes	Immersion	Uranium Detection $\gtrsim 10^{-8}$g	Post-Test Air Leakage (cm^3/s)
Top - 0°	442	√	√	√	√	√	None	$<4.6 \times 10^{-6}$
Top Corner 30°	451	√	√	√	√	√	None	$<4.5 \times 10^{-5}$ probably 1.7×10^{-7}
Side - 90°	445	√	√	√	√	√	None	1.4×10^{-6}
Bottom Corner 150°	443	√	√	√	√	√	None	$<5.5 \times 10^{-6}$
End - 180°	446	√	√	√	√	√	None	1.9×10^{-6}
Side* 90° (-40°C; -40°F)	443	√	√	--	√	√	--	2.4×10^{-6}
Side* 90° (+93°C; 200°F)	424	√	√	--	√	√	--	7×10^{-8}

Individual Test: 600 psig hydrostatic; 8 hours - no detectable water leakage; $\dot{q} < 10^{-10}$ cm^3/s

10 CFR 71 Tests: Package passed all Appendix A (normal) and Appendix B (accident) tests, with double containment.

*Engineering development tests

Containment Vessel Integrity

The containment vessel will lose no radioactive material in the maximum credible accident environment (a bounding assessment indicates 582°C [1080°F] with 8.6 MPa [1253 psi] internal pressure) and is leak tight under maximum normal operating pressure (102°C [215°F] with 0.254 MPa [34.3 psi] internal pressure). The TB-1 containment vessel is highly resistant to sea water corrosion and easily withstands 4.1 MPa (600 psi) hydrostatic pressures specified in the NRC Qualification Criteria; the vessel has been successfully tested to 34.5 MPa (5000 psi) external pressure. Containment vessel integrity, determined by both analysis and test, is summarized in Table 5.

OPERATIONAL CONTROLS

NUREG 0360 (1) and Certificate of Compliance 0361 (7) restrict air shipment of plutonium to cargo aircraft and specify operational controls in the areas of stowage location, tie-downs, and other cargo. These regulations should be carefully examined and followed by plutonium shippers and carriers.

FISSILE CLASS

Reference 6 indicates that the PAT-1 package meets the 10 CFR 71 Fissile Class I (unrestricted) requirements with a cargo of 2 kg $^{239}PuO_2$, or with any other form of plutonium oxide not to exceed 25 watts of thermal activity (6).

TRANSPORT INDEX

Reference 6 also indicates that the PAT-1 package meets all radiation requirements of 49 CFR 173.393 and 10 CFR 71.36; with a theoretical maximum radiation source payload the PAT-1 would have a transport index of 4 (mrem/hr dose rate 3 ft from the package surface); actual loadings may have a smaller transport index.

SAFEGUARDS ASPECTS

The PAT-1 package is essentially a safety-oriented design, and does not have special safeguards features. However, its size and weight, seemingly excessive for its payload, and its ruggedness are advantages from the viewpoint of physical security. The closure mechanism has a provision for the use of a seal. Access requires the removal of a number of fasteners and a number of layers of packaging. The package has demonstrated resistance to modern small arms ballistic attack. The esorting, accounting, and surveillance requirements of 10 CFR 73 (15), which is also under proposed rule changes, would apply to the safeguarding of air shipment of plutonium in the PAT-1 package and must be observed.

CONCLUSION

The world's energy demands and available energy sources are such that there is an increased international interest and commerce in plutonium. For perceived reasons of safety, safeguards, and reliability, much of this plutonium will be designated to be transported by air. Recent pressures from public interest, legislative, and regulatory groups have already influenced the packagings and operational procedures for the air shipment of plutonium in the U.S.; other states are also reevaluating their requirements. The PAT-1 package, developed for the U.S. Nuclear Regulatory Commission by Sandia Laboratories' PARC Program, survives the severe accident-modeling test threats of the new USNRC Qualification Criteria, and meets the acceptance criteria for containment, shielding, and criticality. The PAT-1 package, which can accommodate only a small quantity of plutonium oxide or mixed oxide, is the first of what may be a family of shipping packages that provide some increased measure of safety for the air transport of plutonium, in a manner compatible with current safeguards regulations.

TABLE 5

CONTAINMENT VESSEL INTEGRITY

Internal Pressure

-- Maximum Credible Accident Environment - 582°C (1080°F)
(Bounding Assessment) 8.6 MPa (1253 psi)

Tested to: 538°C (1000°F), 22.9 MPa (3330 psi), 18 hrs
Many tests @ 582°C (1080°F), 8.6 MPa (1253 psi)

Analysis: 126 MPa (18,300 psi) stress
641 MPa (93,000 psi) strength
At 582°C (1080°F) and 8.6 MPa (1253 psi),
Margin of Safety ≈ 4

-- Maximum Normal Operating Pressure - 102°C (215°F)
0.254 MPa (34.3 psi)

Analysis: 3 MPa (455 psi) stress
965 MPa (140,000 psi) strength
At 102°C (215°F) and 0.245 MPa (34.3 psi),
Margin of Safety ≈ 306

External Pressure

-- Hydrostatic Requirement - 4.1 MPa (600 psi)

Tested to: 34.5 MPa (5,000 psi) - No leak

Analysis: 34.5 MPa (5,000 psi) load produces
-296 MPa (-43,000 psi) stress
1 GPa (150,000 psi) strength gives
Margin of Safety ≈ 2.5
Margin of Safety ≈ 20 @ 4.1 MPa (600 psi)

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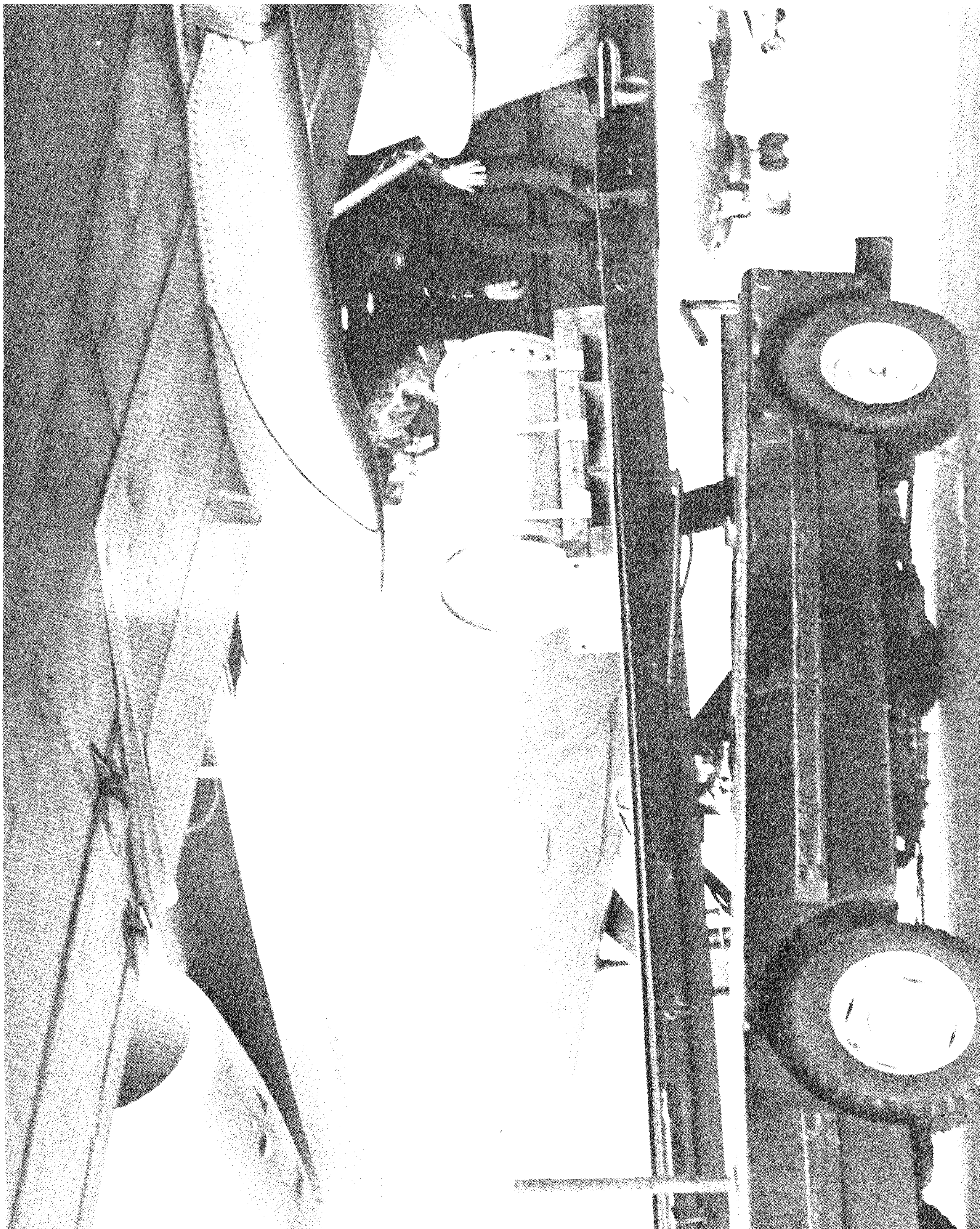
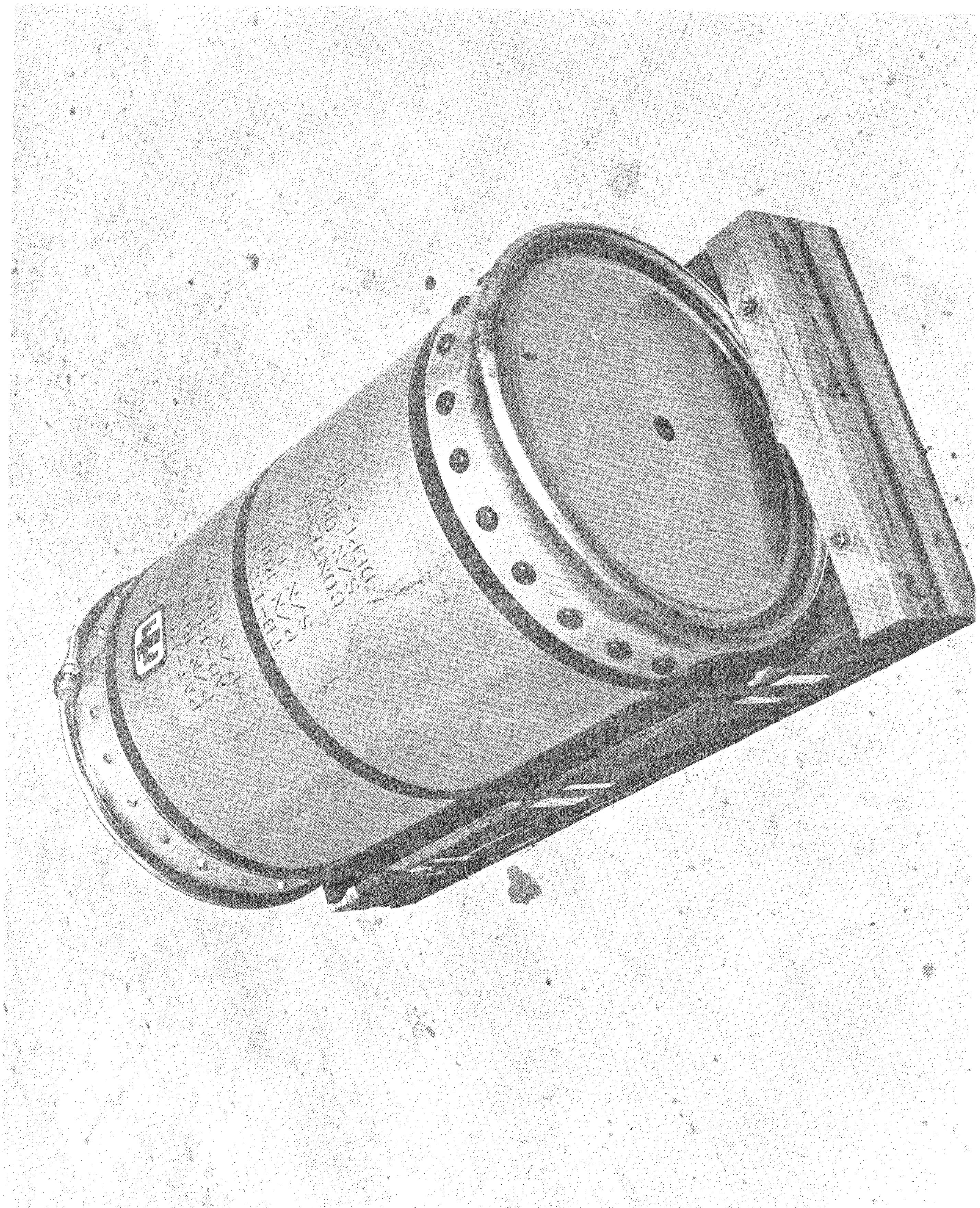
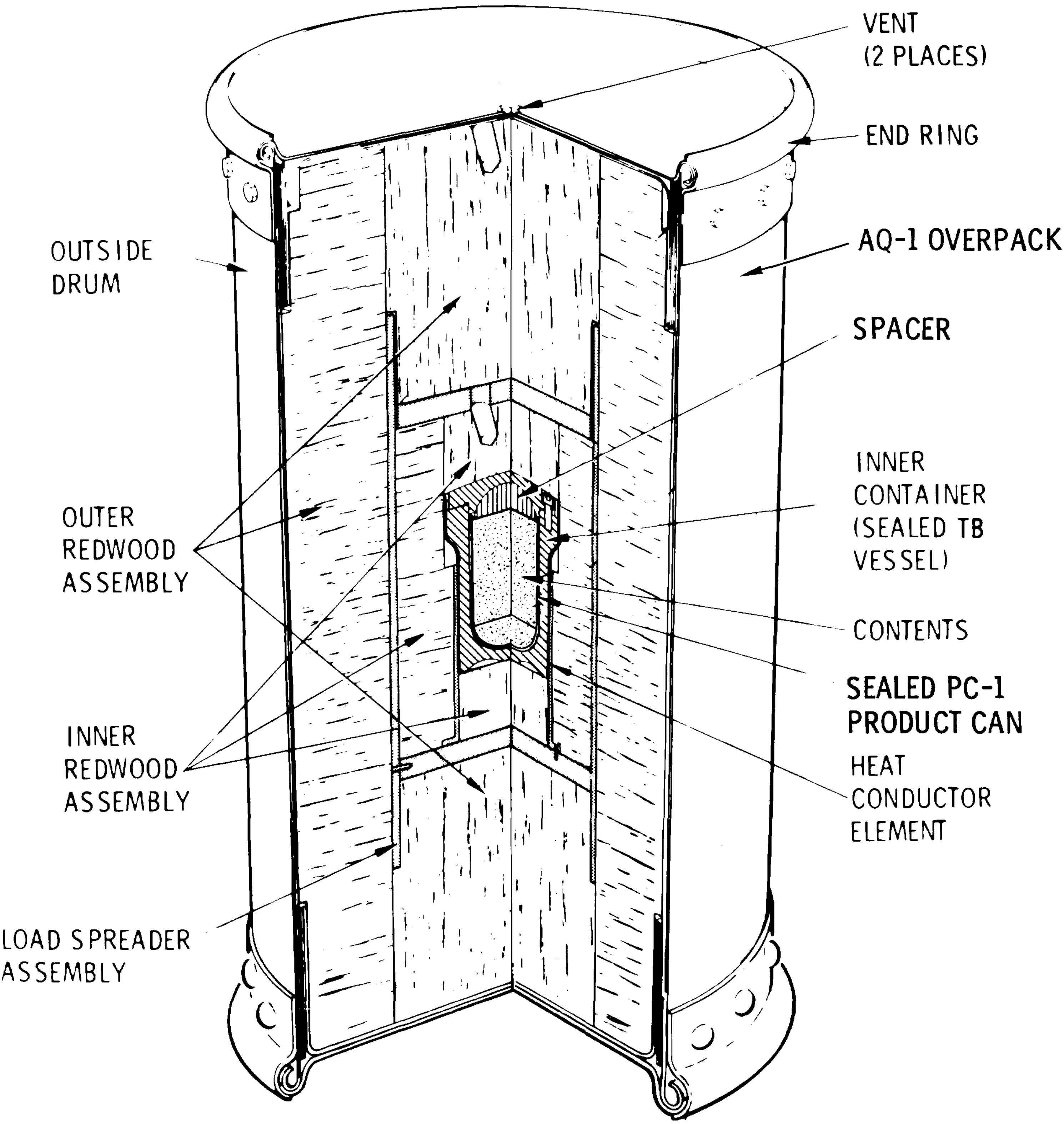


Fig. 1. PAT-1 Package Aircraft Loading





PAT-1 PLUTONIUM AIR TRANSPORTABLE PACKAGE

Fig. 2. PAT-1 Cutaway

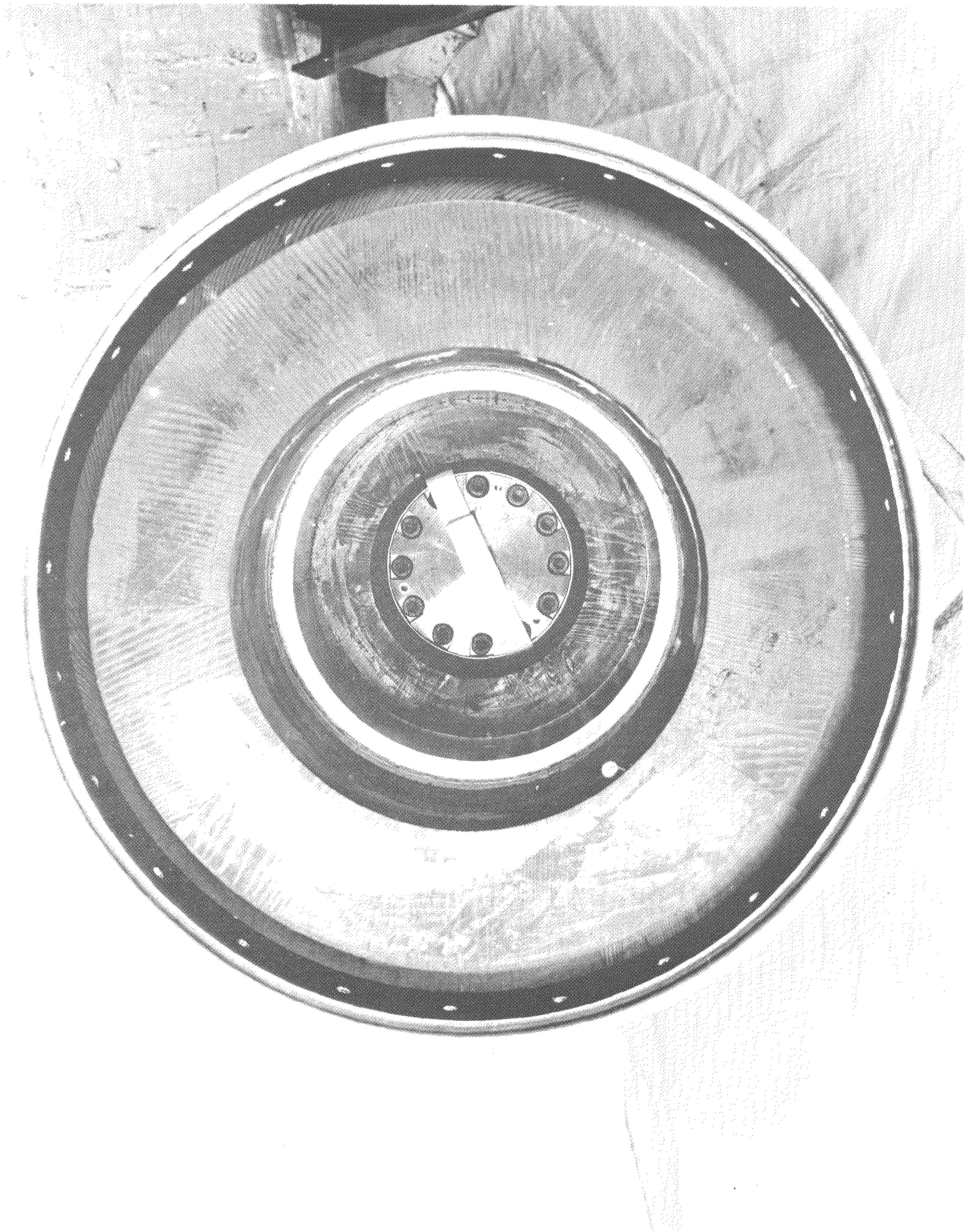


Fig. 3. PAT-1 Package Interior

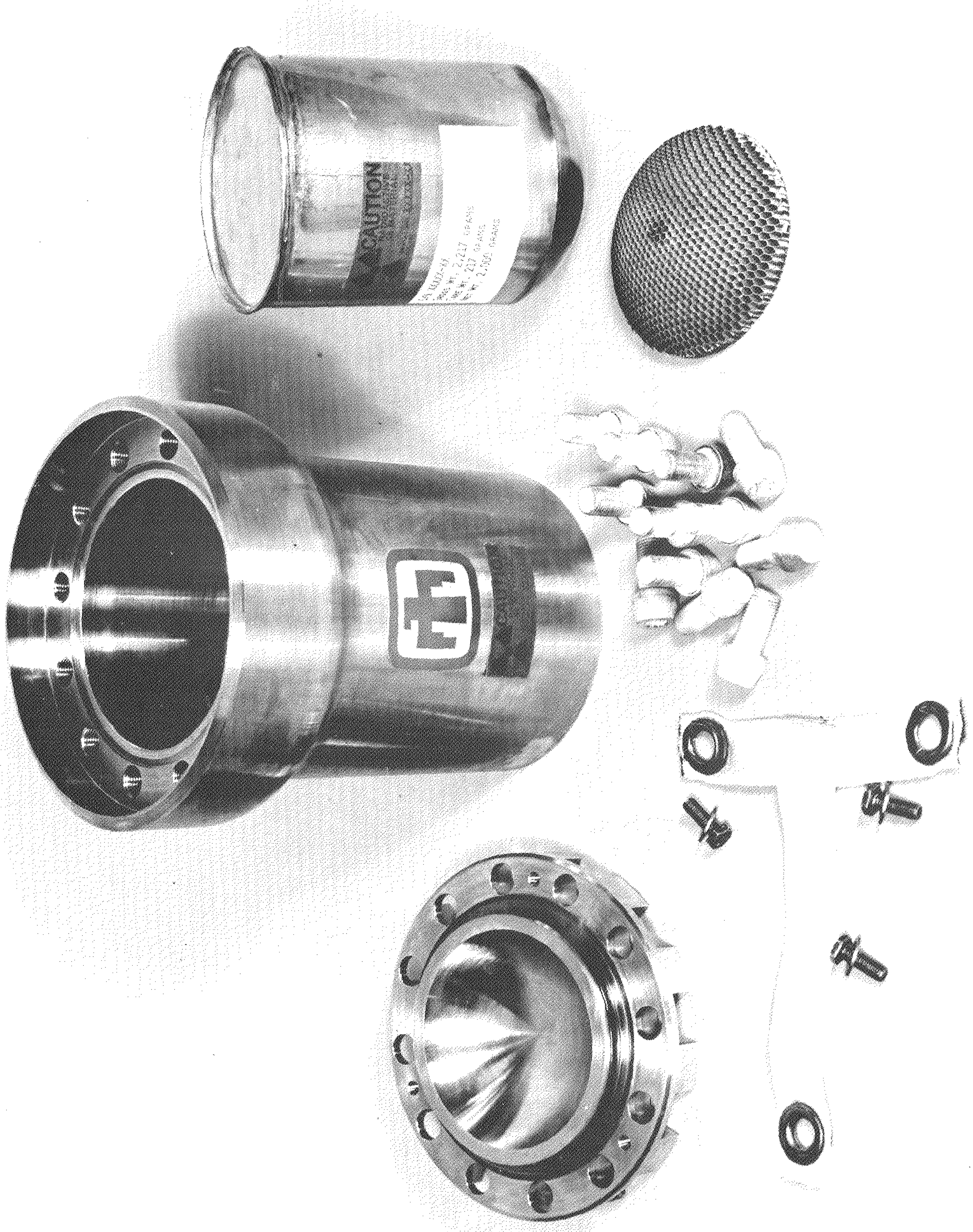


Fig. 4. TB-1 Containment Vessel with PC-1 Product Can

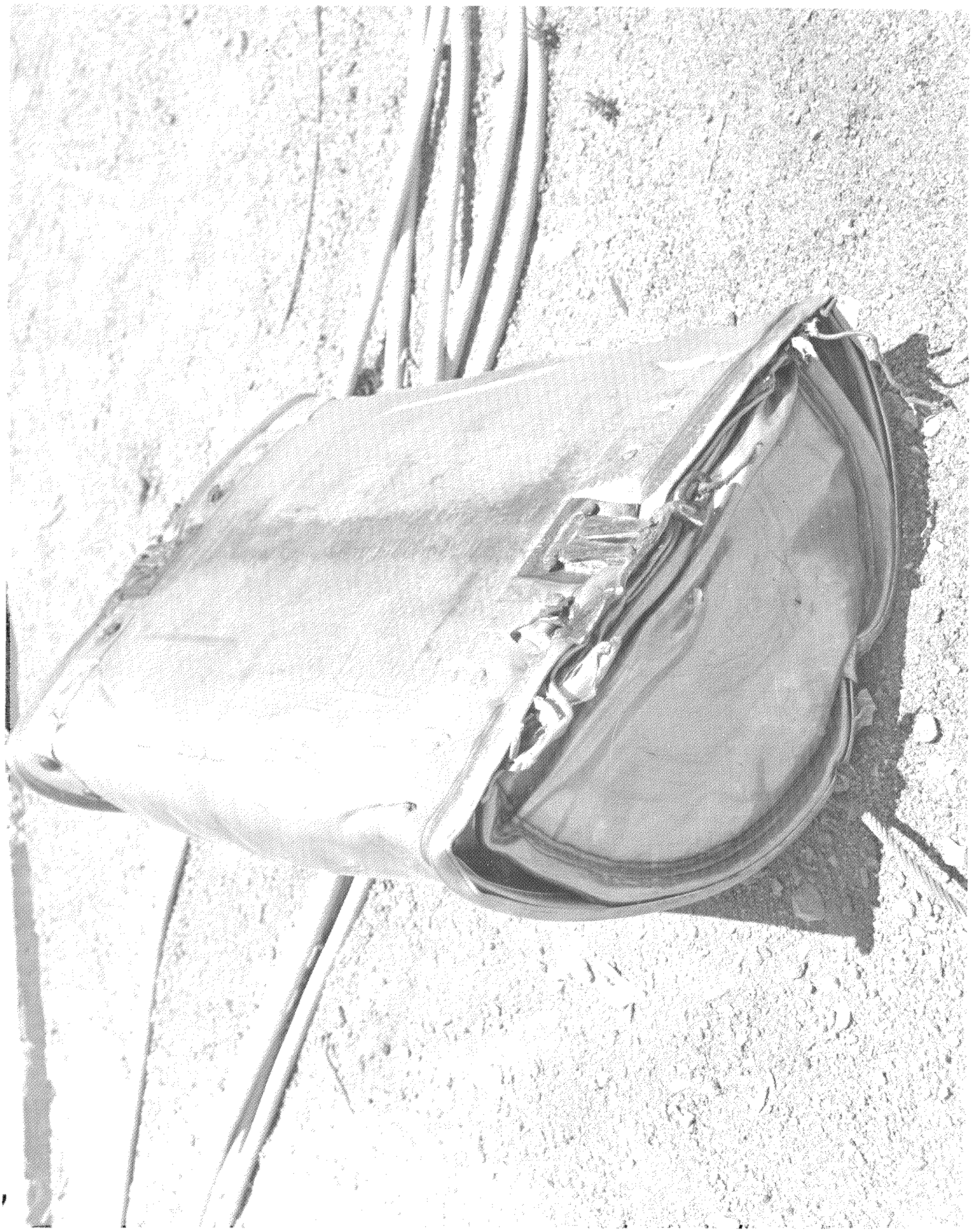


Fig. 5. PAT-1 Package After Pull-down Test

Analysis of MUF Data Using ARIMA Models

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INTRODUCTION

The analysis of MUF has taken several steps from the pioneering work of Jaech[1] who introduced several statistical methods to evaluate MUF data, to Stewart[2] with his minimum variance unbiased estimator techniques, and most recently the application of Kalman Filtering to detect losses in MUF data by Pike and Morrison[3]. The references above as well as others have presented techniques to detect losses using inventory and transfer data. In this paper we present a new technique for estimating the loss when the loss scenario is known. This technique differs from the others in that it applies the Box-Jenkins[4] time series analysis to model the stochastic process (the observed MUFs) and uses the one-step-ahead forecasts to indicate whether a loss is occurring or not. The purpose of this paper is twofold: 1) to introduce the Box-Jenkins time series analysis methods and 2) to use these techniques in determining whether a significant loss has occurred.

ARIMA TIME SERIES MODELS

Over the last several years a modeling technique developed by Box and Jenkins[4] has proven to be an invaluable tool in the analysis of discrete time series. The class of models developed by Box and Jenkins is termed ARIMA (Autoregressive-Integrated-Moving Average) models. These models have adequately described time series found in economics, engineering, chemistry, physics, and several other fields. The basic ARIMA (p,d,q) model is given by:

$$(1-\phi_1 B-\phi_2 B^2-\ldots-\phi_p B^p)(1-B)^d(Z_t-\mu) = (1-\theta_1 B-\theta_2 B^2-\ldots-\theta_q B^q)a_t \; . \quad (1)$$

where B is the backward shift operator, that is

$$\begin{aligned} BZ_t &= Z_{t-1} \\ B^2 Z_t &= B(BZ_t) \\ &= B(Z_{t-1}) \\ &= Z_{t-2} \end{aligned} \quad (2)$$

and in general

$$B^p Z_t = Z_{t-p} \; . \quad (3)$$

The operator (1-B) is called the difference operator since

$$\begin{aligned} (1-B)Z_t &= Z_t - BZ_t \\ &= Z_t - Z_{t-1} \; . \end{aligned} \quad (4)$$

The difference operator is used to induce stationarity in the time series. It can be applied successively, for example:

$$\begin{aligned} (1-B)^2 Z_t &= (1-B)(1-B)Z_t \\ &= (1-B)(Z_t - Z_{t-1}) \\ &= Z_t - 2Z_{t-1} + Z_{t-2} \; . \end{aligned} \quad (5)$$

Thus in the general model defined by Equation (1) the difference operator may be raised to the power d. In practice d is usually 0, 1, or 2. The series is differenced until stationarity is obtained and this new series can be operated on in a reverse method called summing to produce the original series. If we consider summing akin to integration, we can see the reason for the word "integrated" in the model description. In layman terms, stationarity of a time series implies that the joint probability distribution of $Z_{t_1}, Z_{t_2}, \ldots, Z_{t_m}$ does not depend on the position in the stochastic process, but rather on their relative position. That is, the joint distribution of (Z_3, Z_6) is the same as the joint distribution of (Z_4, Z_7) since they are separated by three time units. This type of stationarity is referred to as strict stationarity. Another type, called weak stationarity of order f, describes stochastic processes whose moments up to order f are identical. It can be shown that the assumption of weak stationarity of order 2 and normality imply strict stationarity.

The operator

$$\Phi(B) = (1-\phi_1 B-\phi_2 B^2-\ldots-\phi_p B^p) \quad (6)$$

is called an autoregressive operator of order p. The operator

$$\theta(B) = (1-\theta_1 B-\theta_2 B^2-\ldots-\theta_q B^q) \quad (7)$$

is called a moving average operator of order q. Thus the nomenclature ARIMA(p,d,q). The random variable, Z_t, represents the value of the stochastic process at time t which we can observe by sampling. The constant, μ, is the mean of the process. The random variable, a_t, is assumed to be a white noise process which we do not observe. That is, $\{a_t\}$ is taken to be normally distributed with mean zero and variance σ_a^2 with a_i independent of a_j, $i \neq j$.

Box and Jenkins[4] describe an iterative approach to building the model in Equation (1). It contains three main steps:

1) Model identification - the determination of p, d, and q.
2) Parameter estimation - the estimation of the unknown parameters μ, σ_a^2, ϕ_1, $\phi_2, \ldots, \phi_p$ and $\theta_1, \theta_2, \ldots, \theta_q$, and
3) Diagnostic checking - testing the model for inadequacies.

The identification phase is carried out by computing the autocorrelation and partial autocorrelation functions of the observed time series or some transformation of it. Comparison of the estimated autocorrelation and partial autocorrelation function with those of known ARIMA models leads the analyst to a model (or models) of choice. The model chosen has a known functional form, depending upon parameters whose values are unknown. The parameters are determined in the second phase, i.e., the estimation phase. The output of the estimation phase consists of the parameter estimates (determined by a nonlinear least squares algorithm) together with error variance for the time series. The third and final step in the model building process is the diagnostic checking phase in which the estimated model is analyzed for any possible lack of fit to the data and violation of assumptions used in deriving the model. If the diagnostic checking reveals inadequacies in the model, the model may be dropped from further analysis and a new model processed through the three-phase procedure. Often, the diagnostic checking will suggest modifications to the model that will enable the data to be fit more closely. Once a model has successfully completed the three phases, it can be used to forecast the future and, through feedback, to control the process itself.

A more thorough investigation of each of the three phases can be found in Box and Jenkins[4], C. R. Nelson[5], or O. D. Anderson [6]. Although all three books present essentially the same concept, Box and Jenkins is the more rigorous mathematically; Nelson's book is directed towards business applications; Anderson's book is a less formal mathematical synopsis of Box and Jenkins techniques.

MODELING MUF DATA

As pointed out above, the model identification comes from investigating the autocorrelation and partial autocorrelation function of the time series. Comparing the estimated autocorrelation and partial autocorrelation function with those of known models and finding a match give the analyst a tentative model. To see how this works, we shall consider two simple models;

$$\underline{AR(1)} \qquad (1-\phi B)(Z_t-\mu) = a_t , \quad (8)$$

and the

$$\underline{MA(1)} \qquad (Z_t-\mu) = (1-\theta B)a_t . \quad (9)$$

First we need to define the autocorrelation of lag k, denoted by ρ_k. Let $\{Z_t\}$ be a stationary process, then the autocovariance at lag k is

$$\delta_k = E[(Z_t-\mu)(Z_{t-k}-\mu)] = E[(Z_{t+k}-\mu)(Z_t-\mu)] = \delta_{-k} \text{ for } k = 0, \pm 1, \pm 2, \ldots \quad (10)$$

where E is the expectation operator. $\delta_k = \delta_{-k}$ because the process is stationary. Since the autocovariance is symmetric about k=0, we need only consider the positive half k = 1,2,... . Then the autocorrelation function is defined as:

$$\rho_k = \frac{\delta_k}{\delta_0} \qquad k = 1,2,3,\ldots . \quad (11)$$

It can be shown (see Appendix A) that the autocorrelation function for the first order autoregressive process (Equation 8) is given by:

$$\rho_k = \phi^k \quad k = 1,2,\ldots \quad . \qquad (12)$$

Thus we see that for an AR(1) process, the autocorrelation function decays in an exponential manner. Figure 1 shows the estimated autocorrelation function (solid lines) obtained by simulating an AR(1) process with $\phi = 0.8$. The theoretical autocorrelation function is shown in dashed lines. Thus, if one were to observe an autocorrelation function that decays exponentially, he would be inclined to postulate an AR(1) model.

It is also shown in Appendix A that the autocorrelation function for the first order moving average process (Equation 9) is given by:

$$\rho_1 = -\frac{\theta}{1 + \theta^2}$$

$$\rho_k = 0 \quad \text{for } k = 2,3,\ldots \quad . \qquad (13)$$

Figure 2 shows the estimated autocorrelation function for a simulation in which $\theta = 0.6$. The theoretical autocorrelation function is shown by the dashed line. Here we see that a single spike in the autocorrelation function implies a MA(1) process.

Armed with this knowledge, can we choose a model that characterizes MUF data? The MUF value is calculated by the following:

$$M_t = I_{t-1} + T_{t-1} - I_t \qquad (14)$$

where

M_t = MUF value for period t,

I_t = measured inventory at time t,

T_t = measured transfers during time t.

We shall assume that the inventory measurements have an error, ε_t, with mean zero and variance R_t, and that the net transfers have a measurement error, η_t, with mean zero and variance Q_t. Further we shall assume that R_t and Q_t are constant for all time and shall drop the subscript hereafter. It is easily shown that the covariance structure of MUF is

$$\delta_0 = 2R + Q \qquad (15)$$

$$\delta_1 = -R \qquad (16)$$

and

$$\delta_k = 0 \quad k = 2, 3,\ldots \quad . \qquad (17)$$

Hence its autocorrelation function is given by

$$\rho_1 = -\frac{R}{2R + Q}$$

$$\rho_k = 0 \quad \text{for } k = 2, 3,\ldots \quad . \qquad (18)$$

Thus the autocorrelation function consists of a single negative value at k=1 and zero values for all subsequent lags. Comparing this to our previous results, we conclude that the MUF data can be modeled as an MA(1) process. That is

$$M_t - \mu = a_t - \theta a_{t-1} \qquad (19)$$

and since, under a no-loss scenario, $\mu = E[M_t] = 0$, we may write Equation (19) as

$$M_t = a_t - \theta a_{t-1} \quad . \qquad (20)$$

By comparing Equations (13) and (18), we see that

$$\frac{R}{2R + Q} = \frac{\theta}{1 + \theta^2} \quad . \qquad (21)$$

There are two solutions for θ in the above equation. We shall choose the solution that lies in the interval (-1,1). Box and Jenkins term this the invertibility region and require that the moving average parameter lie in this region. If we allow θ to be greater than unity, then the random shock, a_t, will depend more on the distant values of MUF than on the present and near present values. Obviously, this would be contradictory to reality. Thus, restrictions are placed on the parameter to ensure more realistic behavior of the random shocks. The solution for θ in terms of R and Q is given by

$$\theta = \frac{2R + Q - \sqrt{Q^2 + 4RQ}}{2R} \quad . \qquad (22)$$

Thus, given R and Q, we can calculate θ deterministically.

THE ONE-STEP-AHEAD FORECASTS

A result of Wold[7] can be used to show that the minimum mean square error forecast is simply the expected value of the forecast function conditioned on the past. Assume that we have the stochastic process $\{M_t\}$ which is described by the model

$$M_t = a_t - \theta a_{t-1} \quad t = 1, 2,\ldots \quad . \qquad (23)$$

If we observe M_t for t=1, 2,...,T, then we can estimate $a_1, a_2, \ldots, a_T$. Notice that when t=1 Equation (23) becomes

$$M_1 = a_1 - \theta a_0 \quad . \qquad (24)$$

Since we do not know a_0, we can replace it by its unconditional expected value, namely zero. Then denoting the estimated errors by $\hat{a}$, we have

$$\hat{a}_1 = M_1$$

$$\hat{a}_2 = M_2 + \theta \hat{a}_1 = M_2 + \theta M_1$$

$$\vdots$$

$$\hat{a}_T = M_T + \theta \hat{a}_{T-1}$$

$$= M_T + \theta M_{T-1} + \theta^2 M_{T-2} + \ldots + \theta^{T-1} M_1 \quad . \qquad (25)$$

Another procedure, obtained in [2], is to back forecast a_0 using the data, but we shall not pursue this procedure here. Given $\{M_t\}_{t=1}^T$ and $\{\hat{a}_t\}_{t=1}^T$, we can predict ahead. Recalling that the minimum mean square error forecast is the expectation of the forecast function (Equation 23) conditioned on $\{M_t\}_{t=1}^T$ and $\{\hat{a}_t\}_{t=1}^T$, then our one-step-ahead forecast, denoted by $M_T(1)$, is

$$M_T(1) = E[M_{T+1} | \{M_t\}_{t=1}^T, \{\hat{a}_t\}_{t=1}^T]$$

$$= E[a_{T+1} - \theta \hat{a}_T | \{a_t\}_{t=1}^T]$$

$$= -\theta \hat{a}_T \quad . \qquad (26)$$

The expected value of a_{T+1} vanishes since it has mean zero. Once M_{T+1} becomes available, we can estimate a_{T+1} by

$$\hat{a}_{T+1} = M_{T+1} + \theta \hat{a}_T \qquad (27)$$

and predict M_{T+2} using

$$M_{T+1}(1) = -\theta \hat{a}_{T+1} \quad . \qquad (28)$$

In general, once we observe M_{T+k-1}, we can forecast M_{T+k} by estimating a_{T+k-1} and using the equation

$$M_{T+k-1}(1) = -\theta \hat{a}_{T+k-1} \quad . \qquad (29)$$

In the above we note that our error in forecasting M_{T+k} using the one-step-ahead forecast is simply a_{T+k}, the random shock generating the sequence. It can be shown that these one-step-ahead forecast errors are independent with mean zero and variance σ_a^2. Further, if we assume that $\{M_t\}$ follows a normal distribution, then so does $\{a_t\}$.

Now suppose that at time, T+1, a constant loss of L units begins. Then the true model for M_{T+j} is

$$M^*_{T+j} = L + a_{T+j} - \theta a_{T+j-1} \quad . \qquad (30)$$

Let a^*_{T+1} denote the error obtained in forecasting M^*_{T+1} when we base our forecast on a no-loss model. Then

$$a^*_{T+1} = [M^*_{T+1} - M_T(1) | \hat{a}_1, \hat{a}_2, \ldots, \hat{a}_T]$$

$$= [L + a_{T+1} - \theta \hat{a}_T] - [-\theta \hat{a}_T]$$

$$= L + a_{T+1} \quad . \qquad (31)$$

We may call a^*_{T+1} the actual error. Similarly, we can express the actual error a^*_{T+2} as

$$a^*_{T+2} = [M^*_{T+2} - M_{T+1}(1) | \hat{a}_1, \hat{a}_2, \ldots, \hat{a}_T, a^*_{T+1}]$$

$$= [L + a_{T+2} - \theta a_{T+1}] - [-\theta a^*_{T+1}]$$

$$= [L + a_{T+2} - \theta a_{T+1}] - [-\theta (L + a_{T+1})]$$

$$= L + \theta L + a_{T+2} \quad . \qquad (32)$$

Continuing in this way, it is easy to show that

$$a^*_{T+k} = L + \theta L + \theta^2 L + \ldots + \theta^{k-1} L + a_{T+k}$$

$$= \frac{1 - \theta^k}{1 - \theta} L + a_{T+k} \quad \text{for } k = 1, 2, \ldots \quad . \qquad (33)$$

If θ is small, then the expected value of a^*_{T+k} converges rapidly to its asymptotic value

$$E[a^*] = \frac{L}{1 - \theta} \quad . \qquad (34)$$

If a_{T+j} is assumed normally distributed with mean zero and variance σ_a^2, then a^*_{T+j} will be normally distributed with mean, $[(1-\theta^j)/(1-\theta)]L$, and variance, σ_a^2. Since $a_{T+1}, a_{T+2}, \ldots, a_{T+k}$

are independent, then so are a^*_{T+1}, $a^*_{T+2}, \ldots,$ a^*_{T+k}. Each of the a^*_{T+j} could be used in a test of hypothesis to ascertain whether its mean value was significantly different from zero indicating a significant loss. On the other hand they could be combined in some optimal fashion to give a better estimate of the loss and use this to test for significance. This is the objective of the next section.

OPTIMAL LINEAR COMBINATION OF FORECAST ERRORS

One method of combining the a^*_{T+j} terms is to form a linear combination, e.g.,

$$L(k) = C_1 a^*_{T+1} + C_2 a^*_{T+2} + \ldots + C_k a^*_{T+k} \ , \quad (35)$$

where the k in parentheses indicates the number of terms. We need to choose the coefficients $C_1, C_2, \ldots, C_k$ in some optimal fashion. Following Jaech[8], we want to choose the C's so that L(k) is unbiased and concurrently maximize the probability of detection. Maximizing the probability of detection is equivalent to minimizing the variance of L(k); thus, we want to choose the C's so that L(k) is a minimum variance unbiased estimator (MVUE).

Since L(k) is to be unbiased, this implies that

$$E[L(k)] = \sum_{j=1}^{k} C_j \, E[a^*_{T+j}]$$

$$= \sum_{j=1}^{k} C_j \left(\frac{1-\theta^j}{1-\theta}\right) L \quad (36)$$

must equal L. That is

$$\sum_{j=1}^{k} C_j \left(\frac{1-\theta^j}{1-\theta}\right) = 1 \ . \quad (37)$$

The variance of L(k) is easily shown to be

$$\mathrm{Var}[L(k)] = \sigma_a^2 \sum_{j=1}^{k} C_j^2 \ . \quad (38)$$

We seek the C_j's that minimize this variance subject to the constraint given by Equation (37). This can be done by the method of Lagrange multipliers. Let

$$Q = \sigma_a^2 \sum_{j=1}^{k} C_j^2 - \lambda\left(\sum_{j=1}^{k} C_j \ \frac{1-\theta^j}{1-\theta} - 1\right) \ , \quad (39)$$

taking partial derivatives and equating the results to zero yields the following (K+1) equations:

$$\frac{\partial Q}{\partial C_j} = 0 \Rightarrow 2\sigma_a^2 C_j = \lambda \ \frac{1-\theta^j}{1-\theta} \qquad j = 1, 2, \ldots, k \quad (40)$$

$$\frac{\partial Q}{\partial \lambda} = 0 \Rightarrow \sum_{j=1}^{k} C_j \ \frac{1-\theta^j}{1-\theta} = 1 \ . \quad (41)$$

The solutions of these equations are:

$$\lambda = 2\sigma_a^2 \ (1-\theta)^2 / \sum_{j=1}^{k} (1-\theta^j)^2 \ , \quad (42)$$

$$C_j = (1-\theta)(1-\theta^j) / \sum_{i=1}^{k} (1-\theta^i)^2 \qquad j = 1, 2, \ldots, k \ . \quad (43)$$

The above values for the coefficients forces L(k) to be unbiased with variance given by

$$\mathrm{Var}[L(k)] = \sigma_a^2 (1-\theta)^2 / \sum_{j=1}^{k} (1-\theta^j)^2 \ . \quad (44)$$

The probability of detection is obtained by computing

$$P\left(X > 2 - \frac{E(L(k))}{\sqrt{\mathrm{Var}(L(k))}}\right) \quad (45)$$

where X is normal with mean zero and unit variance. Given a specific loss, L, and inventory and transfer variances R and Q, it is easy to calculate the probability of detection for this constant loss case. Table 1 gives the coefficients and detection probability when R = 100, Q = 10, and L = 5 units. It is seen that within ten periods a constant loss of 5 units will be detected with a probability of 0.969.

It should be mentioned that, although the estimate of loss is a minimum variance unbiased estimate, it is not directly comparable to Jaech's or Stewart's estimators. The estimator we have derived has a smaller variance due to the fact that we assume no loss has occurred until the system reaches steady state. At this time the noise process can be estimated and its variance is considerably smaller than that of MUF. In fact it can be shown that

$$\sigma_a^2 = \mathrm{Var(MUF)}/(1+\theta^2) \ . \quad (46)$$

If one uses Jaech's or Stewart's methods assuming a variance for MUF equal to σ_a^2, then both estimators have the same variance as they should since they are both MVUE's.

SUMMARY

An introduction to Box-Jenkins time series analysis is presented. It is shown how the models presented by Box-Jenkins can be applied to MUF data to detect losses. For the constant loss case an optimal estimate of the loss is found and its probability of detection found.

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APPENDIX A

DERIVATION OF THE AUTOCORRELATION FUNCTIONS

For the AR(1) process we may write

$$(Z_t-\mu) = \phi(Z_{t-1}-\mu) + a_t \quad . \qquad (A.1)$$

Multiplying both sides by $(Z_{t-1} - \mu)$ and taking expectations yield

$$E[(Z_t-\mu)(Z_{t-1}-\mu)] = \phi\, E[(Z_{t-1}-\mu)(Z_{t-1}-\mu)] + E[a_t(Z_{t-1}-\mu)]$$

or

$$\delta_1 = \phi\delta_0 \quad . \qquad (A.2)$$

The term $E[a_t(Z_{t-1} - \mu)]$ vanishes since $(Z_{t-1} - \mu)$ depends on a_{t-1} and previous a's which are independent of a_t. The expectation of the product of independent random variables equals the product of their expected values and since each term has expected value zero, the term is zero.

It can be shown that in general

$$\delta_k = \phi\delta_{k-1} \quad k = 1, 2, \ldots \quad . \qquad (A.3)$$

Using the definition $\rho_k = \delta_k/\delta_0$, we find

$$\rho_k = \phi\rho_{k-1} \quad k = 1, 2, \ldots \quad . \qquad (A.4)$$

Since $\rho_0 = \delta_0/\delta_0 = 1$, then

$$\rho_1 = \phi \ ,$$

$$\rho_2 = \phi\rho_1$$

$$= \phi^2$$

$$\vdots$$

$$\rho_k = \phi\rho_{k-1}$$

$$= \phi^k \quad . \qquad (A.5)$$

The autocorrelation function for an MA(1) process is obtained in a similar manner. For an MA(1) process we can write at time t,

$$Z_t - \mu = a_t - \theta a_{t-1} \qquad (A.6)$$

and at time (t-1)

$$Z_{t-1} - \mu = a_{t-1} - \theta a_{t-2} \quad . \qquad (A.7)$$

Multiplying Equation (A.6) by $(Z_{t-1} - \mu)$ and taking expectations we have

$$E[(Z_t-\mu)(Z_{t-1}-\mu)] = E[(Z_{t-1}-\mu)(a_t-\theta a_{t-1})] \quad . \qquad (A.8)$$

Replacing $(Z_{t-1} - \mu)$ on the right-hand side using Equation (A.7) yields

$$E[(Z_t-\mu)(Z_{t-1}-\mu)] = E[(a_{t-1}-\theta a_{t-2})(a_t-\theta a_{t-1})]$$

or

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Table 1. Coefficients and Variance in Linear Combination of One-Step Ahead Forecast Errors

Period	a^*_{T+1}	a^*_{T+2}	a^*_{T+3}	a^*_{T+4}	a^*_{T+5}	a^*_{T+6}	a^*_{T+7}	a^*_{T+8}	a^*_{T+9}	a^*_{T+10}	VarL(k)	Probability of Detection
1	1.0000										137.016	.058
2	.2505	.4333									34.319	.126
3	.1097	.1899	.2483								15.038	.239
4	.0620	.1072	.1402	.1643							8.489	.388
5	.0404	.0699	.0914	.1071	.1186						5.535	.550
6	.0289	.0500	.0654	.0766	.0848	.0908					3.957	.696
7	.0220	.0380	.0498	.0583	.0646	.0691	.0724				3.013	.811
8	.0175	.0303	.0397	.0465	.0515	.0551	.0577	.0597			2.401	.890
9	.0145	.0250	.0327	.0383	.0424	.0454	.0476	.0492	.0503		1.980	.940
10	.0122	.0212	.0277	.0324	.0359	.0384	.0403	.0416	.0426	.0433	1.676	.969

R = 100, Q = 10, L = 5

$$\delta_1 = E[a_t a_{t-1} - \theta a_{t-1}^2 - \theta a_t a_{t-2} + \theta^2 a_{t-1} a_{t-2}] \quad (A.9)$$

Since the a's are independent with $E[a_t] = 0$ and $E[a_t^2] = \sigma_a^2$, all of the expectations except the second in Equation (A.9) vanish leaving,

$$\delta_1 = -\theta\,\sigma_a^2 . \quad (A.10)$$

It is easy to show that

$$\delta_0 = (1+\theta^2)\sigma_a^2 \quad (A.11)$$

and that

$$\delta_k = 0 \quad \text{for } k = 2, 3, \ldots . \quad (A.12)$$

Hence, the autocorrelation function for an MA(1) process is given by

$$\rho_1 = \frac{\delta_1}{\delta_0} = -\frac{\theta}{1+\theta^2}$$

$$\rho_k = 0 \quad \text{for } k = 2, 3, \ldots \quad (A.13)$$

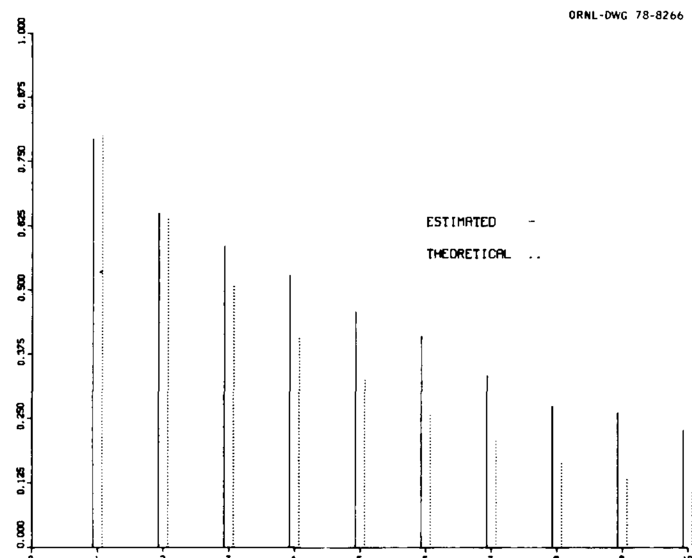

FIGURE 1. ESTIMATED AND THEORETICAL AUTOCORRELATION FUNCTION FOR AN AR(1) PROCESS WITH Φ - 0.8

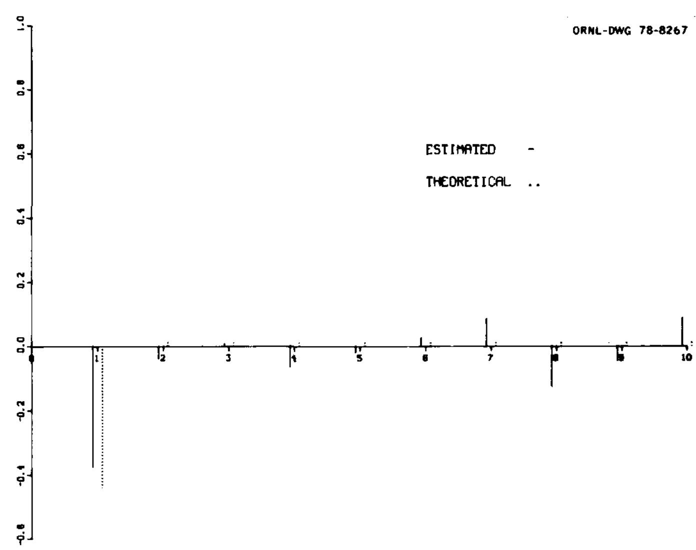

FIGURE 2. ESTIMATED AND THEORETICAL AUTOCORRELATION FUNCTION FOR AN MA(1) PROCESS WITH θ - 0.6

A COMPARISON OF THE V.D.C. AND SHIFT REGISTER NEUTRON COINCIDENCE SYSTEMS FOR ^{240}Pu ASSAY

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ABSTRACT

A comparison is made between the Variable Dead Time Counter (V.D.C.) and Shift Register neutron coincidence systems for the assay of ^{240}Pu. With both systems the total neutron emission of the source is detected by BF_3 proportional counters embedded in a moderator assembly and the fraction arising from spontaneous fissions, which is proportional to the amount of ^{240}Pu present, is estimated.

It is shown that the use of a Shift Register coincidence system leads to a reduction of the long dead time inherent in a V.D.C. instrument but maintains the ability to match the effective coincidence gate length to the mean life time of thermal neutrons in the moderator assembly. For both techniques the precision of the ^{240}Pu mass measurement improves with increasing plutonium masses up to about 20g ^{240}Pu equivalent, the V.D.C. error being equal to the corresponding Shift Register error. Thereafter the V.D.C. coincidence rate - plutonium mass characteristic becomes non-linear due to the manifestation of dead time effects while the corresponding Shift Register response continues to be linear. The relative error in ^{240}Pu mass derived from a Shift Register measurement becomes lower than the relative V.D.C. error at this point and continues to decrease while the V.D.C. relative error starts to increase.

With a constant neutron background and a neutron detection efficiency of 7% both the V.D.C. and Shift Register techniques offer equally valid plutonium assay values for a ^{240}Pu equivalent mass up to approximately 20g, above which value, or when the neutron background is variable, the Shift Register instrument provides the more accurate assay.

List of Symbols

A	=	accidental neutron coincidence rate $c.s^{-1}$
α	=	thermal neutron decay constant of moderator s^{-1}
C_o	=	count rate of the fast pulse scaler $c.s^{-1}$
C_o^n	=	spontaneous fission neutron component of C_o $c.s^{-1}$
C_o^α	=	(α,n) event component of C_o $c.s^{-1}$
C_o^b	=	background event component of C_o $c.s^{-1}$
C_i	=	count rate of scaler (i) $c.s^{-1}$
C_i^n	=	spontaneous fission neutron component of scaler (i) $c.s^{-1}$
$C(t,\Delta t)$	=	coincidence rate during a time interval $(t, t+\Delta t)$ after the trigger pulse $c.s^{-1}$
$C(O,\Delta t)$	=	coincidence rate (Real + Accidental scaler) during a time interval Δt after the trigger pulse $c.s^{-1}$
$C(T,\Delta t)$	=	coincidence rate (Accidental) during a time interval $(T, T+\Delta t)$ after the closure of the Real + Accidental gate $c.s^{-1}$
ϵ	=	neutron detection efficiency %
F_i^n	=	fraction of C_i^n correlated with the gate trigger pulses C_i^n which is called the true coincidence count rate
n	=	number of separate coincidence rate measurements
P	=	counting time s
P(t)dt	=	probability of an event occuring with a time interval t to t + dt
R	=	real coincidence rate $c.s^{-1}$
$\bar{R}$	=	mean value of real coincidence rate $c.s^{-1}$

ΔR = calculated error (1σ) in real coincidence rate from a single shift register measurement $c.s^{-1}$

Sf = spontaneous fission emission rate fissions s^{-1}

Sp = random alpha, n event emission rate neutrons s^{-1}

T = time delay required for spontaneous fission neutron correlation to be reduced to zero s

t = time interval between trigger pulse and second neutron pulse s

Δt = coincidence gate width s

δt = shift register bit width s

τ_i = dead time of scaler (i) s

$\bar{\nu}$ = number of neutrons emitted per fission event

ω = time interval for detection of first neutron (trigger pulse) after the fission event s

X_i = neutron coincidence rate derived from a scaler (i) with a dead time τ_i $c.s^{-1}$

$\bar{X}_i$ = mean value of neutron coincidence rate $c.s^{-1}$

ΔX_i = calculated error (1σ) in neutron coincidence rate from a single V.D.C. measurement $c.s^{-1}$

1. Introduction

One of the byproducts of the processing of spent nuclear fuel is quantities of plutonium contaminated combustible and non-combustible waste. The control and management of such waste requires considerably greater care than most of the fission product waste because of its high degree of toxicity. Plutonium formed from irradiated uranium consists principally of the isotope ^{239}Pu together with smaller quantities of the isotopes $^{240, 241, 242, 238}Pu$ (listed in order of decreasing abundance); the proportions of these latter isotopes increasing with irradiation or fuel burn up. All of the above plutonium isotopes are radioactive and all of them except ^{241}Pu decay via alpha emission (the alpha decay of ^{241}Pu is negligible but not zero). The even nuclides ($^{238, 240, 242}Pu$) also decay via spontaneous fission, emitting 2 to 3 neutrons per fission. The alpha particles emitted by plutonium can also be responsible for the production of neutrons via alpha, n reactions in surrounding material; thus plutonium of any shape, form or composition will always emit neutrons. Since neutrons are considerably more penetrating than the alpha, beta or gamma rays, methods using neutron detection for assay purposes are very useful since larger quantities of material may be handled per measurement and the possibility of accidental or deliberate shielding and hence loss of signal is much reduced when neutron methods are employed.

The alpha,n yield of plutonium contaminated waste varies with the species and concentration of the light elements which are present in the plutonium compounds and in the waste material itself. Total neutron counting can therefore only be an accurate estimate of the plutonium present when the alpha,n yield is known, otherwise it can only be used to give an estimation of the maximum amount of plutonium present: for either case the isotopic composition of the plutonium is required. To overcome these difficulties it is necessary to distinguish between the spontaneous fission neutrons and those neutrons arising from the alpha,n reactions. Considerable effort has been directed towards developing systems to differentiate between neutrons from these two sources for example Jacquesson - (Ja 63), Strain and Omohundro - (St 70), Tarrant and Terrey - (Ta 69), Birkhoff et. al - (Bi 72), Berg et al - (Be 74), Böhnel - (Bo 75) and Vincent (Vi 76).

The direct detection of fast neutrons is a low efficiency process and thus to obtain the high efficiency required for neutron coincidence measurements it is necessary to thermalise the fast neutrons, in a moderator assembly surrounding the samples, before detection in a thermal neutron counter - (Ea 69). Graphite, polyethylene and water are suitable moderators, and in the present HARWELL apparatus a water filled polypropylene tank is used - (La 76). Any assembly of this kind has a characteristic neutron die away time which is the combination of the time taken for the fast neutrons to be slowed to thermal energies and the mean life time (time required for the neutron population to decay to half its initial value) of the thermalised neutrons in the moderator before they are lost either from the surface or by capture in the detectors or other neutron absorbing materials. Leake - (Le 65) has shown that for a polytheylene moderator, fast neutrons take about 5 μs to thermalise, and the mean life time in an infinite polyethylene block with no leakage effects is 173μs. The mean thermal neutron life time and decay constant (α) of a moderator are found by adopting the principle of the Rossi-α technique - (Ke 65, Ed 68). This involves observing the decay of individual spontaneous fission events in succession and continuing this process until a statistically significant spectrum of thermal neutron population vs. time is obtained. Experiments with the HARWELL moderator, using a ^{252}Cf fission chamber neutron source where the fission fragments triggered the time spectrometer, gave values of about 100μs and 7×10^3 s^{-1} for the mean thermal neutron life time and decay constant.

The basic concept of coincident neutron counting using moderator assemblies and thermal neutron detectors is to count the multiple neutron events which occur during the characteristic neutron die away time of the moderator. This is achieved by opening an electronic gate with the first neutron pulse and counting subsequent neutron pulses as coincident events - (St 70).

An alternative system is the Variable Dead Time Counter (V.D.C.), conceived by Birkhoff et. al at ISPRA - (Be 74), and measures the neutron anticoincidence rate from which the neutron coincidence rate is deduced. This measurement in its simplest mode is made using two counting channels, one measuring the total neutron count-rate, the other registering the count-rate using a scaler with a suitable dead time. More sophisticated systems use the data from four counting channels (Be 74).

For both of the above situations the value of the live (or dead) time is chosen to match the mean thermal neutron lifetime of the moderator assembly, which can typically be in the range 15μs to 150μs.

A different approach to coincident neutron counting has been developed by Böhnel (Bo 75, Ste 75) and employs shift registers. Each neutron pulse detected enters the shift register and is propogated through the register at a rate determined by the applied clock frequency. The number of coincidences (i.e. pairs) are given by the number of pulses contained in the shift register when a neutron pulse is detected. This method has the advantage over the live gate and dead time scaler systems in that each neutron pulse detected effectively opens a new gate whose length is determined by the number of bits in the shift register and the clock frequency, but with a maximum dead time of a clock pulse period. The facility to match gate length to the moderator characteristic neutron die away time is therefore retained but the system has a much reduced dead time.

This report compares both theoretical and practical aspects of the V.D.C. and shift register techniques for counting coincident neutrons and therefore provides a guide to the selection of an assay system which has to fulfil specific requirements.

2. Theoretical Analysis of the Two Neutron Coincidence Systems

2.1 Theory of the V.D.C. System

The V.D.C. technique measures the neutron anticoincidence rate from which the neutron coincidence rate is deduced. This measurement is made with two counting channels, one measuring the total neutron count rate, the other registering the count rate using a scaler with a suitable dead time. (See Appendix 1 for further discussion). Thus, in this experimental programme, pulses from the thermal neutron detectors, after suitable amplification and shaping, were mixed and fed in parallel to two scalers, one fast (with a dead time of the order of 0.1 μs) and one slow scaler with a dead time of nominally 128 μs. The ability to differentiate between spontaneous fission neutrons and alpha,n events depends strongly on the accuracy to which the slow scaler dead time (τ) is known. An error of ± 0.1% in τ can lead to an error approximately ± 1% in the plutonium assay values. Thus, the instrument must have a high electronic stability over the temperature range in which it is to operate. As shown in Appendix 1, the dead time losses of the scalers can be analysed to separate the count rates due to spontaneous fission neutron events and (alpha,n) neutron events. An expression for the neutron coincidence rate is then developed which has zero value for random events and is proportional to the total fission rate of all spontaneously fissile material present. As the Sf neutron yields of U, $^{239, 241}$Pu are negligible cf to those of $^{238, 240, 242}$Pu, the assay parameter is defined as ^{240}Pu* equivalent mass. Total plutonium mass is then obtained from a knowledge of the isotopic composition of the material under investigation.

2.2 The Shift Register System

2.2.1 Theory

The Shift Register technique is based on making two measurements of the number of neutron coincidences occurring in two separate, equal, time gates of length Δt. The first gate opens near to time zero, i.e. close to the occurrence of the fission event, and thus measures the total fission coincidences plus counts due to accidental (random) coincidences. The second gate is arranged to measure coincidences occurring T seconds (T >> Δt) from the first gate, i.e. when the time correlation of the fission neutrons has decayed, and thus measures only the accidental coincidences. This is achieved experimentally by delaying the pulse chain by T seconds before it enters the second gate and simultaneously interrogating both gates, i.e. the second gate samples events which occur before the fission event thus giving a better measurement of the uncorrelated portion of the pulse chain. The required quantity i.e. the Real coincidence rate which is proportional to the amount of spontaneously fissile material present is obtained from the difference of the two gate count rates.

An expression for the Real coincidence rate is developed by considering a fission event which results in the detection of two fission neutrons. The first, the trigger pulse neutron, is detected in a time interval (ω, $\omega + \Delta\omega$) after the fission event and the second neutron in a time interval (t, t + Δt) after the trigger pulse. As shown in Appendix 2 the total coincidence rate C(t, Δt) i.e. Real plus Accidental events in an interval (t, t + Δt) after the trigger pulse for a moderator with a thermal neutron decay constant of α is

$$C(t, \Delta t) = \epsilon^2 [(\bar{\nu}.Sf + Sp)^2 \Delta t + \frac{\overline{(\nu - 1)\nu}}{2} . Sf\, e^{-\alpha t} (1 - e^{-\alpha \Delta t})] \qquad (1)$$

The total coincidence rate for a time interval Δt measured from the trigger pulse is

$$C(0, \Delta t) = \epsilon^2 [(\bar{\nu}.Sf + Sp)^2 \Delta t + \frac{\overline{(\nu - 1)\nu}}{2} . Sf\, (1 - e^{-\alpha \Delta t})] \qquad (2)$$

which is the content of the Real plus Accidental scaler. The contents of the Accidental scaler correspond to the coincidence rate in an interval (T, T + Δt) where T, as defined above, is the time delay between the two coincidence gates

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*^{240}Pu equivalent mass = mass ^{240}Pu + 1.64 (mass ^{242}Pu) + 2.66 (mass ^{238}Pu). The mass weighting factors result from the spontaneous fission neutron yields of the various Pu isotopes - (US 74).

i.e. $C(T, \Delta t) = \epsilon^2 (\bar{\nu} \cdot Sf + Sp)^2 \Delta t$ (3)

The contents of the Real plus Accidental and the Accidental scalers are shown as a function of time in Fig. 1, from which it can be seen that for identical values of Δt the Real coincidence rate is obtained from the difference of the two scalers i.e.

$$(2) - (3) = \epsilon^2 \frac{\overline{(\nu - 1)\nu}}{2} (1 - e^{-\alpha \Delta t}) \cdot Sf = R \quad (4)$$

Eqn.(4) can be expressed as

$$R = K \cdot Sf \quad (5)$$

where K is a constant for $t \simeq 1/\alpha$

However, for high count rates, eqn. (5) becomes nonlinear due to a variation in K. This is attributed to the deadtime of the trigger pulse which is the width (Δt) of the gate (Ed 68).

2.2.2 Reduction of the Gate Dead Time

The problem of the long dead time Δt, which can be in the order of $100\mu s$, is overcome by dividing the gate width Δt into a number of smaller gates of width δt such that each pulse up to a maximum frequency of $1/\delta t$ is counted into a separate gate. The Harwell moderator has a neutron die away time of approximately $100\mu s$ which is adequately matched by a gate time Δt of $128\mu s$. Such a gate is realised by driving a 64 bit shift register by a 0.5 MHz clock resulting in a δt of $2\mu s$. The action of a clock pulse is to move a pulse already in the shift register onto the next stage which results in a maximum dead time of a clock pulse period i.e. $2\mu s$. The dead time has therefore been reduced by a factor of 64.

Due to the large number of scalers involved it becomes impracticable to count 1 pulse into m scalers, i.e. one scaler per shift register bit, so this system counts m pulses into one scaler by applying the following technique. Consider the circuit shown in Fig. 2. When a pulse enters the shift register, a 1 is added to the up-down counter and when the pulse has been clocked through the shift register a 1 is subtracted. Thus at any time the up-down counter holds the number of pulses present in the shift register i.e. the effective $128\mu s$. gate. Pulse accountancy is performed as follows:-

Consider the system reset to the zero condition. The first pulse is delayed entering the shift register by one clock pulse period in order to allow it to interrogate the up-down counter and transfer its contents which are zero via the adder to a scaler i.e. the first pulse puts zero counts into the scaler. This pulse is then allowed normal entry to the shift register. The second pulse interrogates the up-down counter which contains the contents of the shift register i.e. the first neutron pulse, which is also added to the scaler i.e. the scaler now holds one pulse - the second pulse then enters the shift register. The build up of the scaler contents i.e. the number of neutron pairs detected within the gate time Δt is given by $n(n - 1)/2$ where n is the number of neutron pulses contained in the shift register. For a fission event which results in the detection of 3 neutrons, 3 neutron pairs are produced which is a more efficient situation than the conventional gated or dead time systems which produce only 2 neutron pairs as the first neutron pulse is taken as a reference.

Identical circuits are used to obtain the number of Real plus Accidental and Accidental coincidence events and a further three 64 bit shift registers in series provide a delay of $T = 3\Delta t$ s between the two gates. The up-down counters of both Real plus Accidental and Accidental scalers are interrogated simultaneously by a given incoming neutron pulse. However, the pulse train entering the Accidental coincidence section of the system has been delayed by time $3\Delta t$ i.e. it occurred $3\Delta t$ s earlier therefore allowing sampling to occur from an uncorrelated portion of the pulse train.

The overall system is maintained in synchronism by using the same clock pulse generator to pulse all the shift registers used.

3. The HARWELL Neutron Detector Assembly and Electronic Pulse Processing Systems

The well counter consists of a polypropylene well with space between the inner and outer walls filled with water, and the external wall covered with 1 mm thick cadmium sheet to reduce the neutron background from external sources. A polypropylene base plate is provided but the well counter operates without a top cover. Internal dimensions are designed to accommodate a 210 l drum.

Twelve BF_3 counters, located at the peak of the thermal neutron flux distribution, are divided into three separate groups each with its own head amplifier and discriminator in order to reduce gamma pulse pile-up. Each counter is of active length 1.07 m, 50 mm diameter and filled to a pressure of 700 torr with BF_3 enriched in ^{10}B to 90%.

The neutron pulse chain from the detector assembly is simultaneously presented to both the V.D.C. and shift register units, as shown in Fig. 3, in order to facilitate the intercomparison of the two techniques. The pulse processing systems are realised in HARWELL(R) 6000 series modular units, the V.D.C. following the concepts considered in section 2.1 and illustrated in Fig. 3, while the operation of the shift register system is described in section 2.2 and shown schematically in Fig. 2.

4. Experimental Comparison of the Neutron Coincidence Systems

4.1 Assay of Spontaneously Fissile Material

Plutonium laboratory standards with ^{240}Pu equivalent masses in the range 12 mg to 120 g were analysed simultaneously by the V.D.C. and Shift Register systems with the detector assembly operating in the normal configuration of 12 equally spaced BF_3 counters and in an experimental configuration of 3 equally spaced BF_3 counters. The neutron coincidence rate is plotted as a function of ^{240}Pu equivalent mass for these four situations as shown in Fig. 4 (V.D.C. - 12 counters), Fig. 5 (Shift Register - 12 counters), Fig. 6 (V.D.C. - 3 counters) and Fig. 7 (Shift Register - 3 counters). Each graph point is the mean value of five separate coincidence rate measurements and the error bars are the calculated 1σ error in coincidence rate (using eqns. 30 and 34) from a single measurement. (The justification for using the calculated 1σ value obtained from a single measurement instead of the 1σ value obtained from eqn. 36 is given in section 4.2). This presentation indicates the 1σ error which can be expected when making a single plutonium assay measurement, which would be the situation under normal plant operational conditions. All of the assay data contained in this report relates to a nominal gate length of 128 μs for both the V.D.C. and Shift Register systems in order to give the best available match to the neutron die away time of the moderator assembly.

The lower detection limit for both V.D.C. and Shift Register systems is determined by the neutron background rate, the spontaneous fission neutron yield of the plutonium under assay and the efficiency of the detector assembly - the HARWELL detector assembly with a 7% efficiency can measure about 10 mg ^{240}Pu equivalent material.

The ultimate upper limit of a coincidence system is determined by the maximum count rate and dead time losses acceptable to that system. In these investigations the maximum ^{240}Pu mass assayed was 120 g, at which point the V.D.C. response (Fig. 4) was in a non linear region while the Shift Register system with its much lower dead time losses still exhibited a linear response (Fig. 5). The coincidence rate is proportional to the square of the detector assembly efficiency. Therefore a reduction in the detection efficiency results in the dynamic range of an assay system being moved upwards in mass value as shown in Figs. 6 and 7 for the V.D.C. and Shift Register, respectively, the response of the V.D.C. system now being linear at 120 g ^{240}Pu. A reduction of efficiency results in an increase in the relative error of the coincidence rate and hence assay accuracy, therefore the design of a system is an optimisation between the required dynamic assay range and accuracy.

At high fissile concentrations i.e. for plutonium masses in excess of 100 g - (Bi 74) neutron multiplication effects (i.e. spontaneous fission and alpha,n events inducing fissions in fissionable material) will reduce the accuracy of the assay. At any fissile concentration neutron capture by hydrogenous material surrounding the plutonium and the escape of neutrons from the detector assembly results in degradation of the neutron coincidence rate and hence reduction of assay accuracy.

4.2 Estimation of the Errors in the Neutron Coincidence Rate

The theoretical random error (1σ) or precision in the coincidence rate for a single assay measurement is derived for both V.D.C. and Shift Register coincidence systems in Appendices 3 and 4 respectively. A laboratory plutonium standard was simultaneously subjected to assay by both coincidence systems for a total of 20 separate counting periods. The calculated random error value per coincidence rate measurement are shown in Table 1 for these 20 measurements. Also given are the mean and standard deviation's (1σ) of the two coincidence rate distributions, the latter calculated using eqn. (36). Comparing, for each coincidence system, the standard deviation (1σ) of the coincidence rate distribution with the calculated random error of an individual coincidence rate measurement, it can be seen that the derived formulae for the random error on a single coincidence rate measurement are valid.

The comparison of the calculated relative error in the neutron coincidence rate derived from the V.D.C. and Shift Register systems as a function of ^{240}Pu equivalent material was perfomed under the following conditions:

(i) Simultaneous assay by V.D.C. and Shift Register systems.

(ii) All samples drawn from the same batch of plutonium, which has a 32% alpha,n event contribution to the total neutron emission.

(iii) Counting normalised to 1 s for all samples.

The functions $\frac{(\Delta X_i)}{\overline{X}_i}$ and $\frac{(\Delta R)}{\overline{R}}$ are plotted to the same scale as functions of ^{240}Pu equivalent material for the 7% efficiency configuration of 12 BF_3 counters in Fig. 8 and for the reduced efficiency (1.75%) of 3 BF_3 counters in Fig. 9. In the linear region of the V.D.C. coincidence rate versus plutonium mass characteristic, it is observed that the calculated relative error in neutron coincidence rate for both coincidence systems has approximately the same value. This is a result of both coincidence systems extracting the same information i.e. the coincidence rate of spontaneous fission neutrons, from the same neutron pulse train, using similar electronic gate lengths. The relative error of the two coincidence rate measurements deviate from equality at the onset of non-linearity of the V.D.C. coincidence rate versus plutonium mass characteristic. This deviation is manifested as a rapid increase of the V.D.C. random error ($\Delta X_i/\overline{X}_i$) due to a decrease in the value of the coincidence rate (X_i) per gram of plutonium. Furthermore, the magnitude of the relative error in coincidence rate obtained by both coincidence systems is inversely proportional to both counting efficiency and total neutron count rate.

Fig. 10 presents the calculated 1σ error in ^{240}Pu mass as a function of measured ^{240}Pu mass for both assay systems using a detection efficiency of 7% and all counting times normalised to 1 s. With reference to Appendices 3 and 4, the 1σ error in coincidence rate and hence plutonium mass varies as $P^{-½}$ where P is the counting time; i.e. the longer the counting period the smaller is the mass error. Using this data both coincidence systems would, for example, produce a 1σ error of approximately 200 mg ^{240}Pu, due to error in coincidence rate measurement, for a 1000 s assay of 10 g ^{240}Pu i.e. a 1σ error of approximately 2%.

4.3 The Effect of the Neutron Count Rate and Alpha,n Event Yield on the Accuracy of Plutonium Assay

The effects of the neutron count rate and the alpha,n component of the total count rate on the spontaneous fission coincidence rate for both the V.D.C. and Shift Register systems were determined as follows. Two plutonium samples with different alpha,n yields were subjected to coincidence rate measurements with successively increasing alpha,n contributions to their total neutron count rates. This was achieved by placing an AmBe neutron source of various positions outside the detector assembly, on its vertical axis. With reference to Table 2, sample A was plutonium nitrate absorbed onto vermicultie which produced a high alpha,n yield and sample B was metallic plutonium with a low alpha,n yield.

The mean value of five measured coincidence rates ± the calculated 1σ error in coincidence rate for sample A as determined by both assay systems are shown in Fig. 11 as functions of the alpha,n event contribution to the total neutron count rate, which corresponds to a total neutron count rate of 371 $c.s^{-1}$, the coincidence rates derived from both instruments show no significant deviation from their initial values. However with sample B a total count rate of 1.7×10^3 $n.s^{-1}$ was required to achieve a 93% random event contribution to the total neutron count rate. It is seen from Fig. 12 for sample B, that the spontaneous fission coincidence rate obtained with the Shift Register system has remained constant whereas that from the V.D.C. instrument exhibits a decrease with increasing neutron count rate.

The following conclusions are drawn:-

(a) V.D.C. System

For low neutron count rates the spontaneous fission neutron coincidence rate can be deduced from a mixture of coincident and random neutron events by application of the V.D.C. expression $X_i = C_o - C_i (1 - C_i \tau_i)^{-1}$. For purely random events this expression has a value of zero and will have a positive value when coincident neutrons are present; therefore the random neutron event contribution to the total neutron count rate is not by itself, a limiting assay factor. However as the total neutron count rate increases, either by coincident or random events, and approaches a rate of τ^{-1} the effect of the scaler dead time will become more pronounced and $X_i = C_o - C_i (1 - C_i \tau_i)^{-1}$ is no longer valid. It is therefore the total neutron count rate which is the limiting factor for accurate plutonium assay with the V.D.C. system. It is, however, prudent to set an upper limit of 90% for the random event contribution to the total neutron count rate (La 76) due to the increase of coincidence rate error for plutonium with high alpha,n event yields.

(b) Shift Register System

Due to the reduced dead time of this system, the count rate limitation manifests itself at much higher count rates than for the V.D.C. instrument. The maximum count rate so far presented to the Shift Register is 1.2×10^4 $c.s^{-1}$. With reference to Fig. 5 this corresponds to 120 g ^{240}Pu equivalent material and it is seen that at this point the coincidence rate - plutonium mass response is still linear; in comparison, the V.D.C. response see Fig. 4 at this mass value is in a non linear region. This is a distinct advantage of the Shift Register instrument over the V.D.C. system for the assay of large amounts of plutonium and small amounts with a high random neutron yield.

4.4 The Effect of a Variable Intensity Uncorrelated Neutron Count-Rate on the Neutron Coincidence Rate

The effect of a variable intensity uncorrelated neutron background on the neutron coincidence rate resulting from V.D.C. and Shift Register measurements has been investigated, as this is of importance for assay systems operating under plant conditions.

A 1.79 g metallic ^{240}Pu source, with a 10% alpha,n contribution to its total count rate was simultaneously assayed by both coincidence systems under three sets of conditions: (a) the ^{240}Pu source only, (b) with the addition of an AmB alpha,n source which increased the uncorrelated neutron contribution to the total neutron count rate to 90% during the entire count period and (c) with this alpha,n source present during half of the counting period. The results summarised in Table 3 are given in terms of the mean and one standard deviation of the ^{240}Pu mass obtained by repeating each 600 s measurement period three times. It is seen that the V.D.C. system is sensitive to variations in uncorrelated neutron background rate as this circuit measures the average neutron count rate during the count period. In contrast, the Shift Register is immune to a variable alpha,n event background rate as it measures the Real and Accidental coincidence rates on a real time basis. These results are in agreement with those of Ensslin et. al - (En 77).

5. Conclusions

A comparison of the performance of the V.D.C. and Shift Register plutonium assay systems has shown that both instruments are suitable for coincident neutron counting using moderated detector assemblies.

The problem of dead time effects associated with the V.D.C. at high count rates is overcome by the Shift Register circuit as its dead time is determined by the Shift Register clock period instead of the V.D.C.'s overall scaler paralysis time.

The performance of the two coincidence systems investigated is summarised as follows:

(a) V.D.C. and Shift Register

As expected:

(i) an increase in the spontaneous fission neutron count rate due to either an increase in counting efficiency or mass of plutonium under assay results in a decrease in the statistical error in the coincidence rate measurement.

(ii) an increase in counting time reduces the statistical error in the coincidence rate measurement.

(iii) an increase in random neutron yield of the assay sample increases the statistical error in the coincidence rate measurement.

(b) V.D.C.

(i) In the linear region of the V.D.C. coincidence rate - mass characteristic, the relative errors in coincidence rate from a V.D.C. measurement are equal to those from a Shift Register measurement. When the scaler dead time effect manifests itself the response characteristic becomes non linear and the relative errors start increasing in magnitude.

(ii) The neutron coincidence rate is vulnerable to a fluctuating alpha,n event background rate.

(c) Shift Register

(i) The Shift Register characteristic remains linear and the relative errors continue to decrease and become progressively smaller than the corresponding V.D.C. statistical errors for plutonium mass values in excess of that where the V.D.C. response characteristic becomes non linear.

(ii) The neutron coincidence rate is immune to a fluctuating alpha,n event background rate.

The final conclusion is that, for a counting efficiency of 7%, both types of neutron coincidence systems are equally suitable for the assay of plutonium in the range of milligrams to approximately 20 g of ^{240}Pu. However, for

^{240}Pu masses in excess of approximately 20 g and where the neutron background rate is subject to variation, the Shift Register system is the more suitable assay technique.

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TABLE 1

Calculated and statistical errors in neutron coincidence rate for the V.D.C. and Shift Register systems

V.D.C.		SHIFT REGISTER	
X_i c.s^{-1} Calculated from eqn.26	ΔX_i c.s^{-1} Calculated from eqn.30	R c.s^{-1} Calculated from eqn.32	ΔR c.s^{-1} Calculated from eqn.34
5.922	0.268	5.812	0.269
5.771	0.267	5.523	0.263
5.789	0.268	5.678	0.266
5.633	0.265	5.403	0.266
5.858	0.269	5.508	0.267
5.652	0.268	5.371	0.268
5.890	0.269	5.547	0.269
5.707	0.268	5.189	0.271
6.363	0.273	6.239	0.272
5.859	0.269	5.729	0.270
5.416	0.260	4.956	0.257
5.527	0.265	5.329	0.265
5.953	0.270	5.484	0.268
6.164	0.274	6.031	0.277
5.697	0.271	5.596	0.284
5.998	0.272	5.649	0.269
5.773	0.271	5.461	0.267
5.454	0.265	5.634	0.266
6.389	0.275	5.638	0.281
5.803	0.267	5.656	0.273

V.D.C. Distribution $\overline{X}_i \pm 1\sigma = 5.831 \pm 0.260$ c.s^{-1}

(calculated from column 1 using eqn.36).

Shift Register Distribution $\overline{R} \pm \Delta R = 5.572 \pm 0.276$ c.s^{-1}

(calculated from column 3 using eqn.36).

Count time per measurement = 180 s

This series of measurements was performed with the following modifications to the neutron well counter:

(i) four extra BF_3 proportional counters each with the central 400 mm of active length covered with 1 mm thick cadmium sheet.

(ii) the inner wall covered with 1 mm thick cadmium sheet.

TABLE 2

Neutron Yields of Plutonium Sources

	Sample A - Pu nitrate 0.23 g Pu-240		Sample B - metallic Pu 1.79 g Pu-240	
	α,n yield %	total neutron count rate c.s^{-1}	α,n yield %	total neutron count rate c.s^{-1}
Pu sample only	80	78	10	134
Pu sample + AmBe	96	371	93	1710

TABLE 3

Comparison of the V.D.C. and Shift Register performance with a variable alpha,n event background

	Average total count rate c.s^{-1}	^{240}Pu mass ± 1σ (g)	
		V.D.C.	Shift Register
^{240}Pu sample	138	1.79 ± 0.02	1.83 ± 0.08
^{240}Pu + AmB (constant α,n rate)	1136	1.71 ± 0.32	1.87 ± 0.17
^{240}Pu + AmB (variable α,n rate)	660	12.71 ± 0.34	1.73 ± 0.32

APPENDIX 1

Analysis of the Dead Time Losses of the V.D.C. Pulse Scalers (Following the notation of Berg - Be74)

The balance of count rates for the fast (total) scaler is

$$C_o = C_o^n + C_o^\alpha + C_o^b \qquad (6)$$

Similarly for a slow scaler (i) with a dead time (i)

$$C_i = C_i^n + C_i^\alpha + C_i^b \qquad (7)$$

The components of the total count rate can themselves be expressed in terms of the count rate from a scaler (i) with dead time τ(i)

$$C_o^n = C_i^n (1 + F_i^n) + C_i \tau_i C_o^n \qquad (8)$$

$$C_o^\alpha = C_i^\alpha \qquad + C_i \tau_i C_o^\alpha \qquad (9)$$

$$C_o^b = C_i^b \qquad + C_i \tau_i C_o^b \qquad (10)$$

Summing equations (8), (9) and (10) gives

$$C_o = C_i + C_i^n F_i^n + C_i \tau_i C_o \qquad (11)$$

Rearranging equations (8) and (11) results in

$$C_o^n = \frac{1 + F_i^n}{F_i^n} \left[C_o - \frac{C_i}{1 - C_i \tau_i} \right] \qquad (12)$$

or

$$C_o^n = K_i \cdot X_i \qquad (13)$$

Where X_i, the spontaneous emission neutron coincidence rate is in terms of parameters which are directly measured i.e. the count rates of the fast scaler (C_o) and a slow scaler (C_i) and the dead time of that scaler (τ_i).

APPENDIX 2

Derivation of the Neutron Coincidence Rate for the Shift Register Coincidence System (Following the notation of Böhnel - Bo75)

Consider a fission event resulting in the production of a pair of fission neutrons.

Let the probability that the first neutron, the trigger pulse, is detected in a time interval (ω, $\omega + \Delta\omega$) after the fission event be

$$P_1 (\omega)\, d\omega$$

It follows that the probability of the second neutron being detected in a time interval (t, t + Δt) after the detection of the first neutron is

$$P(t)\, dt = 2 \int_o^{\omega = \infty} P_1 (\omega)\, d\omega \,.\, P_2 (\omega + t)\, dt \qquad (14)$$

The total source emission rate consists of spontaneous fission and random Poisson i.e. alpha,n event components i.e. $\overline{\nu}$ Sf + S p. The uncorrelated pair production rate for a time dt is therefore

$$(\overline{\nu}.Sf + Sp)^2 \,.\, dt$$

Let the average number of neutron pairs produced from a fission event be

$$\frac{\overline{\nu(\nu - 1)}}{2}$$

Therefore including the detector efficiency ϵ, the total coincidence rate i.e. Real plus Accidental coincidences during a time interval (t, t + Δt) after the trigger pulse is

$$C(t, \Delta t) = \epsilon^2 \left[(\nu\, Sf + Sp)^2 \Delta t + \overline{\nu(\nu - 1)} \,.\, Sf \int_t^{t+\Delta t} dt \int_o^{\omega = \infty} P_1 (\omega)\, P_2 (\omega + t)\, d\omega \right] \qquad (15)$$

For a moderator with a thermal neutron decay constant of α

$$P(t) = \alpha e^{-\alpha t} \tag{16}$$

therefore

$$P_1(\omega) = \alpha e^{-\alpha\omega} \tag{17}$$

and

$$P_2(\omega + t) = \alpha e^{-\alpha(\omega + t)} \tag{18}$$

Therefore substituting (17) and (18) into (15) results in the following expression for the total coincidence rate during the time interval (t, t + Δt) after trigger pulse for a moderator detector system:-

$$C(t, \Delta t) = \epsilon^2 \Bigg[(\bar{\nu}\,.\,Sf + Sp)^2 \,\Delta t + \overline{\nu(\nu-1)}Sf \int_t^{t+\Delta t} dt \int_0^{\omega=\infty} \alpha e^{-\alpha\omega}\, \alpha e^{-\alpha(\omega+t)}\, d\omega \Bigg] \tag{19}$$

which simplifies to

$$C(t, \Delta t) = \epsilon^2 \Bigg[(\bar{\nu}\,.\,Sf + Sp)^2 \,\Delta t + \overline{\nu(\nu-1)}Sf\,.\frac{\alpha}{2} \int_t^{t+\Delta t} e^{-\alpha t}\, dt \Bigg] \tag{20}$$

and results in

$$C(t, \Delta t) = \epsilon^2 \Bigg[(\bar{\nu}\,.\,Sf + Sp)^2 \,\Delta t + \frac{\overline{\nu(\nu-1)}}{2}\,.\,Sf\,.\,e^{-\alpha t}\,(1 - e^{-\alpha\Delta t}) \Bigg] \tag{21}$$

From this basic expression the contents of the Real plus Accidental scaler for a time interval Δt measured from the trigger pulse is

$$C(0, \Delta t) = \epsilon^2 \Bigg[(\bar{\nu}\,.\,Sf + Sp)^2 \,\Delta t + \frac{\overline{\nu(\nu-1)}}{2}\,\alpha\, Sf \int_0^{\Delta t} e^{-\alpha t}\, dt \Bigg] \tag{22}$$

i.e.

$$C(0, \Delta t) = \epsilon^2 \Bigg[(\bar{\nu}\, Sf + Sp)^2 \,\Delta t + \frac{\overline{\nu(\nu-1)}}{2}\,.\,Sf\,(1 - e^{-\alpha\Delta t}) \Bigg] \tag{23}$$

Similarly, the contents of the Accidental scaler for a time interval (T, T + Δt) after the closure of the Real plus Accidental gate is

$$C(T, \Delta t) = \epsilon^2 \Bigg[(\bar{\nu}\,.\,Sf + Sp)^2 \,\Delta t + \frac{\overline{\nu(\nu-1)}}{2}\,\alpha\, Sf \int_T^{T+\Delta t} e^{-\alpha t}\, dt \Bigg] \tag{24}$$

which becomes, for T>>t,

$$C(T, \Delta t) = \epsilon^2 (\bar{\nu}\, Sf + Sp)^2 \,\Delta t \tag{25}$$

APPENDIX 3

Estimation of Errors in the Neutron Coincidence Rate Derived from a V.D.C. System

From equations (12) and (13) in Appendix 1, the neutron coincidence rate is denoted by

$$X_i = C_o - \frac{C_i}{1 - C_i \tau_i} \tag{26}$$

Rearranging equation (11) gives

$$C_o - \frac{C_i}{1 - C_i \tau_i} = \frac{C_i^n F_i^n}{1 - C_i \tau_i} \tag{27}$$

i.e. the neutron coincidence rate.

Furthermore the term $\frac{C_i \tau_i C_o}{1 - C_i \tau_i}$ denotes the random coincidences produced by the V.D.C. system.

Therefore equation (11) is rearranged in the form

$$\frac{C_o - C_i}{1 - C_i \tau_i} = \frac{C_i^n F_i^n}{1 - C_i \tau_i} + \frac{C_i \tau_i C_o}{1 - C_i \tau_i} \tag{28}$$

i.e. $\frac{C_o - C_i}{1 - C_i \tau_i}$ = Real Coincidences + Random Coincidences

Therefore real coincidences (X_i) =

$$\frac{C_o - C_i}{1 - C_i \tau_i} - \frac{C_i \tau_i C_o}{1 - C_i \tau_i} \qquad (29)$$

Therefore the calculated error (1σ) in neutron coincidence rate from a single V.D.C. measurement is given by

$$\Delta X_i = \pm \frac{1}{\sqrt{P}} \sqrt{\frac{(C_o - C_i) + C_i \tau_i C_o}{1 - C_i \tau_i}} \qquad (30)$$

and the relative error (1σ) is given by

$$\frac{\Delta X_i}{X_i} = \pm \frac{1}{\sqrt{P}} \sqrt{\frac{(C_o - C_i) + C_i \tau_i C_o}{1 - C_i \tau_i}} \Big/ X_i \qquad (31)$$

These expressions are valid for the linear region of the coincidence rate versus plutonium mass characteristic.

APPENDIX 4

Estimation of Errors in the Neutron Coincidence Rate Derived from a Shift Register System

The neutron coincidence rate is obtained from the difference of the (Real + Accidental) coincidence rate and the Accidental coincidence rates i.e.

$$\text{Coincidence Rate } R = (R + A) - A \qquad (32)$$

The error (1σ) in neutron coincidence rate from a single Shift Register measurement is therefore

$$\Delta R = \pm \frac{1}{\sqrt{P}} \sqrt{(R + A) + A} \qquad (33)$$

i.e.

$$\Delta R = \pm \frac{1}{\sqrt{P}} \sqrt{R + 2A} \qquad (34)$$

and the relative error (1σ) in neutron coincidence rate is given by

$$\frac{\Delta R}{R} = \pm \frac{1}{\sqrt{P}} \frac{\sqrt{R + 2A}}{R} \qquad (35)$$

APPENDIX 5

Standard Deviation of a Series of n Observations

The standard deviation σ of a series of n observations $X_i \ldots X_n$ is defined as

$$\sigma = \sqrt{\frac{\sum_1^n (X_i - \overline{X})^2}{n - 1}} \qquad (36)$$

where $\overline{X}$ is the mean value of the n observations.

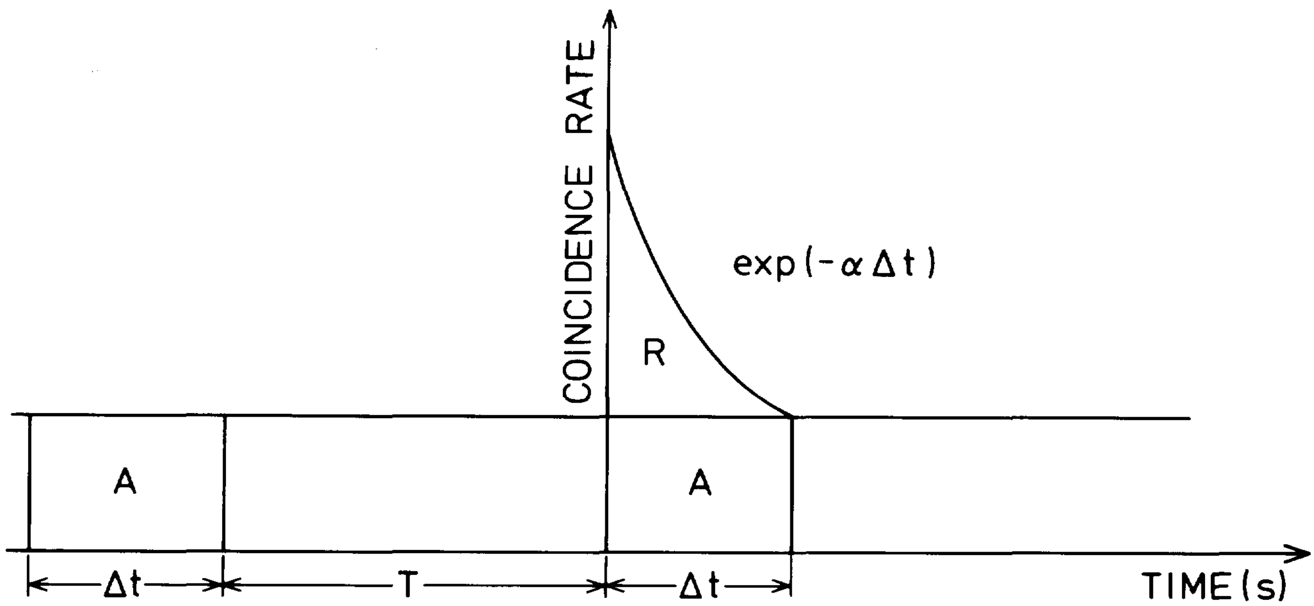

FIG.1.CONTENTS OF THE REAL (R) PLUS ACCIDENTAL (A) AND ACCIDENTAL (A) SCALERS

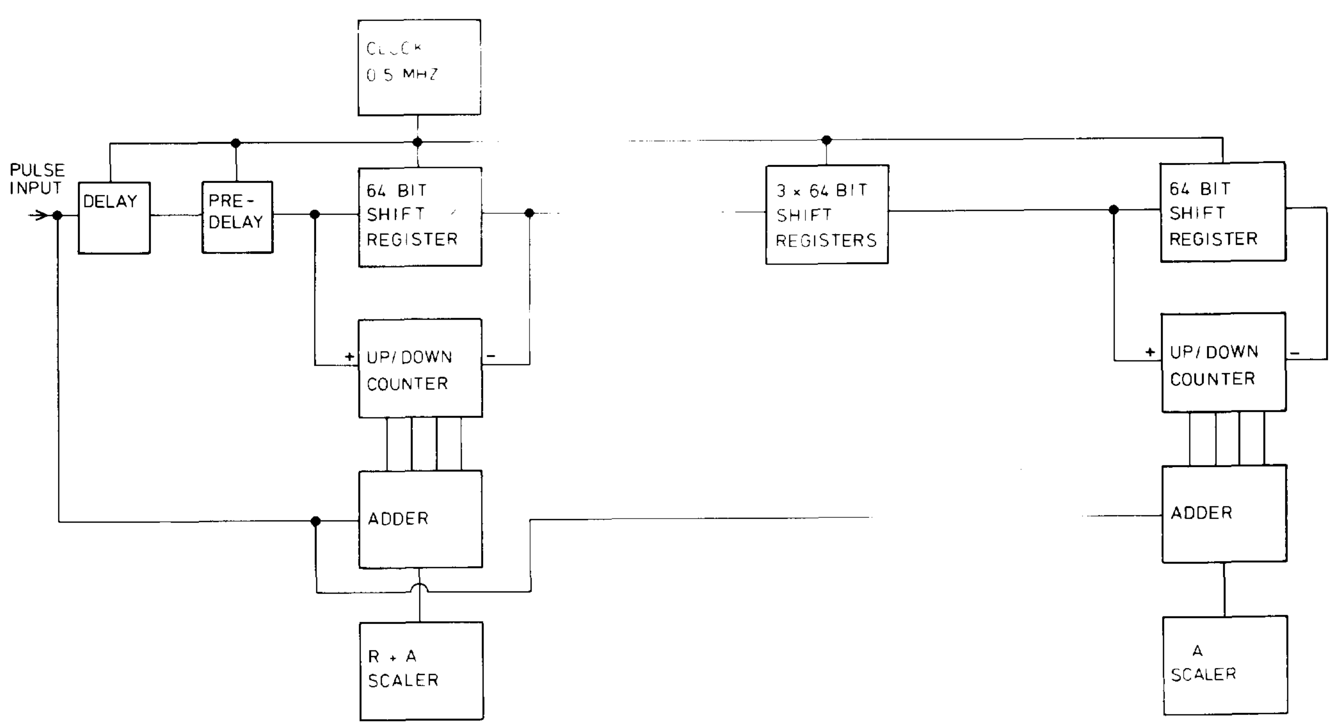

FIG. 2. THE SHIFT REGISTER NEUTRON COINCIDENCE UNIT

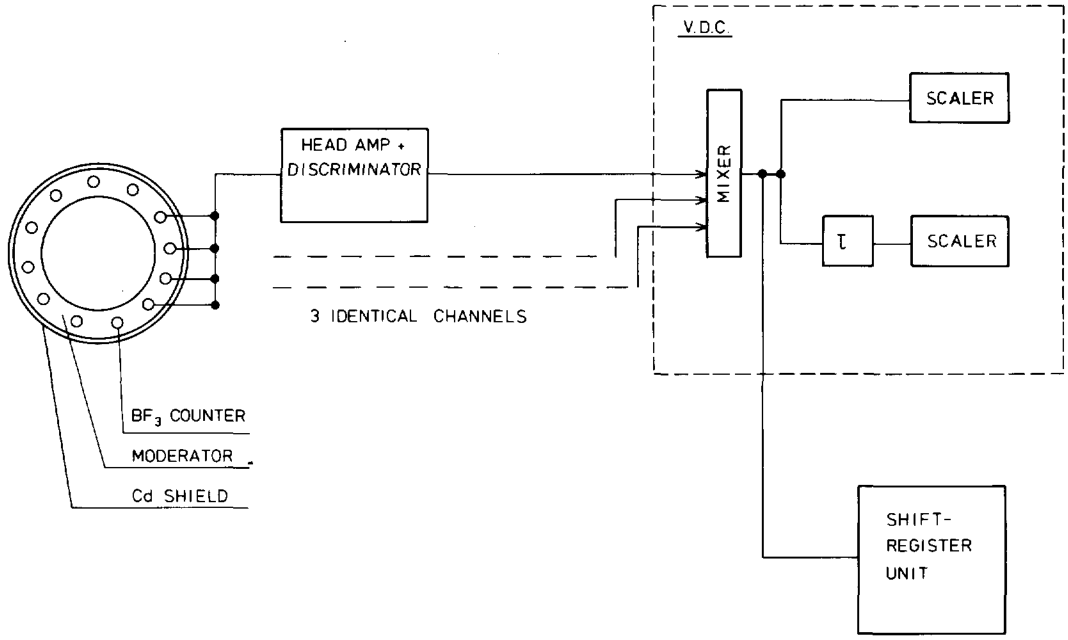

FIG. 3. THE NEUTRON DETECTOR ASSEMBLY AND PULSE PROCESSING SYSTEMS

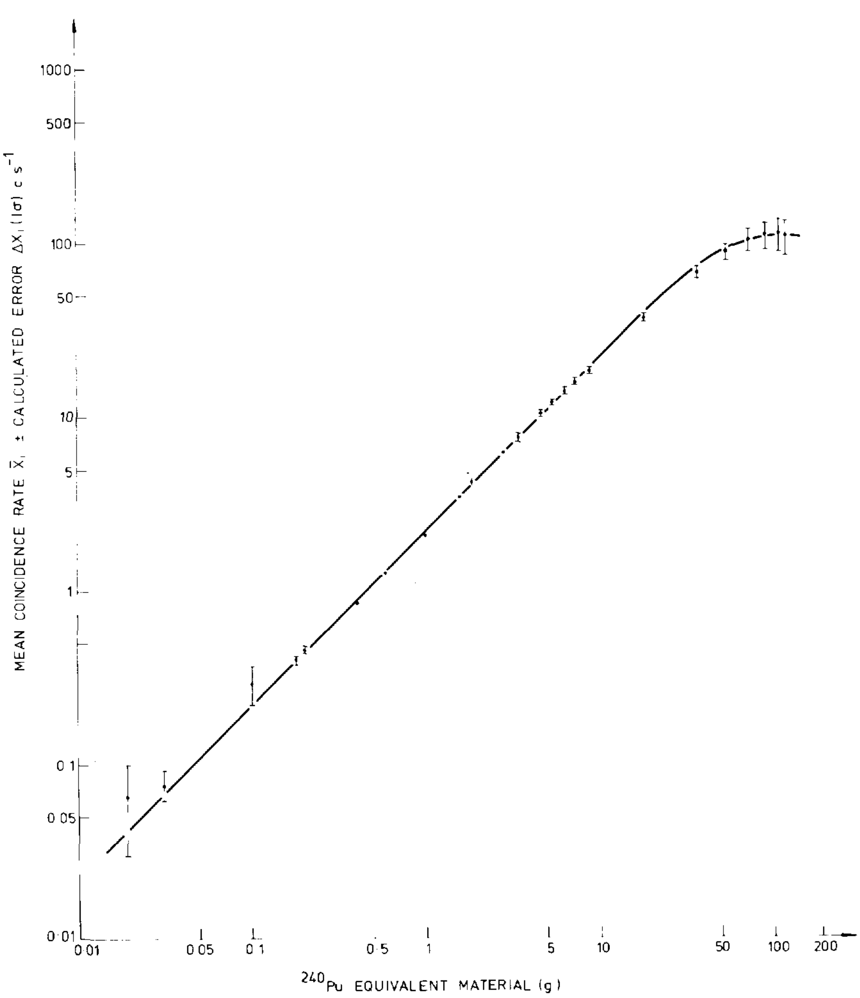

FIG. 4. V.D.C. RESPONSE FROM 12 BF_3 COUNTERS, $\varepsilon = 7\%$

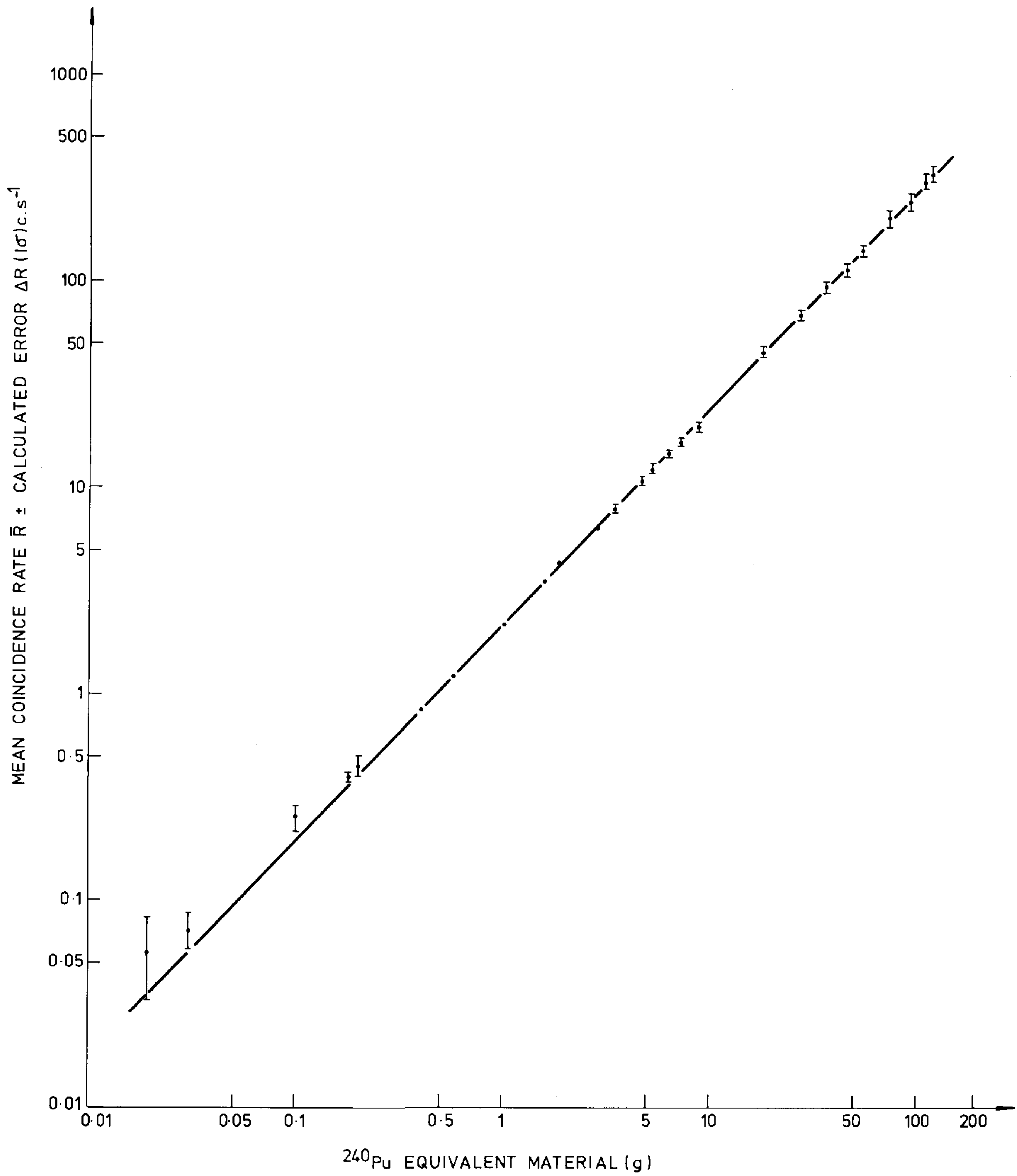

FIG.5. SHIFT REGISTER RESPONSE FROM 12 BF_3 COUNTERS, $\varepsilon = 7\%$

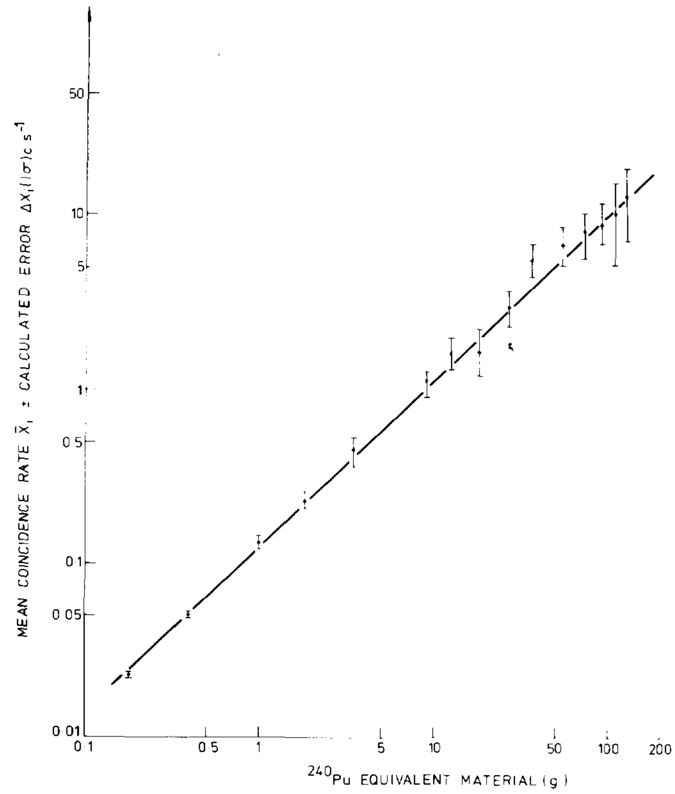

FIG.6. V.D.C. RESPONSE FROM 3 BF_3 COUNTERS, $\varepsilon = 1.75\%$

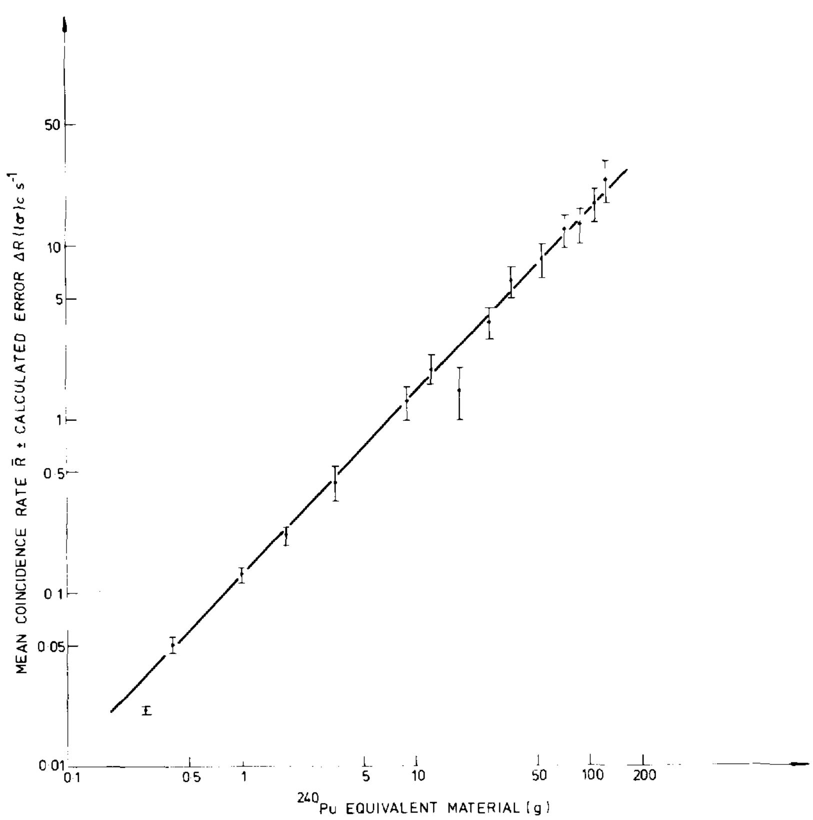

FIG.7. SHIFT REGISTER RESPONSE FROM 3 BF_3 COUNTERS; $\varepsilon = 1.75\%$

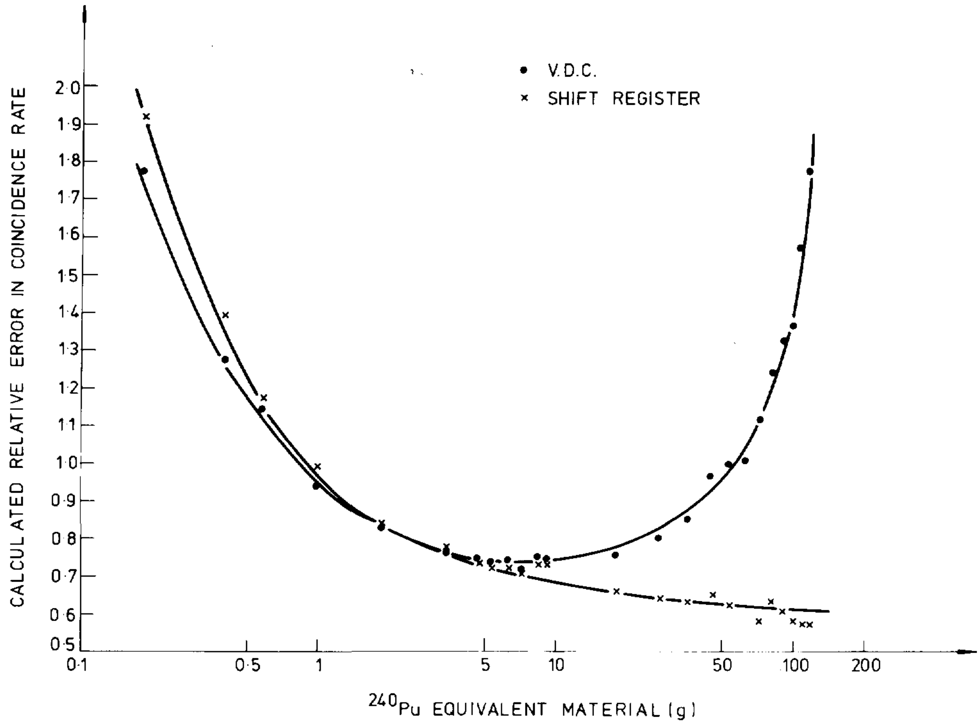

FIG. 8. CALCULATED RELATIVE ERROR IN COINCIDENCE RATE AS A FUNCTION OF ^{240}Pu EQUIVALENT MATERIAL FOR THE V.D.C AND SHIFT REGISTER SYSTEMS. 12 BF_3 COUNTERS, $\varepsilon \simeq 7\%$, COUNT TIME NORMALISED TO 1s

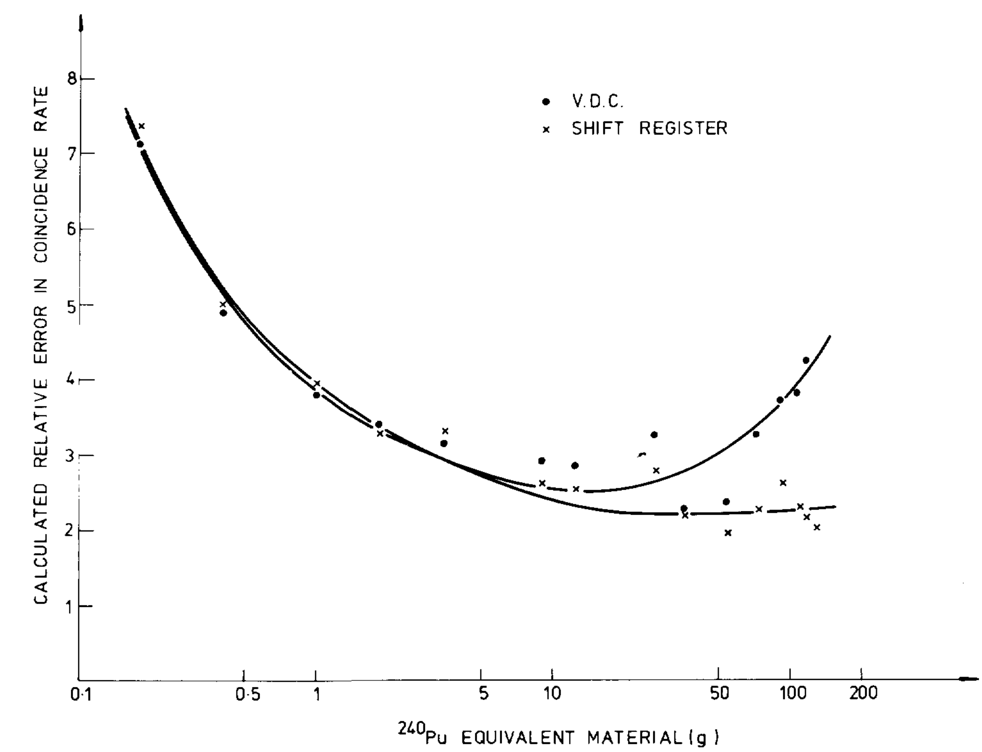

FIG. 9. CALCULATED RELATIVE ERROR IN COINCIDENCE RATE AS A FUNCTION OF ^{240}Pu EQUIVALENT MATERIAL FOR THE V.D.C AND SHIFT REGISTER SYSTEMS. 3 BF_3 COUNTERS, $\varepsilon = 1{\cdot}75\%$, COUNT TIME NORMALISED TO 1s

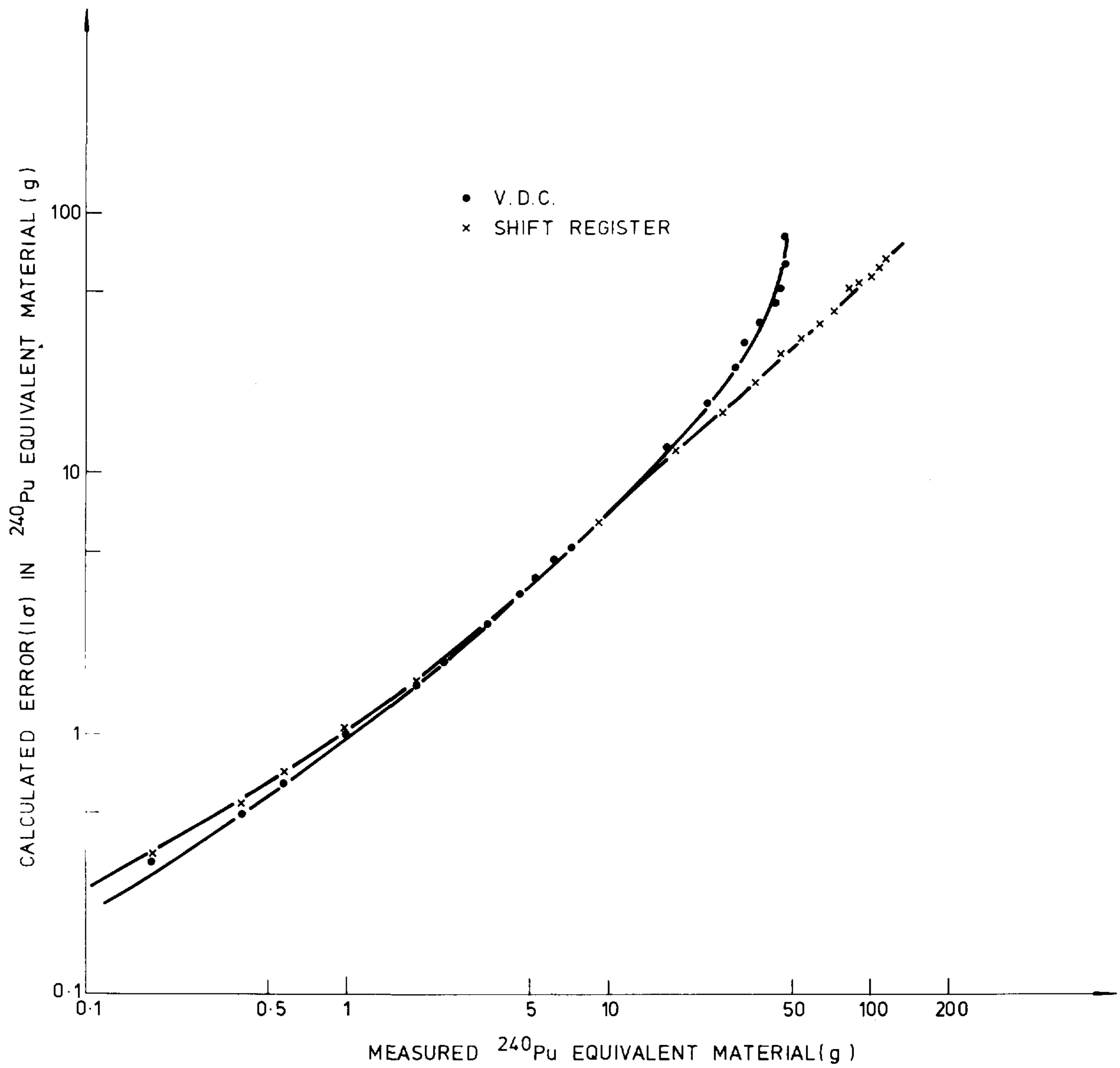

FIG. 10. CALCULATED ^{240}Pu EQUIVALENT MASS ERROR (1σ) AS A FUNCTION OF TOTAL ^{240}Pu EQUIVALENT MATERIAL MEASURED BY THE V.D.C. AND SHIFT REGISTER SYSTEMS. 12 BF_3 COUNTERS, $\varepsilon = 7\%$, COUNT TIME NORMALISED TO 1s

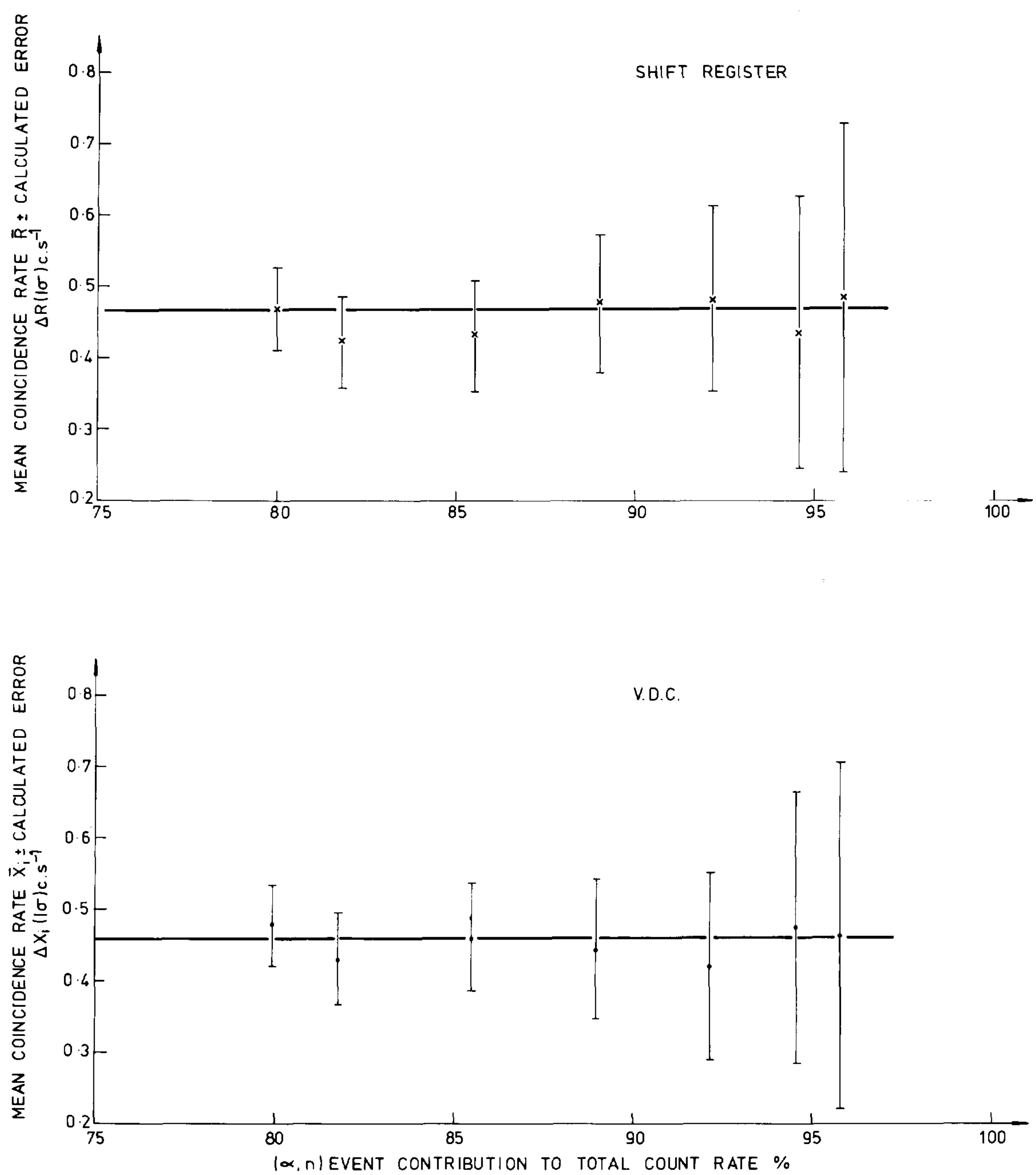

FIG. 11. COINCIDENCE RATES FOR THE V.D.C. AND SHIFT REGISTER SYSTEMS AS A FUNCTION OF (α, n) EVENT CONTRIBUTION TO THE TOTAL COUNT RATE, SAMPLE A, 600 S COUNTING TIME.

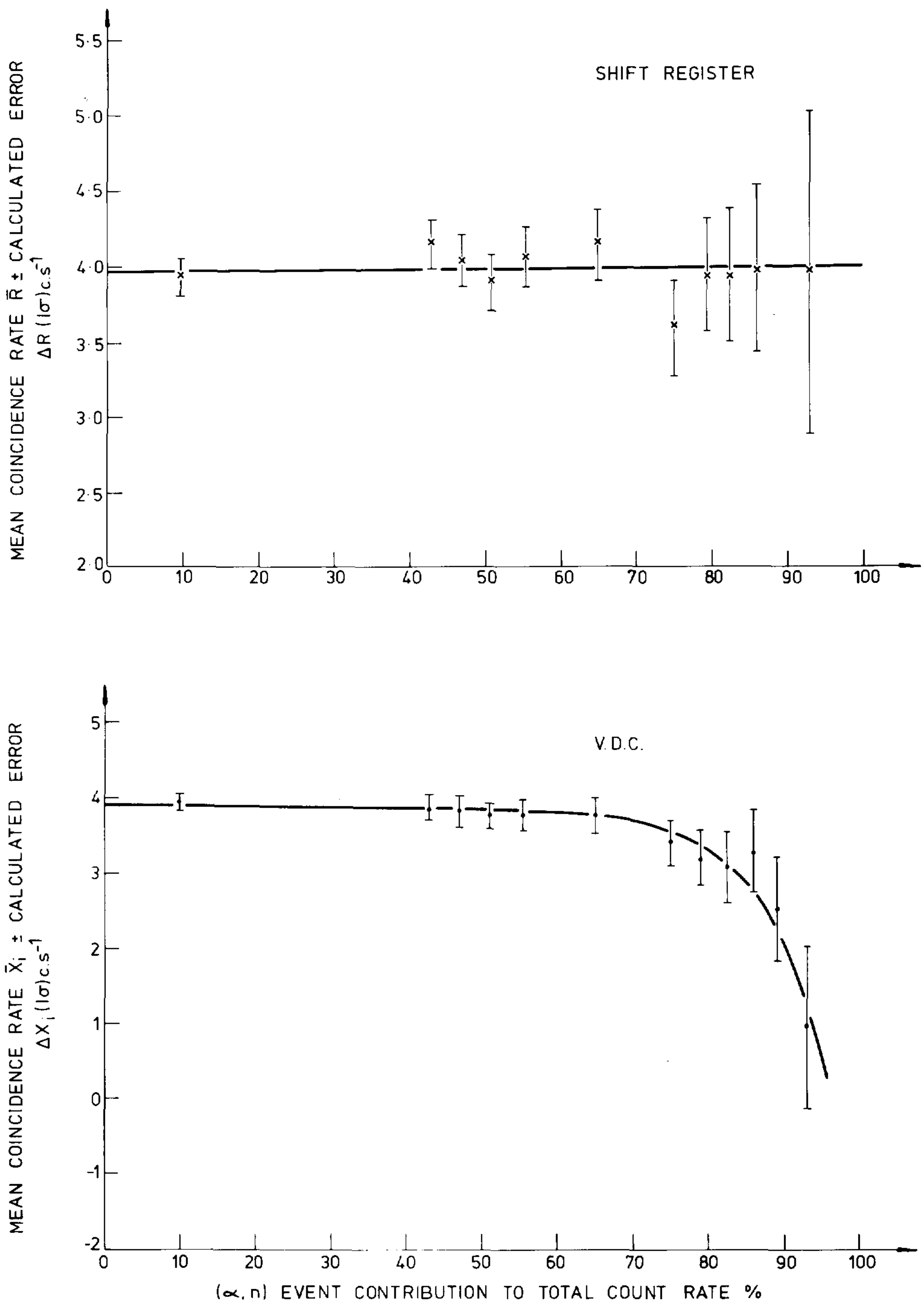

FIG. 12. COINCIDENCE RATES FOR THE V.D.C. AND SHIFT REGISTER SYSTEMS AS A FUNCTION OF (α, n) EVENT CONTRIBUTION TO THE TOTAL COUNT RATE, SAMPLE B, 600 S COUNTING TIME.

Materials Safeguards and Accountability in the Low Enriched Uranium Conversion-Fabrication Sector of the Fuel Cycle

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INTRODUCTION

Today materials accounting in the low enriched conversion-fabrication sector of the LWR fuel cycle is of increased importance. Low enriched uranium is rapidly becoming a precious metal with current dollar values in the range of one dollar per gram comparing with gold and platinum at 7-8 dollars per gram. In fact, people argue that its dollar value exceeds its safeguards value. Along with this increased financial incentive for better material control, the nuclear industry is faced with the impending implementation of international safeguards and increased public attention over its ability to control nuclear materials. Although no quantity of low enriched uranium (LEU) constitutes a practical nuclear explosive, its control is important to international safeguards because of potential misuse by a national capability via plutonium production or further enrichment to an explosive grade material.

Our purpose is to examine and discuss some factors in the area of materials safeguards and accountability as they apply to the low enriched uranium conversion-fabrication sector. The paper treats four main topics: (1) basis for materials accounting; (2) our assessment of the proposed new IAEA requirements; (3) adequacy of current practices; and (4) timing and direction of future modifications.

BASIS FOR MATERIALS ACCOUNTING

Currently, materials accounting is the principal safeguards measure for low enriched uranium. It is based on the intrinsic value of the material, fuel manufacturing needs, national and international safeguards requirements, and the need to provide assurance that material control measures have been effective.

Dollar Value

The current dollar value for low enriched uranium (LEU) is shown in Table 1 (excluding any added value contributed by fuel fabrication). The values are based on natural uranium at \$42 a pound of U_3O_8, separative work at \$75 a SWU, and standard U_3O_8-UF_6 conversion costs.

It is apparent from the dollar values for either kilograms of low enriched uranium or grams of U-235 contained that real financial incentives exist for good material control. For example, the value of a typical fuel pellet is \$10. Thus, of particular importance is the cost incentive for waste loss reduction and improvements in waste recovery. These programs are also basic to improved safeguards performance since they often lead to significant reductions of the plant MUF and LEMUF. The high monetary value also provides a very strong incentive for close material control of an extremely valuable asset.

Fuel Manufacturing Needs

At LWR fuel conversion-fabrication plants, a high degree of material control and accountability is required for purposes of criticality safety, quality and process control, production control, and contract performance. These needs are not new but need mentioning for completeness, and the fact that they exist represents important adjuncts to safeguards which are inherent in the fuel fabrication business.

Safeguards Requirements Imposed by Authorities

Safeguards accountability requirements for U.S. plants stem from Title 10, Part 70 of the Code of Federal Regulations. Those for Euratom countries arise from the Regulations of the Commission of the European Communities concerning Euratom safeguards. The pertinent IAEA safeguards agreement is the Agreement between IAEA and those States on safeguards under NPT. That agreement is covered in IAEA Information Circular 153 commonly referred to as the "Blue Book."

The common requirements for materials accounting and safeguards from these three safeguards authorities are shown in Table 2. The requirements shown apply generally to all bulk handling facilities. Thus, all operators of bulk handling facilities are required to:

1. Measure all quantities of nuclear material received, shipped, discarded, and on inventory;

2. Maintain a formal accounting system for recording all internal and external transactions;

3. Conduct physical inventories;

4. Maintain material control areas;

5. Provide to the safeguards authorities reports of all external transfers, material status reports, and all usual events or discrepancies;

6. Maintain a measurement control program for estimating and controlling measurement errors; and

7. Provide for audits, verification activities, and performance evaluation by safeguards inspectors.

The requirements for materials accounting for low enriched uranium, which is not a strategic special nuclear material (SSNM), differ sharply in degree but not in kind from those required for plutonium or other SSNM. The main differences in degree are in the areas of timeliness and intensity of internal control measures. There are also some differences in the requirements of the three safeguards authorities which are discussed briefly later.

The bottom line with regard to materials accounting requirements for low enriched uranium is that a high quality measurement and accounting system is required.

Assurance to the Public

A very important objective of materials accounting is providing continual assurance to the public that materials control measures are effective; that is, assuring that quantities of low enriched uranium which are judged to be of safeguards importance have not been lost or could not be lost without a positive indication from the accounting data. This objective is of particular importance because difficulties exist in public differentiation between safeguards significance of low enriched uranium and high enriched uranium; to the public, uranium is uranium.

A plant operator measures his ability to provide this form of assurance by his MUF and LEMUF. The plant LEMUF is a measure of the capability of the measurement and accounting system to distinguish loss from measurement uncertainty. For example, if the calculated LEMUF is small compared to a quantity of LEU that is judged to be of safeguards importance, then there is a high degree of assurance that the loss of a quantity of LEU of safeguards importance would not go unnoticed upon completion of a material balance.

MUF performance can be judged by comparing the observed MUF to both the LEMUF and to a quantity of LEU of safeguards importance. It is the sum, MUF plus LEMUF, which represents the upper end of the interval in which the "true" MUF lies, and hence, attention should be focussed on this sum as well as on the two components of the sum.

ASSESSMENT OF REQUIREMENTS

The common elements of material accounting requirements under NRC, Euratom, and IAEA safeguards were shown earlier. Although the basic elements are much the same, there are important differences in the safeguards objectives of those safeguards authorities. Under NRC safeguards for low enriched uranium conversion-fabrication plants, safeguards reliance has been placed primarily on the plant operator's accountability data. Substantiation or verification activities in the LEU sector by NRC inspectors have been centered largely on the quality of the licensee's measurements rather than on the direct verification of quantities in inventory or quantities of flow. By contrast, under Euratom and IAEA safeguards, the emphasis is placed on the direct substantiation or verification of the plant operator's data by the safeguards authority. As a result, both Euratom and IAEA safeguards requirements include provisions to facilitate quantitative verification. The special requirements for such verification are shown in Table 3.

Before discussing these requirements and their impact on plant operations, it should be noted that the added requirements do not apply in the same manner to all plants. Plants under IAEA safeguards in nonweapon countries need to meet all the requirements, whereas plants in nuclear weapon states coming under "voluntary programs" may be affected differently. For example, under the proposed U.S.-IAEA agreement, all plants in the U.S. on the eligible list would come under the general reporting requirements. However, not all U.S. plants will be subject to inspection at any one time. As a result, the need to provide advance notification and to provide for inspection activities is required only during the time period for which a particular U.S. plant is under inspection.

The reporting aspects of the requirements for verification, although they involve an extra coordination effort, should not in themselves be a major burden. The requirement for advance notification will be, however, of concern to both the operator and the inspector. The operator is concerned that the advance notification requirement for exports or imports will become a production commitment such that he might have to slow or stop production to meet a previously made verification date. The inspector is concerned with having ample advance notice to arrange his inspection schedules or having to rearrange inspection schedules in the case of plant delays or requests for the inspector to arrive earlier than the date of advance notification to accommodate plant production changes. It is apparent that a high degree of cooperation and coordination will be necessary. In some cases, special arrangements between the operator and the inspector may be the most practical solution.

The other areas of impact are the verification activities themselves for which there is as yet little U.S. experience. Our comments are based primarily on initial discussions with IAEA and Euratom safeguards staff members. In the low enriched conversion fabrication sector of the fuel cycle, we anticipate both types of verification activities--flow verification and inventory verification. We assume that flow verification will consist of random on-the-spot verifications of imports and exports. We expect that verification of imports would take place shortly after receipt of the material and for exports just prior to packaging.

We expect that inventory verification at LEU conversion-fabrication plants would become an integral part of the operator's annual or semiannual inventory.

We envision a two-step process. First, the operator completes his inventory and reconciliation and then the inspector carries out his verification sampling plan with the assistance of the operator in moving items selected in the sampling plan for verification measurements such as NDA testing, weighing, or sampling. With the exception of measurements made using the inspector's equipment, the operator would perform all the measurements under the observation of the inspector. The operator would also perform all material handling functions and packaging of samples for shipment to a safeguards laboratory. Our understanding is that at least some of these costs will be borne by the IAEA.

Both flow and inventory verification activities can have a significant impact on plant operations.

Hopefully, the cost impact can be minimized by suitable practical arrangements.

It is also apparent that successful verification requires the active cooperation of both the operator and the inspector. The basis for such a cooperative effort is provided for in the governing enactments which make the operator a party to all discussions relating to verification at his facility. Article 8 of the Euratom Regulations provides for consultations with the operator prior to determining the "particular safeguards provisions." Under IAEA safeguards, the plant operator is a party to the discussions of the Facility Attachments which include the detailed arrangements for verification.

Our initial experience in such discussions has been quite favorable, both in Europe and in the U.S. We found in our case that the plant operator is indeed a true party to such discussions. We also found our inspectors to be knowledgeable, practical, and reasonable.

Here in the U.S., where international safeguards activities will be a completely new experience, a number of concerns[2] have been expressed over the implementation of IAEA safeguards. Some of these concerns were discussed earlier. Additional concerns include the question of protecting commercially sensitive information, whether more than one MBA per facility will be required for IAEA reporting, and the logic of batch designations for flow and inventory reporting. These concerns have not been fully resolved in our minds as yet; but we are confident that as we continue to interact with NRC and IAEA representatives, continued progress can be made in easing them.

During the past year, certain licensees, including ourselves, have participated in an exercise on the implementation of IAEA safeguards under a joint program by NRC and IAEA. Our exercise consisted of the preparation, submittal, and IAEA review of a Design Information Questionnaire and the co-preparation of a Facility Attachment by the IAEA, NRC, and ourselves for our LEU conversion-fabrication plant in Richland, Washington. Currently, we are in the last stages of the Facility Attachment part of the exercise. In our opinion, the completion of the Design Information Questionnaire is equivalent in effort to the preparation of a Fundamental Material Control Plan. For our LEU fuel assembly plant located in Lingen, Germany, our progress (except for the verification section of the attachment) has been similar, with Euratom in the role of the Community inspector.

We and other licensees have also participated in a session on material type codes for converting plant codes to the IAEA coding system. We understand that conversion from plant material type codes to IAEA material type codes will be done by computer on the Nuclear Materials Management and Safeguards System at Oak Ridge. We heartily endorse that effort.

ADEQUACY OF CURRENT PRACTICES

A continuing question is: "are the current safeguards accountability practices in the LEU-conversion fabrication sector adequate for safeguards?" If we could answer this question from a purely domestic point of view, our answer would be a resounding yes. That answer would be based primarily on the argument that no quantity of low enriched uranium currently constitutes a safeguards risk in the context of its use as starting material in the direct preparation of a nuclear explosive.

Unfortunately, one cannot separate purely domestic from international safeguards concerns since the consequences of national misuse can impact on all inhabitants of our earth. As a result, to evaluate adequacy one must consider quantities of LEU which are judged to be important from an international standpoint. For given quantities of LEU of safeguards importance, it is possible to evaluate the ability of materials accounting to distinguish between loss and measurement uncertainty. Two examples of this type of analysis are shown in Tables 4 and 5; one for a single plant and one for a LEU conversion-fabrication sector (i.e., a group of plants).

To perform the example analysis, we assumed that the U-235 LEMUF for an individual plant is equal to the NRC limit of 0.5 percent of throughput. For the LEU sector case, we assumed five plants of equal throughput and assumed the measurement systems to be truly independent such that propagated LEMUF for the five-plant sector is 0.224 percent of throughput or a relative reduction of the square root of five for the individual plant LE's of 0.5 percent (i.e., $0.5/\sqrt{5}$). In both cases, the average enrichment processed is assumed to be three weight percent U-235.

Since we do not believe that it is possible to sharply define the quantity of LEU which is of safeguards importance, we chose a range of values for kilograms of U-235 contained to correspond to multiples of five, ten, and twenty times the approximate fast critical mass of high enriched uranium;[3] that is, multiples of 25 kgs of U-235 contained. This value compares to an IAEA value for evaluation purposes of 75 kg contained U-235[3] and 5 ekg (167 kg U-235 at three percent U-235) from a recent INMM Safeguards Committee study.[4]

It is further assumed that a central safeguards authority such as IAEA would evaluate the observed MUF of an individual plant versus its LE and the observed MUF of the LEU sector of a state against the propagated LE of the sector as part of the battery of tests used by them for safeguards evaluations.

Table 4 for a single plant illustrates the power of loss distinction as a function of throughput and as a function of the assumed quantity of safeguards importance. The probability in the last column is the probability of the observed MUF exceeding its LE given that the loss of a quantity of safeguards importance has occurred. To place the probabilities in better perspective, it should be noted that the probability of an observed MUF exceeding its LE is 0.50 at the point where the true loss is equal to the LE which is the trigger point for investigation. Thus, in Table 4, probabilities exceeding 0.5 indicate that the accounting system is adequate to signal a loss of the assumed quantity of safeguards importance. The "success zone" is marked in the tables.

Table 5 shows similar information as Table 4, but this time for an assumed LEU sector of five plants of equal throughput and having equal but independent LEMUF's of 0.5 percent per plant such that the relative LEMUF of the sector taken as a whole is 0.224 percent of throughput as discussed previously.

Assuming that the range of values chosen for safeguards loss distinction goals are realistic and that LEMUF values are upper limit values, it can be concluded from the examples that materials accounting can indeed provide an adequate degree of safeguards assurance. Obviously, assuming lower LEMUF values and higher loss distinction goals would provide even higher probabilities. But if one includes the mid-range probabilities, even they are for the most part in a useful range of loss distinction.

Of equal importance is the timeliness of the accountability system in detecting apparent losses of safeguards importance. In safeguards systems analysis, the concept of critical time is often used in determining the required frequency of physical inventory taking or material balance closing. The critical time is defined as the time required to convert a given type of nuclear material into a nuclear explosive.

For low enriched uranium, it is not possible to sharply define the critical time because of the long and complex nature of the processes leading to SSNM and the complexity of the assumptions regarding the capabilities of the assumed diverter. For international safeguards, this time has been estimated to be in the order of one year[3] to two years.[4] Thus, to meet the lower estimate of critical time, a plant operator would need to have either some form of continued assurance that quantities of safeguards importance are not missing or else take physical inventories more frequently than once a year. We believe the current NRC requirement of six month cleanout inventories or their equivalent to be adequate. More frequent "tag value" (i.e., no clean-out) inventories could be of some benefit in detecting trends and in providing early warning. However, the benefit of tag inventories for conversion areas is seriously limited by the magnitude and variability of equipment holdup. In some cases quarterly cleanout inventories may be the best compromise between inventory quality and timeliness.

We do not believe that real time materials accounting is required for safeguards assurance in the LEU conversion-fabrication sector. Real time accounting is similar in benefit to frequent (monthly or bimonthly) tag inventories and suffers from the same deficiencies such as the inability to measure equipment holdup. To some extent, the computer-based accounting systems used in the LEU conversion fabrication sector approach real time accounting. In some instances, book values for material balance areas and item listings for item control areas are maintained on a daily basis. Such features ease the taking of inventories and reduce the costly nature of frequent inventory taking. However, as yet there does not appear to be any practical substitutes for physical inventories accompanied by equipment cleanouts in the low enriched conversion-fabrication sector. If the size of hidden inventory buildups due to equipment holdup could be realistically modeled as a function of time, then the major deficiency of tag inventories (e.g., variable holdups) would be eliminated and tag inventories would then take on added value as a safeguards detection tool. Our experience with monthly MUF's is that such modeling is generally not possible in the LEU conversion-fabrication sector.

The last and most difficult aspect of adequacy is the actual demonstration by MUF performance that important quantities of LEU could not have been lost. Because of a historical positive MUF trend of the industry, the demonstration of adequate MUF performance (MUF $\rightarrow$ 0) is a difficult task facing the nuclear industry today. Although we are convinced that most of the positive MUF trend can be explained by the underaccounting of liquid and solid wastes due to waste measurement problems, an explained MUF is no substitute in credibility for good actual MUF performance. A current indication of the positive MUF trend in all major U.S. plants is shown by the low enriched uranium inventory difference values reported in NUREG 0430[5] which covers fiscal year 1977.

TIMING AND DIRECTION OF FUTURE MODIFICATIONS

Areas of Improvement

We believe that there are remaining areas where cost-effective improvements can be made in safeguards materials accounting practices in the LEU conversion-fabrication sector. These are in the areas of MUF performance, loss distinction, and safeguards emphasis.

As was noted earlier, the nuclear industry is faced with a common positive MUF trend. Based on our experience, we believe that this trend is primarily due to the underaccounting of solid and liquid wastes. At the current high dollar value of low enriched uranium, there is increased incentive for waste reduction and recovery programs and for improved waste measurement systems which should alleviate some of these problems.

We have carried out a number of solid waste recovery experiments and liquid waste measurements to verify or improve our own waste measurements. From these experiments and results of modifications, we have become convinced that our MUF performance is directly related to our ability to reduce the level of uranium going to waste and/or improvements in our waste measurement systems. We and other West Coast licensees are also currently engaged in a solid waste measurement experiment with the Battelle-Northwest Laboratories under the sponsorship of NRC in which various NDA systems are being evaluated. Part of the experiment involves a comparison between chemical recovery and NDA values. Results are as yet tentative, but there are indications that biases in NDA systems for measurement of solid waste can be quite significant. A major part of this problem lies, in our opinion, with developing realistic calibration standards, a problem that is difficult to solve.

In the LEU conversion-fabrication sector of the U.S., a significant gain in the sensitivity of loss distinction can be made by changing from the traditional emphasis of U-235 MUF to U element MUF. We estimate that a gain of about 40 percent may be achieved by such a change of emphasis. For MUF accounting in LEU conversion-fabrication plants, the enrichment does not play a critical role since the enrichment of fuel materials cannot be changed except by blending. The adding of the enrichment measurement errors to the measurement errors associated with determining quantities of uranium element creates an additional measurement component uncertainty in U-235 accounting which is not essential in detecting material loss. (The use of U-element MUF and LEMUF will not in any way eliminate the need for the nuclear industry to maintain high quality enrichment measurements to detect substitution scenarios and to provide best "state-of-the-art" enrichment values for material going into reactors.)

A suggested way for changing the loss distinction emphasis to U element and still retain the same control for U-235 would be to have two LEMUF limits, one for the U LEMUF and one for enrichment LEMUF or that part of the U-235 LEMUF which arises solely from the enrichment measurement errors.

Based on our experience that the variances for U element and enrichment measurement errors are about equal, a suggested approach would be to set the limit for both U LEMUF and enrichment LEMUF at 0.35 percent of throughput. The propagated combined U LEMUF and enrichment LEMUF is then equal to the current U-235 LEMUF, since the root mean square of 0.35 and 0.35 yields the current NRC limit of 0.5 percent for the U-235 LEMUF.

The gain in loss distinction sensitivity for this change in emphasis is shown in Table 6 for one of the single-plant cases discussed earlier. Now, in this example, all loss distinction probabilities are above 0.5 (i.e., in the "success zone").

In recent years we have observed a U.S. regulatory trend toward placing a greater emphasis on internal MUF's and the isolation of loss by individual internal material control areas. We believe that these objectives of greater internal control should be deemphasized with respect to the more important safeguards objective of "zero" MUF across the total plant. We believe that it is far more important to spend available efforts on controlling and improving the overall plant MUF than in trying to reduce to zero the inherent "paper" MUF's which arise between two adjoining MBA's which often involve a large number of transactions in both directions. We believe that the most important indices of safeguards performance in the LEU conversion-fabrication sector are the periodic and cumulative plant MUF's.

External Checks and Balances

With the advent of international safeguards in the U.S., we expect to see a greater emphasis placed on the safeguards position of fuel fabrication in the fuel cycle and on the external checks on the output of fuel fabrication.

In the LWR fuel cycle, conversion-fabrication plants play an important part in the overall safeguards plan by their position in the fuel cycle. First, as fuel receivers of the output of enrichment plants, they provide an independent check on accountability statements made on the enrichment plant's product shipments. As the fuel supplier to the reactor, they provide, through their measured values for uranium element and enrichment, the basis for computing plutonium production. The initial values measured at fuel fabrication when corrected for reactor burnup can also provide important safeguards verification cross-checks if the spent fuel is eventually reprocessed.

We also expect to see a greater emphasis in the future on establishing cross-checks and means of protecting the integrity of the product measurements made at fuel fabrication. We believe that the fuel supplier has capability to provide "best state-of-the-art" measurements for his product shipments. The inspector by contrast, is currently severely handicapped in his capability to verify the output of fuel fabrication and to verify that the integrity of the fuel has been maintained as it goes from the fuel plant to the reactor and later to fuel storage and/or reprocessing.

Currently, it is technically feasible for the inspector to verify the output of fuel fabrication up through the rod loading process. With the general use of fuel rod assay units, it is technically possible to verify the contents of loaded rods to a fair degree of exactness. However, once the fuel bundle is assembled, the inspectors' capability to verify is severely limited.

We should note that LASL is currently active in developing NDA instruments for verifying the contents of assembled fuel bundles. We plan to assist them in performing some of the experiments at our fuel fabrication plant in Richland.

We are also engaged in a cooperative program with Euratom Safeguards and the Sandia Laboratories in the development of seals for fuel assemblies. The seal approach has great promise in that it could allow the inspector to obtain assurance that his initial verification of fuel content at fuel rod loading is maintained through the later stages of the fuel cycle until the fuel assembly is discharged from the reactor and shipped to its ultimate destination.

An additional and possibly routine overcheck on the output of fuel fabrication is provided by the reactor in terms of the startup reactivity tests made after fuel loading for safety evaluation. The effect of an off-standard fuel loading would be seen in physics testing experiments conducted for reactor safety purposes during startup after fuel loading. A shortage of U-235 would give a lower reactivity than expected. For example, if our lower quantity of safeguards importance (125 kilograms of contained U-235) were missing from a 30 tonne reload of three percent enriched uranium, the reactivity would be more than one percent lower than expected. A difference this large is detectable in the reactor and would, of course, be of serious concern to the reactor operator. An off-standard fuel loading may also be seen to some extent in the reactor's radial power distribution. As yet, we have not had an opportunity to evaluate the safeguard potential of these kinds of crosschecks in a quantitative way, but they may offer a good overall crosscheck for diversion of significant quantities of safeguards importance.

SUMMARY

In summary (Table 7) any safeguards risk of low enriched uranium arises from considerations of national misuse rather than its potential use by small subnational groups or individuals. The international hazard of low enriched uranium is generally not well recognized by the plant operator; the risk, if any, is remote and distant. The high monetary value of low enriched uranium provides the plant operator with a more concrete incentive for good accountability measures.

The implementation of international safeguards which will have only modest impact on the low enriched uranium sector in the U.S. requires the verification of material quantities by safeguards inspectors. The cooperation of both the operator and the inspector will be essential to the success of these activities.

The safeguards role of materials accounting in the LEU conversion-fabrication sector is to provide assurance that quantities of LEU of safeguards importance are not missing. Current practices are sufficiently timely and have good power of loss distinction to provide adequate assurance.

Based on one year's data, the low enriched uranium conversion-fabrication industry has a common positive MUF trend which unfortunately might reduce the safeguards credibility of the industry. We believe that this common positive MUF is due in large part to underaccounting of liquid and solid wastes and improvements in these areas are judged to be cost-effective and should be evaluated.

The sensitivity of loss distinction can be improved by placing the safeguards emphasis on the U-element MUF and U LEMUF rather than on the U-235 MUF and U-235 LEMUF as is currently done in the U.S.

We recommend that the future direction of materials accounting safeguards in the LEU conversion-fabrication sector places a greater importance on the total plant MUF and the cumulative plant MUF than on the internal MBA structure. For international safeguards, the role of conversion-fabrication plants as part of a safeguarded fuel cycle will receive greater emphasis.

Research and development efforts for international safeguards are being directed at closing the final product verification deficiency which currently exists in fuel fabrication plants. Fuel assembly seals, NDA devices, and reactor reactivity tests all hold promise of improving that situation.

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TABLE 1

CURRENT VALUE OF LOW ENRICHED URANIUM

Wt. % U-235	$/Kg U	$/Gram of U-235 Contained
1.0	206	21
1.5	380	25
2.0	563	28
2.5	751	30
3.0	943	31
3.5	1136	32
4.0	1332	33
4.5	1529	34
5.0	1726	35

TABLE 2

COMMON REQUIREMENTS FOR MATERIALS ACCOUNTING

- Measurement of All Quantities
- Records of All Transactions
- Physical Inventories
- Mass and Item Control Areas
- Reports of Transactions, Status, and Discrepancies
- Measurement Control Programs
- Audits, Evaluation, and Verification by Safeguards Inspectors

TABLE 3

SPECIAL REQUIREMENTS FOR QUANTITATIVE VERIFICATION

- Reporting by Batch Designations
- Reporting of Physical Inventory by Stratum and Batch
- Advance Notification of Imports, Exports, and Inventory Times
- Provision for Verification Activities

TABLE 4

EXAMPLE ANALYSIS OF THE POWER TO DISTINGUISH LOSS FROM MEASUREMENT UNCERTAINTY FOR A LEU PLANT

Annual Plant Throughput			Probability(1) of loss Exceeding LEMUF		
			Loss, Kgs U-235		
Tonnes U	Kgs U-235	% U-235 LEMUF	125	250	500
400	12,000	0.50	.98	>.99	>.99
800	24,000	0.50	.53	.98	>.99
1,200	36,000	0.50	.27	.78	.99

(1) Probability of the observed loss (MUF) exceeding LEMUF if true loss is as indicated.

TABLE 5

EXAMPLE ANALYSIS OF THE POWER TO DISTINGUISH LOSS FROM MEASUREMENT UNCERTAINTY FOR LEU SECTOR

Annual Sector Throughput		Sector	Probability(1) of Loss Exceeding LEMUF		
			Loss, Kgs U-235		
Tonnes U	Kgs U-235	% U-235 LEMUF	125	250	500
2,000	60,000	0.224	.44	.96	>.99
4,000	120,000	0.224	.14	.44	.96
6,000	180,000	0.224	.08	.22	.68

(1) Probability of the observed loss (MUF) exceeding LEMUF if true loss is as indicated.

TABLE 6

EXAMPLE OF GAIN IN POWER OF LOSS DISTINCTION

BY USE OF U LEMUF VERSUS U-235 LEMUF

Annual Plant Throughput			Probability(1) of loss Exceeding LEMUF Loss, Kgs U-235		
Tonnes U	Kgs U-235	% U-235 LEMUF	125	250	500
800	24,000	0.5	.53	.98	>.99
		% U-LEMUF			
800	24,000	0.35	.84	>.99	>.99

(1) Probability of the observed loss (MUF) exceeding LEMUF if true loss is as indicated.

TABLE 7

SUMMARY OF IMPORTANT POINTS

- LEU Important From International Viewpoint Only
- High Monetary Value Provides Incentive for Improved Control
- Verification Requires Cooperative Effort
- Current Accountability Practices Adequate for Safeguards
- Improvement of MUF Trend by Better Waste Control and Waste Measurements
- Improved Sensitivity with U-MUF and U-LEMUF
- Future Direction: Plant MUF and CUM MUF; Safeguards Fuel Cycle Cross-Checks; and Verification of Fuel Fab Plant Product

INDEX OF ARTICLES (1972 - 1978)

Editor's Note: For years 1972-1977 (Volumes 1-6 of **Nuclear Materials Management**), No. 3 is the proceedings issue of that year. Beginning in 1978 (Volume VII), No. 3 becomes a regular issue of the Journal. The proceedings of the 1978 annual meeting is designated, Volume VII, Proceedings Issue. Future issues of the INMM Proceedings will be designated similarly, i.e., in 1979 it will be designated Volume VIII, Proceedings Issue. Copies of the tables of contents for INMM Proceedings issues are available on written request to the editors.

NBS Demonstrates Improved Tank Volume Calibration System

The following is a technical note on a paper titled, **The Application of an Improved Volume Calibration System to the Calibration of Accountability Tanks,** by **Frank E. Jones** of the National Bureau of Standards, which was presented by a rapporteur at the IAEA Symposium on Nuclear Materials Safeguards, Vienna, Austria, 2-6 October, 1978. The following is a summary of the paper.

The paper describes a very significantly improved system for the volume calibration of nuclear materials accountability tanks. The system involves the transfer of the current technology of liquid volume measurement and differential pressure measurement to the field, enabling an improvement of tank volume calibration accuracy by 1 to 2 orders of magnitude and a consequent improvement in process solution volume measurement leading to significantly improved accountability of nuclear materials for Nuclear Safeguards purposes. The system has been used in a very successful calibration of an input accountability tank at the Savannah River Plant operated for DOE by E.I. DuPont de Nemours & Co., Inc.

Conventionally, chemical process tanks have been calibrated by adding accurately weighed amounts of water and measuring the liquid depth using oil manometers or differential pressure gages. Calibration curves or tables relating liquid volume to measured differential pressure are then developed for the particular tank.

The calibration effort on the Savannah River Plant accountability tank, conducted by **F.E. Jones** assisted by **J.F. Houser** and **R.M. Schoonover,** drew on previous NBS results and experience. Volumetric test measures calibrated at NBS were used to introduce water into the tank and a commercially available pull-operated quartz Bourdon-type differential pressure gage was used for the pressure measurements. The calibration of the gauge was checked at NBS at several points in the pressure range of interest. The accountability tank has a capacity of 13,600 liters, is essentially cylindrical with a diameter of 2.4 m and a height of 3.3 m, and contains cooling coils, an agitator, vanes and several probes. Seven calibration runs were made, six in a "Mock-up" area of the plant and one in the process location.

Linear equations relating liquid volume to differential pressure have been developed using the calibration data; the data were treated separately for regions in the tank which, due to geometrical considerations, are most suitable for nuclear materials accountability. As an indication of the fit of the experimental points to the fitted equations, the maximum deviation for the run in the process location was 1.1 liter, which corresponds to 0.05% of the liquid volume at that point. The results for this calibration represent an improvement by between 1 and 2 orders of magnitude when compared with the results of a calibration made in 1971 of a similar tank using a weigh tank and an oil manometer.

The system described in the paper is the ideal system for tank volume calibration, employing volumetric **transfer standards** and a state-of-the-art differential pressure gage. Consequently, the data gathered using this system are much more precise and accurate than those provided by other systems in present use or being considered for use.

Nuclear Reactors Built

"Nuclear Reactors Built, Being Built, or Planned in the United States as of June 30, 1978" contains current information about facilities for domestic use or export which are capable of sustaining a nuclear chain reaction. Civilian, production, and military reactors are listed, as are reactors for export and critical assembly facilities.

Revisions are published twice a year, and the information presented is current as of June 30 or December 31. The publication (44 pages, 8 x 10½, paper back) is available as TID-8200-R38, for $4.75 from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

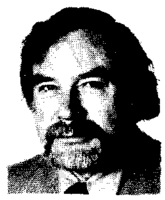

Andersen


Downing


Lambert


Leake


Morrison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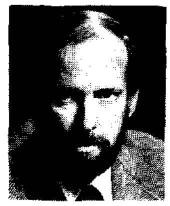
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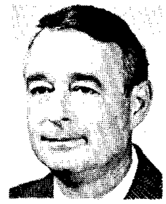
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