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EDITORIAL

Willy's Special Modus Operandi

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

Each editor of a technical journal has his special modus operandi with its advantages and disadvantages. It is important that I explain my method, such as it is, so that contributors and readers will understand when and why to complain.

Both the Journal editor and I solicite contributions. Solicited papers, like contributed papers are subjected to peer review, usually by two reviewers, more if there is a disagreement. Consequently, even solicited papers may be rejected.

Criteria for acceptance are the following:

(1) The article has not been submitted to another journal or previously published. In exceptional cases, an article may be republished in this Journal, due to its special relevance to INMM, and with permission.

(2) The article has something new to say that is of general interest to our readers, or to one of our several disciplines.

(3) The article is technically correct, and clearly written.

My system for selecting reviewers is largely dictated by the special nature of the Institute and of the Journal. Ours is a relatively small organization. Safeguards and Materials Management include a wide range of subjects, from technology, through systems design, to threats and assessment, domestic and international. When I started, I tried to set up a review committee or panel of reviewers, as do most technical and other journals. However, the members of this panel frequently referred the papers to colleagues, and papers were submitted for which no one on the list was qualified. When I have appealed for volunteers, no one has responded.

Consequently, when a manuscript is received, I read it and decide what members would be willing and competent to review it, or what safeguards groups. Copies of the manuscript, and a letter, are sent to the individuals I have selected, or to an active INMM member of a safeguards group with a request to locate a reviewer there. In my view this seems to work reasonably well.

There are some problems. I am the first problem. I try to fit this operation into a very busy schedule, and my office is a confused mess. Last fall I lost a manuscript. Some months later *Tom Gerdis* inquired about it and I had to request a replacement from the author. Very embarrassing. If I don't acknowledge receipt of your manuscript in 2 to 3 weeks, don't hesitate to phone or write. A second problem is that the many reviewers do not get credit for their very considerable efforts. By means of this communication I wish to express my deep appreciation to the many INMM members who kindly and conscientiously perform this valuable service. Sometimes, as you may have noticed. I have not taken your advice, either because another reviewer did not consider the criticism to be very important, or because it was close to the time for printing. All comments are appreciated by me and very frequently by the author involved.

Tom and I feel that the lists of titles and abstracts, that we wheedle out of chapters and active institutions, are useful to our readers, since many interesting safeguards papers are published by institutions or in other journals which we might not happen to receive. These lists I edit personally. I do not send reports on safeguards in Japan, or Canada, etc., out for review, but check them for typographical errors.

I have one special plea to contributors: Please try to avoid acronyms. It doesn't cost much to write them out and it is so much easier not to have to remember what an MPSZ is.

Please feel free to complain to me (516-345-2908) about technical articles, those you submitted, those you reviewed, or those that appear to you to have been inadequately reviewed. Complain to the Journal editor (703-471-7880) about misplaced figures or non-technical articles. *Dick Chanda* (303-497-2727) is chairman of the papers selection committee for the annual meetings.

The quality and value of our Journal depends on the continuing interest of our members, and on your contributions. This is an appropriate time to express my personal gratitude to the contributors for your contributions and for your cheerfully responding to criticisms, amending drafts, and meeting deadlines.

Higinbotham

1980 — A Milestone Year of Growth And Progress for the INMM

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

The first year of the new decade, 1980, has indeed been a milestone year of growth and progress for the Institute of Nuclear Materials Management. In addition to the highly successful 1980 Annual Meeting, Institute professional activities in fiscal year 1980 (ending September 30) include sponsorship of five training courses, two technical workshops, and INMM co-sponsorship of two topical meetings, both with extensive domestic and international participation. The INMM membership, which has now climbed to well above the 700 mark, continues to reach new all-time highs.

Under the timely theme, "Safeguards Today and Tomorrow," our 1980 Annual Meeting at Palm Beach attracted nearly 400 attendees from throughout the US and overseas. The keynote address, "Regulation of the Nuclear Power Industry: Its Uses and Abuses" by **Robert Uhrig,** Vice President, Florida Power and Light, presented a broad ranging survey and critique of nuclear power regulation in the United States today. Uhrig referred to a "Lilliputian network of regulatory strings, most of which taken in isolation do not seem unreasonable, but whose sum total consitutes a straightjacket that is slowly but surely killing the nuclear industry and along with it the hope that nuclear power might play a significant role in alleviating US heavy dependence on foreign oil." Uhrig examined some of the root causes of the problem and proposed possible corrective actions.

The present posture and future prospects for IAEA safeguards were reviewed and evaluated in an invited paper by Dr. **Hans Gruemm,** Deputy Director General, Department of Safeguards of the International Atomic Energy Agency. Dr. Gruemm discussed IAEA safeguards objectives and their "translation" into practical detection sensitivity and timeliness goals or guidelines for the application of IAEA safeguards to generic types of nuclear facilities. In addition to describing current IAEA safeguards implementation at discrete-item facilities and small bulk-handling facilities, a survey was given of current studies and approaches to safeguarding the anticipated large bulk-handling facilities of the future.

Also in the opening plenary session, the outlook for US Nuclear Safeguards in the commercial sector was discussed by **Robert Burnett,** Director of the US NRC Division of Nuclear Material Safety and Safeguards. Burnett emphasized that in addition to continuing concerns about nuclear theft, "future safeguards attention will also concentrate upon the perennial problem of nuclear material accountability as we seek to make the 'closed material balance' a practical working reality in the licensed nuclear industry." He also indicated that, as a result of the accident at Three Mile Island, more regulatory attention can be expected to focus on safeguards at power reactors in the 1980's.

The final paper of the opening plenary session at Palm Beach, entitled "Future Directions for Safeguards" was presented by **George Weisz,** Director, Office of Safeguards and Security, US Department of Energy. Mr. Weisz identified DOE safeguards program elements in support of DOE facilities and the safeguards mission of the International Atomic Energy Agency. Among the key challenges cited in implementing new upgraded safeguards are the formulation of future criteria and requirements, and the integration of safeguards into new fuel cycle facilities at the earliest stages of design. Mr. Weisz's paper concluded with an overview of the program of support to international safeguards managed by DOE in concert with NRC, the Arms Control and Disarmament Agency, and the Department of State, as well as a brief look at future prospects for international safeguards in the post-INFCE period.

Contributed paper sessions at Palm Beach were devoted to a wide range of safeguards topics including Safeguards Measurement Technology, Non-proliferation and International Safeguards, Physical Protection, Analysis of Materials Accounting Data, Materials Control and Accountability Systems, Safeguards Evaluation Methodology, and Safeguards Trends. Special sessions of invited papers dealt with safeguards in ESARDA (European Safeguards Research and Development Association), Public Information, Measurement Technology, and Emergency Response for Accounting and Physical Security Systems.

The afternoon plenary session on Tuesday, July 1, opened with a presentation of the Student Award Paper "CIVEX Reprocessing Technique: Assessment of Technology and Institutional Problems," by Student Award winner **Mohammad Sharafi** of MIT. This plenary session also included a review of the National Perspective on Waste Management by **J. L. Crandall** of Savannah River Laboratory and an entertaining and informative address by **Willy Higinbotham** of BNL, recipient of the 1979 INMM Distinguished Service Award. The plenary session concluded with presentation of the 1980 Distinguished Service Award to **Louis E. (Lou) Doher** by INMM Chairman Bob Keepin.

The INMM Annual Business meeting opened with highlights of the 1980 Annual Report to the Membership presented by the INMM Chairman and Executive Committee members. Significant accomplishments of FY 80 were summarized, followed by questions and comments from the audience.

At the Bahamian Goombay Buffet on Tuesday evening, awards and recognition were presented to **Douglas E. George** (Meritorious Service Award) and to outgoing Executive Committee members, **Dennis Bishop, Roy Cardwell,** and **Frank O'Hara.** INMM special service recognition was also given to **Tom Gerdis** for his dedicated service as INMM Journal Editor; to **James Lee,** retiring INMM Membership Chairman; and to **Tom Sellers,** Chairman of the very active Technical Working Group on Physical Protection.

In short, the 1980 Annual meeting was obviously a real winner, and it provided again this year, a most important and timely contribution to the professional posture and progress of safeguards technology in the US and the international nuclear community.

Fiscal year 1980 has also brought a number of important developments in the nuclear energy field generally, and particularly in the increasingly prominent area of international safeguards and non-proliferation. In March, the two-year INFCE study was concluded and the resulting consensus of the 66 participating nations included an endorsement of stringently safequarded nuclear energy systems for the future, including the judicious deployment of plutonium breeder reactors (again under strict safeguards and controls) as an important factor in avoiding future shortages of uranium fuel. The total plutonium inventory in irradiated civilian reactor fuels today is increasing at a rate of some 25-30 tons per year. Breeder reactors will eventually reduce this, but serious non-proliferation concerns about potentially large stockpiles of plutonium (in whatever form) have given rise to a number of international studies and evaluations — involving both technical improvements and institutional arrangements — designed to place sensitive materials and fuel-cycle facilities under some form of international control.

Some representative institutional arrangements that have been proposed for international consideration include (1) the familiar concept of Regional Fuel-Cycle Centers in which large fuel reprocessing and fabrication plants would be colocated thus providing economies of size and operational efficiency, as well as minimizing vulnerability to theft and diversion; (2) an International Fuel Authority with responsiblity for providing fuel service and allocating fuel resources; (3) establishment of International Plutonium Storage Centers; and (4) the concept of regional nuclear waste repositories, fuel reprocessing plants, and/or enrichment plants under international or multinational authority. Working out the details of any such international arrangements (e.g., siting; ownership/management; equitable, mutually agreeable rules for "deposits and withdrawals", etc.) would be a monumental task indeed, and would, of necessity, involve the potential participants themselves.

INMM Chairman Bob Keepin discusses safeguards technology with Institute members Pierre Busquet and Philippe Guay, both of the French CEA (Commissariat at l'Energie Aromique) during a visit to nuclear facilities in France in April, 1980.

Also in this milestone year, 1980, two important international safeguards agreements have cleared the US Congress, thereby opening the way for their early implementation. The first is the US-Australian Agreement on the Peaceful Uses of Nuclear Energy, which represents the first renegotiated safeguards agreement under the new safeguards provisions of the Nuclear Non-Proliferation Act (NNPA) of 1978. The second agreement, ratified by the Senate on July 2, is the US-IAEA Agreement for the Application of IAEA Safeguards in the United States, pursuant to the US voluntary offer to implement IAEA safeguards in US facilities, excluding only those having national security significance. It is indeed gratifying and significant that the Senate ratification process has been completed prior to the (potentially contentious) NPT five-year review conference of the 106 NPT signatory nations at Geneva this August (yet another key development in 1980). It is believed that this action on the part of the United States may help to alleviate a growing concern and possible hardening of position by some countries with regard to the NPT.

A key aspect of NPT acceptability and workability is assurance of nuclear fuel supply (basically uranium, at present). Irrevocable fuel assurances are indeed an essential quid pro quo of the NPT Agreement, and should be promptly extended to nations that meet their non-proliferation undertakings. There is little doubt that the uncertainties that have hung over supply assurances in recent years have had serious repercussions — including for safeguards and non-proliferation — throughout the world nuclear community. In international safeguards, the basic quid pro quo of the NPT Treaty is often expressed by the simple, direct slogan "Guaranteed Safeguards for Guaranteed Supply."

Turning to the domestic picture in the US, ever since Three Mile Island nuclear events and issues have received much attention — both "good" and "bad" —

from the media. There has also been a commensurate increase in Congressional and public interest in all nuclear issues, not only in reactor safety, but also in the area of nuclear waste and to some extent in nuclear safeguards and security. The three main reactor safety "lessons learned" from Three Mile Island — namely the need for (1) better professional training of reactor operators; (2) better measurement instrumentation; and (3) better emergency response — have had an inevitable impact (albeit somewhat less directly) in the safeguards and security area. Thus one of the by-products of TMI has been new emphasis on better training and upgraded operational performance standards of nuclear operators — mainly, to be sure, in the area of reactor safety, but also on better training and operational performance standards in the vital areas of safeguards, materials management, and physical security.

The thrust of all this has translated into a rather widely preceived need to establish an objective means for formal certification of the professional qualifications of safeguards practitioners. The newly established INMM certification program is one reponse to this need. Toward the goal of an objective means for certification, two specially commissioned INMM certification subcommittees have formulated a test library of over 700 examination questions covering the overall safeguards and security field. This test library has undergone an intensive process of formal validation in order to ensure an effective and objective examination regimen. As described elsewhere (e.g., see INMM Certification Application Form, "Rules and Procedures"), the INMM certification process consists of two levels of qualification — (1) Certified Safeguards Intern, and (2) Certified Safeguards Specialist — and covers five basic areas:

1. General (physics, chemistry, fuel cycle, safeguards principles)
2. Nuclear Materials Accountability
3. Measurement (Destructive and Nondestructive Assay)
4. Statistics
5. Materials Control (incl. Containment and Surveillance)
6. Physical Protection

A Certification Board, consisting of nine members has been established in accordance with INMM Bylaws (Article IV, Section 6g) to implement, administer, and maintain strict control over the entire certification process. Both levels of the Certification Examination under the new INMM Certification Program were offered at the Institute's 1980 Annual Meeting and are expected to be offered at all future INMM Annual Meetings and at most, if not all, INMM sponsored training courses.

Clearly the Insititute's Certification program, in order to have maximum value and impact, must be closely coordinated with (or at least not inconsistent with) existing safeguards training and education programs, whether they be under the auspices of IAEA, DOE, NRC, INMM, or others. In this connection, some in the INMM have begur advocating the general concept of the professional association as a learning community. The Institute's expanding training program includes five INMM-sponsored courses in fiscal year 1980: two held last fall, one in May on Accounting and Audit Techniques held at Battelle Columbus Laboratories, and two upcoming "back-to-back" statistics courses: (1) Fundamentals of Statistics, Sept. 10-12, and (2) Selected Topics in Statistics, Sept. 15-19, both to be held at Battelle Columbus Laboratories.

The extensive ongoing Department of Energy and Nuclear Regulatory Commission training programs and courses in safeguards, material accounting, and physical protection are periodically reviewed and updated to reflect changing needs and requirements of plant operators and inspectors alike. Also in the academic community there are indications of growing interest on the part of some universities in establishing formal curricula and elective courses in the safeguards and materials management field. As already noted, it is most important that the INMM certification program be coordinated, insofar as possible, with all such training and educational activities in both the government and private sectors.

In another priority area of Institute activity, namely communication and public information, 1980 has also been a very productive year. A variety of innovative approaches have been introduced to increase our effectiveness in communicating with the public, with government leaders and decision makers, and with our colleagues in the technical community. In an attempt to obtain more favorable media coverage of nuclear events and developments, the INMM Public Information Committee has initiated a series of cartoons, notable quotes, and humorous-but-informative pro-nuclear editorials in newspapers and magazines. We have also established an INMM Speakers Bureau, a Communications Bureau, and an INMM News Bureau consisting of Institute representatives in major cities to monitor press releases concerning safeguards and security issues and incidents, and to develop appropriate responses to inform and educate the public.

In response to developmemts of direct concern in the area of safeguards and materials management, an ad hoc Public Information/Response subcommittee of the INMM Safeguards Standing Committee has been assigned the specific task of developing an INMM "Skills Resource Directory" of INMM expertise and capabilities. Such a Directory will be of great value (1) in providing public information, education, consultation, and expert assistance when and as needed and (2) for responding appropriately to new safeguards/security incidents — whether they be of an abrupt, emergency, or gradually evolving nature. Such INMM response might range, for example, from explaining in laymen's terms, physical protection or materials accountancy principles, to helping resolve and explain the practical significance of inventory differences at nuclear facilities.

Toward this iImportant goal, an "INMM Membership Skills Resource Questionnaire" has been prepared and will be sent to the entire INMM membership in the near future.

Another priority activity of the INMM Safeguards Committee in the area of communication has been an ongoing technical dialogue with the Nuclear Regulatory Commission with regard to possible revision of safeguards regulations concerning low-enriched uranium. Several meetings have been held with NRC commissioners and staff, and action is underway at NRC to review and revise the regulations for this specific category of nuclear materials.

A notable example of the Insititute's effort to increase effective communication with government leaders has involved providing INMM expert testimony to US Congressmen and their staffs on nuclear issues pending congressional action, such as the US/IAEA Agreement on Safeguards Implementation in the US and the new US/Australia Agreement for Nuclear Cooperation under the provisions of the NNPA.

The INMM N15 Standards Committee (Methods for Nuclear Materials Control) has had an extremely productive year in 1980. Writing group activity has been at its highest level ever, with some 200 individuals participating on thirteen N15 subcommittees. During this period of reorganization and growth, the N15 Standards Committee, under the leadership of Dennis Bishop, has placed considerable emphasis on refocusing of resources to stay abreast of new technical developments and issues related to sfaeguards. Key results of the past year's efforts are summarized in the N15 Standards Committee report in this issue of the Journal. Many in the N15 standards program foresee an important synergistic role that International and professional organizations such as IAEA, ESARDA, and INMM can'play in advancing international cooperation and exchange in the vital area of safeguards standards and performance guidelines.

To achieve more effective INMM interactions on technical matters, and to better represent the professional interests and specialty areas of Institute members, we have begun the formation of INMM Technical Working Groups. The first such group, the INMM Physical Protection Technical Working Group, was established last summer under the leadership of **Tom Sellers.** By December the group had already organized and conducted an INMM Technical Workshop on Intrusion Detection Systems and is now planning a second INMM Workshop on Guard Training, to be held this summer (August 27-29) in Gatlinburg, Tennessee. Based on the success of the Physical Protection Technical Working Group, other INMM Technical Groups are foreseen in the areas of Accountability and Materials Management; Measurement and Statistics; System Studies; and International Safeguards.

All of us in the Institute can take great pride in the continuing accomplishments of our INMM Awards Committee, chaired by Ralph Lumb. Again this year our Distinguished Service Award and Student Award winners, as well as the other awards and recognitions presented at Palm Beach, have carried on the traditionally high standards that have characterized the INMM Awards program.

A proven valuable feature of the INMM functional reorganization in FY 79 was assignment by the INMM Chairman of Oversight responsibliity for designated areas of Institute activity to each Executive Committee member. Assigned oversight responsibilities for FY 80 have been as follows: **D. M. Bishop** — N-15 Standards, and Public Information; **R. G. Cardwell** Nominating, *Site Selection and Advanced Arrangements*; **Y.M. Ferris** — INMM Journal, Constitution and Bylaws; **S. C. T. McDowell** — Awards, Safeguards, and Long Range Planning; **F. A. O'Hara** — Certification and education. Each of these Executive Committee members, and the Chairmen of the various INMM committees, have indeed carried out their assigned duties and responsibilities with dedication and distinction, and we all owe each of them a great debt of gratitude for a job extremely well done.

Turning now to a matter of paramount inportance, namely the future direction and management of the Institute in the challenging decade of the 80's, you will recall that a Long Range Planning Committee was established earlier this year to review and evaluate the Institute's present position and current operations, and to make recommendations to the Executive Committee with respect to both near-term and long-term goals of the INMM. The Long Range Planning Committee, under the Chairmanship of **Sam McDowell,** has undertaken this important task with enthusiasm and dedication and has generated a number of specific recommendations with regard to both intermediate and long-term objectives. The committee has confirmed and endorsed our urgent need for establishment of a national office with a paid executive director, business manager, or administrative official. Observing that the current INMM annual budget, $150,000, does not allow for funding a national office with a full-time director, the committee has set as its first task the indentification of possible ways to promote growth, increase the budget, and in general to expand the Institute's program, member services, operational efficiency, and its overall effectiveness as the leading professional association in the field of safeguards and nuclear materials management. A number of important recommendations (see 1980 Annual Report to the INMM membership, July 1, 1980; pp 11-13) with respect to both short-term and long-term objectives have been submitted and are currently under intensive consideration by the INMM Executive Committee with a view toward timely implementation as may be deemed appropriate and feasible.

Needless to say, ideas, critiques, and input from the INMM membership on any or all of the important issues just outlined are actively sought by all members of the INMM Executive Committee. Your input is clearly essential as together we proceed to chart our future role and unique professional contribution to safeguards and materials management, and thereby to the viability of the nuclear power option.

As officially announced at the 1980 Annual Business Meeting, our newly elected INMM Chairman is **Gary Molen** of Savannah River Laboratory, our new INMM Vice Chairman is **John Jaech** of EXXON Nuclear, and our Executive Committee members are **Carleton Bingham** of New Brunswick Laboratory and **Roy Crouch** of DOE's Albuquerque Operations Office. As most of you are well aware, all of these gentlemen have had long and distinguished experience in the safeguards and materials management field, and we extend to all of them best wishes for success in their new positions of leadership (and hard work!) in the INMM.

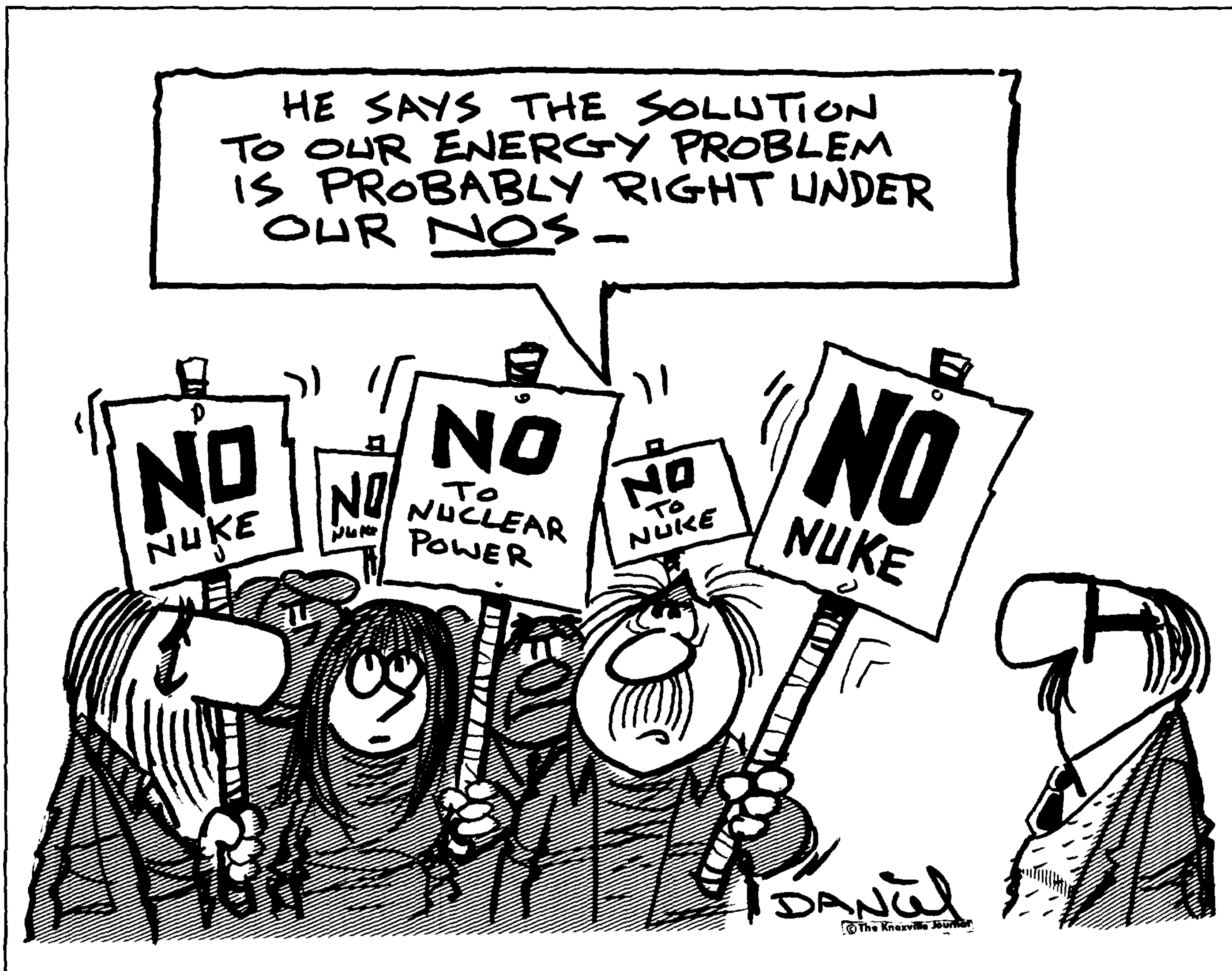
At the same time we want to thank the three outgoing *members of the INMM Executive Committee* — **Dennis**

Bishop of GE — San Jose: immediate past Chairman **Roy Cardwell** of Oak Ridge; and **Frank O'Hara** of Battlle Columbus and IAEA — for their outstanding leadership and service to the Institute in the areas of Standards, Public Information, Nominations, Constitution and Bylaws, Certification, Education, and Professionalism. The results of the dedicated efforts of each of these distinguished colleagues are readily apparent in the Institute's expanded N15 Standards program, in the updated Constitution and Bylaws, and in our newly established Professional Certification Program, which exemplifies the high standards of professionalism that the Institute stands for and seeks to foster.

In summary — 1980, the first year of the new decade, has indeed been a year of significant growth and progress for the Institute. Far from resting on our laurels, however, we must squarely face the challenge and the realities of the 1980's, and vigorously build on our present solid base of professional programs, activities, and member services toward full realization of the great potential of the Institute as the leading professional association in the vital area of safeguards and nuclear materials management.

With reference to Frank O'Hara's excellent Guest Editorial: "Rewards of Professionalism?" (INMM Journal, Vol. IX No. 1, Spring 1980), and by way of personal testimony, I can state unequivocally that my years of service in the INMM — including the past two years as Institute Chairman — have been a most challenging and rewarding professional experience, and one that I can wholeheartedly recommend to others. In the new fiscal year (beginning October 1), as immediate past Chairman and a member of the INMM Executive Committee, I look forward to continued active participation in Institute affairs and progress under the able leadership of our new Chairman, **Gary Molen,** and our new Vice Chairman, **John Jaech.** Finally, let me take this opportunity to express my sincere gratitude for the pleasure and deep satisfaction of working with all of you who have, on a voluntary "labor-of-love" basis, worked so hard and contributed so much to the success of our growing Institute.

Keepin



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Tribute to Tom

By **Mr. Roy G. Cardwell**
Executive Committee
Oak Ridge, Tennessee

Of the many phone calls I have received from my good friend **Tom Gerdis** during his several years with INMM, the one I most regret was the one I received on May 15. Tom called to tell me he was resigning to accept a new position as Director of Community Relations with Nuclear Engineering Company of Louisville.

This, of course, provoked mixed emotions . . . . happiness for Tom who certainly deserves the very best . . . . unhappiness for INMM who is losing its business and editorial centerpiece.

Tom first came to us while in graduate school at Kansas State University (Manhattan), principally to help create and develop a technical journal befitting our growing society. Kansas State University was selected because it associated him with **Dr. Curtis Chezem**, then head of the Nuclear Engineering Department, who had agreed to act as Editor while Tom was Managing Editor and Advertising Director. You might say that Curt engineered the plans and managed quality control while Tom mixed the mortar and laid the brick!

Chezem eventually left KSU and Tom assumed complete responsibility as the Journal's publisher with **Willy Higinbotham** (Brookhaven National Laboratory) as Technical and Editorial Editor along with an extensive staff of Editorial Advisors.

Tom's first journal was all of 16 pages and opened with a full page ad each from Eberline Instrument Corporation and Gulf Radiation Technology. It featured a total of two technical articles, one by yours truly and the other by two of my colleagues at ORNL. It also announced on the back cover that **Armand Soucy** was having us to Boston for our 13th Annual Meeting, which I still fondly remember as one of our greatest!

Tom's latest volume, received this month, was *112 pages* with many good technical articles and another first . . . . for the first time this one was to big to be stapled and had to be book bound. There is no question that Tom's efforts have raised our journal up to a high level reflecting both the growth and increasing significance of the Institute.

The story does not end with the *Journal*. Tom has continued to take on more and more responsibility and his activity and influence are heavily felt, particularly at and in connection with our annual and topical meetings. You do not replace key individuals like him easily, and INMM will feel the impact of his leaving for months to come.

Tom also brought with him to INMM one of the best looking families around. **Judy Gerdis** has truly been another one of the pillars of our Institute business operation while keeping a close eye on two very sweet youngsters, daughter Trina and son Joel. If all of our families were as close together as this one, ninety-percent of our social problems would disappear overnight.


Tom Gerdis

And so to you . . . . Tom, Judy, Trina, and Joel . . . . the very best, which you certainly deserve. INMM will miss all of you! (or should I say 'you all'?)

CONGRESSIONAL INFORMATION PROGRAM

The Communications Bureau has obtained a listing of nuclear-related legislation which has been introduced into the first and second sessions of the 96th Congress, which includes a brief description of the content of each piece of legislation and its status. This listing will be mailed to all INMM members in the near future.

A listing of the voting records of all members of Congress on the various nuclear issues is being prepared and will be made available to the INMM membership at the Annual Meeting in Palm Beach. This information is intended to provide background information for INMM members in their efforts to assist individual Congressmen in making informed decisions in nuclear legislative activities — *E.R. Johnson*, 11702 Bowman Green Drive, Reston, VA 22090 (703-471-7880).

INMM Has Code of Professional Responsibility

By **Dr. Fred H. Tingey**
University of Idaho
Idaho Falls, Idaho

By now all members of INMM should be familiar with the procedures and conditions governing certification under the INMM sponsored certification program. This information was included in the application form distributed to the membership in conjunction with the annual meeting. The form and associated instructions essentially reflects the by-laws of the Board. A copy of the by-laws and/or an application for future examinations can be obtained from the Board Chairman on request.

Considerable effort has been expended in formulating the certification program and bringing it to its present state. Many members of the Institute and others have been involved and thus have a personal conviction as to the program's merits. Others may view with some skepticism the need or desirability of being "certified". It is apparent that without INMM membership support and participation the program will fail regardless of how well it might be conceived and administered.

The need for "Safeguards Engineers" is pointed up by Mr. **Simon Rippon** in an article entitled "Safeguards Engineering — A New Profession" which appeared in the May 1980 issue of **Nuclear News** and is reprinted with permission in this issue of the Journal. I think it is implicit that if safeguards engineering is to be recognized as a profession it must be institutionalized in the manner of the Certificate Program or one similar to it. An analogy is provided by the American Society for Quality Control, a professional organization that has had a certification program for many years and with considerable success. The membership of that organization takes great professional pride in being "certified". Also, many engineering societies provide training and examination leading to the designation of "Professional Engineer". The membership of these organizations has made certification programs go in most instances simply in the name of professionalism without a requirement being imposed by Federal or State agencies. The recognition by peer groups and self-satisfaction in reaching a recognized competency level has been sufficient motivation for a healthy response by the membership to these programs.

Just as the membership has a responsibility to support programs of this nature, those in charge of the programs have a responsibility to insure that the programs are constructed and administered under the highest standards of professional ethics and the requirements are sufficiently challenging as to give credibility to the program. With regard to the former, all members of the Certification Board have satisfied those requirements necessary for Safeguard Specialist, including the examination. They have also, by signature, subscribed to the INMM Code of Professional Responsibility, which is required of all successful applicants for certification. This code is printed at the conclusion of this article. With regard to credibility, the Certification Board believes the requirements and subsequent examination are sufficiently stringent as to differentiate in levels of competence. Experience with the program should bear this out.

Consequently the decision in a large part on the success of this program is now in your hands. How you, the membership, respond will have a significant impact on whether Safeguards Engineering has truly reached professional status.

INMM Code of Professional Responsibility

In order to uphold and advance the honor and dignity of the profession and maintain high standards of ethical conduct, each applicant for certification as a Safeguards Intern or a Safeguards Specialist pledges that he/she will:

1. Endeavor to perform his/her professional duties in accordance with the highest moral principles.
2. Be honest and impartial and serve with devotion his/her employer, his/her clients and the public.
3. Use his/her knowledge and skill for the advancement of the profession in providing the safeguarding of nuclear materials and their use for the public welfare.
4. Promote programs designed to raise standards, improve efficiency and increase the effectiveness of Safeguards.
5. Observe strictly the precepts of truth, accuracy, prudence and professional integrity.

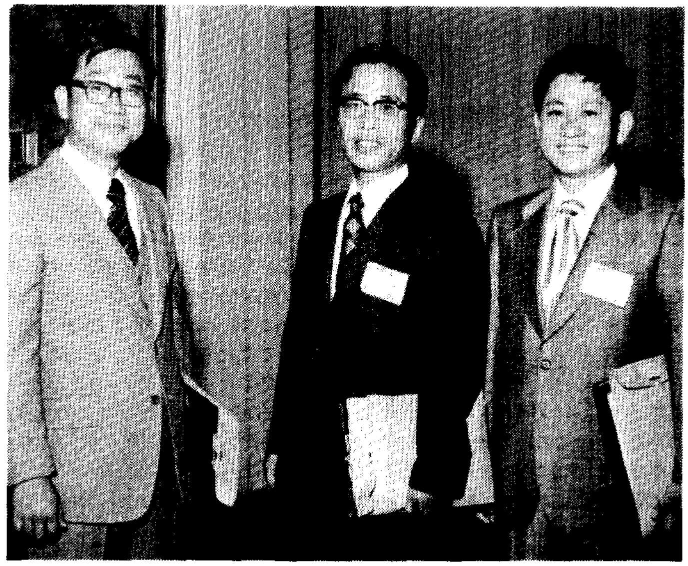
Tingey

INMM Membership Skills Resource Directory Being Compiled

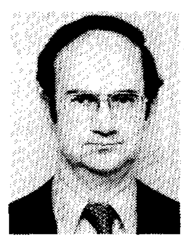
By **Dr. James A. Powers,** Chairman
INMM Safeguards Committee

The low enriched uranium regulations and the INMM membership skills resource directory, both discussed in the Spring issue of the Journal, were the priority items to receive attention by the Safeguards Committee. After meeting with NRC in January 1980, the Committee periodically checked on the status of the low enriched uranium (LEU) regulation review. After two months of inaction on NRC's part, the Committee sent a letter to Commissioners Bradford and Gilinsky, transmitting a copy of the INMM Special Report "Assessment of Domestic Safeguards for Low Enriched Uranium" and requesting their assistance in effecting a response to the report. Subsequently, I met with Commissioners' staff to discuss the report and the Institute's concern over the imbalance of NRC regulations in comparison with the threat and risk posed by LEU. As a result of this meeting, in which I also brought up the possibility of a petition for rule making, there have been discussions between the Commissioners' offices and the Division of Safeguards with a priority placed on the staff taking action on the matter. The situation is far from resolved, however, and continued interaction with the Commission will be required in the future to keep the project on track.

The ad hoc Public Information/Response Committee, consisting of **Dennis Bishop, Herman Miller, Joseph Stiegler** and me, as chairman, completed a questionnaire to be sent to INMM members. The questionnaire will be used to prepare a membership skills resource directory for use in areas ranging from obtaining consultative assistance to obtaining assistance in dire emergency situations. The questionnaire will be sent out later this summer.



Also attending the 1978 ANNUAL MEETING are (left to right) Mr. Keisuke Kaieda who worked at that time at Los Alamos Scientific Laboratory, then returned to work for the Japan Atomic Energy Research Institute and now works at IAEA. Mr. Hiroshi Okashita and Mr. Kouji Ikawa both work for the JAERI and are experts on safeguards.



Powers

Education Committee Plans for Fall and Winter Programs

By **Harley L. Toy,** Chairman
INMM Education Committee
Columbus, Ohio

The INMM's Educational Program took another giant step this past May when it staged the first Accounting and Auditing Techniques (AAT) course. Eighteen attendees representing DOE, contractors, and licensees took advantage of our first AAT course which was presented at Battelle's Columbus Laboratories on May 19-22. A tremendous thanks is due to Shelly Kops, CPA-Consultant, our lead instructor for the course. Providing excellent assistance to Shelly were co-instructors Cal Solem of NRC and Paul Korstad of Battelle's Northwest Laboratories. Attendee feed-back on the course was most favorable and supportive. According to Shelly, our first AAT course provided a learning curve for adjusting and modifying the curriculum for future courses.

Looking at this fall and winter, our plans were firm for presenting John Jaech's two statistics courses here in Columbus. The Introductory Course was held September 10-12 while the 5-day Selected Topics Course was given the week of September 15.

We are still in the planning stage with the presentation of John's courses to be given at NRC headquarters. The course will probably be given at NRC in early '81.

Further plans are under way, as noted in this issue, to present the Accounting and Auditing Techniques (AAT) course in the Richland, Washington area on November 18-21, 1980. The course will be coordinated by the Pacific Northwest Chapter under the direction of Bob Sorenson. Course instructors will be Shelly Kops, Cal Solem, and Paul Korstad. Your Education Committee will continue to pursue this regional concept in presenting short courses and workshops. Along this line, discussions have been held with Roy Caldwell regarding the presentation of the AAT course in the Oak Ridge area.

Your Education Committee continues to provide nuclear educational material to student requests. As reported earlier, the AIF has been most supportive in this area by furnishing up-to-date nuclear educational materials.

The Education Committee welcomes and encourages your comments and suggestions. We need your input.

Our continuing program to provide upcoming meetings, conferences, and workshops is presented below. As stated in the last issue of the Journal, this will be a continuing program. We have been most successful in obtaining such meeting and workshop information from allied professional societies.

Upcoming Programs of Interest

- ANS WINTER MEETING
  November 16-21, 1980
  Washington, DC
  Sheraton-Washington Hotel
  Technical Chairman: M. J. OHANIAN
  202 Nuclear Science Center
  University of Florida
  Gainesville, FL 32611
- ANS ANNUAL MEETING
  June 7-12, 1981
  Miami Beach, FL
- ANS WINTER MEETING
  November 29 — December 4, 1981
  San Francisco, CA
- ANS ANNUAL MEETING
  June 6-11, 1982
  Los Angeles, CA
- ANS WINTER MEETING
  November 14-19, 1982
  Washington, DC
- ANS ANNUAL MEETING
  June 12-17, 1983
  Detroit, MI
- ANS WINTER MEETING
  October 30 — November 4, 1983
  San Francisco, CA
- ANS ANNUAL MEETING
  June 10-15, 1984
  New Orleans, LA
- ANS WINTER MEETING
  November 11-16, 1984
  Washington, DC

U.S. Department of Energy
Safeguards Technology Training Program

- GAMMA-RAY SPECTROSCOPY FOR NUCLEAR MATERIALS ACCOUNTABILITY
  December 8-12, 1980
  Los Alamos, NM
  Contact: KAREN HUMPHREY
  USDOE Safeguards Technology Training Program, MS 550
  Los Alamos Scientific Laboratory
  P.O. Box 1663
  Los Alamos, NM 87545
  (505) 667-6394 or FTS 843-6394

Attendee identification on AAT course photo. Standing: Cal Solem, Claudiz Baxter, Dawn Snelson, Laura Giles, Paul Korstad, Ralph Hall, Wayne Harbarger, Sheldon Kops, David Lewis, William Rarick, Charles Montano, Harry Linton, Robert Shutt, Dale Stitt, Ken Long, Lavella Adkins, Martin Hershkowitz. Seated: Barbara Hughes, Alan Bieber, Harvery Cohen, Don Knapp, Dennis Helton, Harley Toy.

- NOTE:

  This coming year will be a transition period during which we will endeavor to revise the course offerings in the LASL/DOE Safeguards Technology Program. The In-Plant NDA Instrumentation course, usually held in December, will be phased out of the program. Part of the material covered in this course will be included in the gamma-ray spectroscopy course. The remaining portion will be incorporated into a new course that will deal with advanced instrumentation based on neutron detection methods and will be offered yearly, beginning in 1981.

  For further technical information on course content on the above listings, call Hastings Smith or Norbert Ensslin, (505) 667-6141 or FTS 843-6141.

International Atomic Energy Agency

- SEMINAR ON SELECTION AND IMPLEMENTATION OF SAFETY STANDARDS FOR NUCLEAR POWER PLANTS (IAEA/ISO)
  December 15-19, 1980
  Vienna, Austria
  Contact: International Atomic Energy Agency
  Wagramerstrasse 5
  P.O. Box 100, A-1400
  Vienna, Austria
- REGIONAL SEMINAR ON FUNCTIONS AND ORGANIZATION OF SECONDARY STANDARDS DOSIMETRY LABORATORIES WITHIN THE IAEA/WHO NETWORK OF SSDLs FOR DEVELOPING COUNTRIES IN AFRICA
  Location and dates to be announced later
  Contact: International Atomic Energy Agency
  Wagramerstrasse 5
  P.O. Box 100, A-1400
  Vienna, Austria

International Energy Associates Limited

- TECHNICAL WORKSHOP ON PHYSICAL PROTECTION
  December, 1980
  Place to be announced
  Contact: J. MARK ELLIOTT
  International Energy Associates Limited
  600 New Hampshire Avenue, NW
  Washington, DC 20037
  (202) 338-8230
  Telex 89-2680
  Cable IEAL WASHDC

Atomic Industrial Forum
1981 Conference Schedule

Date	Conference	Location
2/22-25	INFO '81	Adams Hotel Phoenix, AZ
3/15-18	Fuel Cycle Conference '81	Century Plaza Los Angeles, CA
4/12-15	Workshop on Reactor Licensing and Safety	Royal Sonesta New Orleans, LA
5/3-6	Finance Conference	New York Hilton New York, NY

Contact: Conference Office
Atomic Industrial Forum, Inc.
7101 Wisconsin Avenue
Washington, DC 20014
TWX 7108249602 Atomic for DC

Nuclear Safeguards Course Underway

Los Alamos, N.M. — An international training course on nuclear materials accountability and control for safeguards purposes began May 27 at Santa Fe's Bishop's Lodge.

The two-week course, sponsored by the Department of Energy and the United Nations' International Atomic Energy Agency (IAEA), was conducted by the Los Alamos Scientific Laboratory (LASL).

Nearly 30 representatives of 24 IAEA-member nations participated in the course designed to provide nuclear-capable nations with methods for developing safeguards regulations and requirements commensurate with their needs. Participants discussed methods for implementation of a domestic safeguards system compatible with the IAEA International Safeguards System of Inspection and Verification.

"This course emphasized safeguards requirements, necessary resources, and implementation as applied to power reactor/spent fuel storage and research reactor facilities in anticipation of the interests of the prospective attendees," **George Weisz,** Director of the DOE's Office of Safeguards and Security, said, "We regard our program of international training as a major vehicle for strengthening international collaboration in safeguards."

Adolph von Baeckmann, director of the Division of Development in the IAEA's Department of Safeguards, told course participants that the IAEA promotes the peaceful uses of atomic energy while at the same time providing assurances that elements of the nuclear industry are not subverted for non-peaceful purposes. He said the IAEA-sponsored courses are designed to standardize accountability and control allowing access by IAEA inspectors.

LASL Director **Donald M. Kerr** welcomed participants to New Mexico by saying LASL is making significant contributions to all three of the major problems facing the nuclear industry: assured nuclear safety, acceptable waste disposal, and effective safeguards. He said LASL has designed instrumentation for nondestructive assay of nuclear materials, allowing timely measurements of nuclear materials at all stages of the fuel cycle.

Kerr said that the Los Alamos Scientific Laboratory has the principal responsibility of transferring this technology to industry, to our own national safeguards system, and under approriate bilateral agreements for cooperation, to other countries.

"In this role the Laboratory has for many years conducted an extensive program of training courses, technical consultation and technical support programs in conjunction with the IAEA," Kerr said.

G. Robert Keepin, LASL's Program Manager for Safeguards Affairs and the course organizer, detailed the course's structure and content.

He told participants they would be exposed, under international agreement, to all elements of nuclear safeguards ranging from historical background to legal requirements and advanced state-of-the-art technological developments.

Nations represented at the course include Yugoslavia, Israel, Kenya, Egypt, Romania, India, Malaysia, Indonesia, Paraguay, Brazil, Canada, Portugal, Japan, Hungary, Pakistan, Chile, Korea, Philippines, Taiwan, Italy, Turkey, The Federal Republic of Germany, United States, and the EURATOM organization of the Commission of the European Communities, as well as the co-sponsoring organization, the IAEA. United States industry and government facility safeguards experts are also represented at the course.

INMM SHORT COURSE IN ACCOUNTING AND AUDITING FOR NUCLEAR MATERIALS

SAFEGUARDS INMM RELIABILITY ASSURANCE

Sponsored By

Pacific Northwest Chapter of the
Institute of Nuclear Materials Management

Battelle, Pacific Northwest Laboratories
Richland, Washington 99352
November 18-21, 1980

For more information please contact:

Paul A. Korstad — (509) 375-2427 or **Robert J. Sorenson** — (509) 376-4437 — FTS 444-4437

Battelle, Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington 99352

Two New Subcommittees Formed

By **D. M. Bishop,** Chairman
N15 Standards Committee
General Electric Company
San Jose, California

In order to keep pace with the multi-faceted expansion of safeguards technology during the 1980's, the N15 Standards Committee has been carefully scrutinizing its overall scope, goals and organization. The membership of the Institute has been kept informed of key aspects of this assessment in N15 reports over the past year. The objective has been to better focus limited Institute resources on key technical issues where the most benefit can be achieved.

As a result of this assessment, the N15 organization was substantially changed during 1979. Key results are summarized as follows:

- New subcommittees were created:
  - — INMM-5 Measurement Controls
  - — INMM-12 Site Response Planning
- New Advisory Groups were formed:
  - — INMM-13 Transportation
  - — INMM-14 International Safeguards
- Existing subcommittees were restructured:
  - — INMM-1 Accountability Systems
  - — INMM-7 Audit, Records & Reporting Techniques
  - — INMM-11 Training & Certification

Building on this progress, two new N15 Standards Committee activities have recently been authorized. They include:

Subcommittee	Title	Chairman
INMM-2	Material Classification	M.M. (Whitey) Thorpe (LASL)
INMM-14	International Safeguards	Robert Sorenson (BMI-PNL)

Both activities have been defined to satisfy vital roles in the current safeguards program. Both will also help assure the technical excellence and timeliness of INMM contributions in the years to come. Including these new areas, the current N15 organization is shown in Figure 1.

INMM-2

The basic charter for the N15 INMM-2 (Material Classification) Subcommittee is to develop standards related to the identification, characterization and classification of materials subject to nuclear materials control. Initial emphasis will be placed in the areas of plutonium and uranium scrap. However, INMM-2 also plans on looking at worldwide systems for classifying

FIGURE 1. INMM — N15 STANDARDS COMMITTEE ORGANIZATION

SUBCOMMITTEE	TITLE	CHAIRMAN	AFFILIATION	PHONE
—	N15 Chairman	Dennis Bishop	General Electric Co.	(408) 925-6614
—	N15 Secretary	Robert Kramer	Northern Indiana Public Service Company	(219) 787-8531
—	N15-NSMB Representative	Lou Doher	Rockwell International	(303) 497-2575
—	ANSI Staff Representative	Mary Crehan-Vaca	ANSI	(212) 354-3360
INMM-1	Accountability	Howard Menke	Westinghouse	(412) 373-4511
INMM-2	Material Classification	Whitey Thorpe	LASL	(505) 667-5886
INMM-3	Statistics	Frank Wimpey	Science Applications	(703) 821-4429
INMM-5	Measurement Controls	Yvonne Ferris	Rockwell International	(303) 497-4441
INMM-6	Inventory Techniques	Frank Roberts	Battelle — PNL	(509) 375-2606
INMM-7	Audit, Records and Reporting Techniques	Marv Schnaible	Exxon	(509) 375-8153
INMM-8	Calibration	Syl Suda	Brookhaven National Laboratory	(516) 345-2925
INMM-9	Nondestructive Assay	Darryl Smith	LASL	(505) 667-6514
INMM-10	Physical Security	John Darby	Sandia Labs	(505) 844-8977
INMM-11	Training and Certification	Fred Tingey	University of Idaho	(208) 526-9637
INMM-12	Site Response Planning	Ed Young	Rockwell International	(303) 497-2518
INMM-13	Transportation (Proposed)*	Bob Wilde	Sandia Labs	(505) 264-7323
INMM-14	International Safeguards	Bob Sorenson	Battelle — PNL	(509) 376-4437

**Currently under review by an N15 Advisory Group to evaluate scope and feasibility.*

nuclear materials, with the goal of establishing a consistent international system of nomenclature and classification.

Based on this scope, the first order of business for INMM-2 will be to review and update two prior N15 standards:

1. N15.1-1970 — Classification of Unirradiated Uranium Scrap
2. N15.10-1972 — Classification of Unirradiated Plutonium Scrap

Writing groups are currently being finalized in each area. The first informal subcommittee meeting was held in conjunction with the recent annual meeting of the Institute in Palm Beach, Florida. Individuals interested in participating in this activity or staying informed of its progress should contact **Whitey Thorpe** (LASL).

INMM-14

During the past year, the N15 Standards Committee has also been looking into the need for standards related to international safeguards. An Advisory Group under **Bob Sorensen** (BMI-PNL) reported on their finding in April, 1980. They determined that standards work in this area is indeed needed and that the INMM can make a valuable contribution.

Based on this recommendation, the N15 INMM-14 Subcommittee on International Safeguards was formalized. The basic charter of INMM-14 is to develop standards related to the implementation of forthcoming IAEA safeguards requirements. Emphasis will be placed on technical areas which are unique to international requirements. Past N15 standards (related primarily to domestic safeguards) will be used where possible. However, where needed, standards will be developed to satisfy unique international applications or requirements.

One of the primary needs expressed by the INMM-14 advisory group was for standardization activities at the interfaces between national facility operators and international inspectorate This emphasis is needed to coordinate the inspection function with plant operators, and to provide uniform guidelines for the inspectors.

Based on this need, the overall focus of INMM-14 will be to provide interface models for an intermediate system, i.e., the interface between the operator and the inspector. This will include:

- Implementing the formalization and standardization of common international guidelines.
- Identifying where standards are needed and providing a method of developing these standards.
- Assisting in providing leadership and guidance to further the goals of non-proliferation.

Specific standards will be limited to practical guidance rather than philosophical activities (i.e., discussions on the role and structure of the SSAC).

Two subjects have tentatively been selected by INMM-14 for initial standards writing activities:

(1) Design Information Review
(2) Inventory Taking

A list of other possible standards that INMM-14 is evaluating follows:

- Measurement Control
- Measurement Systems
- Shipper/Receiver Differences
- MUF Evaluation
- LEMUF Evaluation
- Records Examination
- Internal Control Verifications:
  - ✓ Checking Seals
  - ✓ Location and Installation of Containment/Surveillance Devices
- Physical Inventory Taking
- Physical Inventory Preparation
- Flow Verification (Import/Export)
- Inspector Sampling
- Transfers:
  - ✓ Within State
  - ✓ External to State
- MBA/KMP Structure for a Facility Attachment
- How to Prepare a DIQ and FA
- Verification of Design Information
- Conceptual Criteria for Termination, Exemptions, Starting Point, etc.
- International Sample Exchange Standard (Guide for Designing a sample exchange program/model after SALE program)
- Reference Material Standard (Guide for preparing working reference materials)
- Physical Protection (Containment and Surveillance Standards:
  - ✓ Use of Seals During Shipment (what to do if broken)
  - ✓ Physical Protection of Shipment
  - ✓ Sampling a Shipment
- Criteria for Establishing a National Accountability System
- Nomenclature

The INMM-14 Advisory Group had a hard task defining standardization needs in the area of international safeguards. Bob Sorensen and his group are to be commended for their valuable contribution. Other individuals participating in various phases of this important scoping activity included:

Leon Green	**Stan Turel**
Neil Harms	**Ivan Waddoups**
Roy Nilson	**Hal Werner**
Ken Sanders	**C. Pietri**
Cal Solem	**Doug Reilly**
Glen Hammond	**Ted Sherr**
Art Waligura	**D. Swindle**
Marc Cuypers	

A more detailed discussion of INMM objectives in the area of international safeguards standardization was presented at the ESARDA Symposium by Dennis M. Bishop and will be published in the Proceedings of the Edinburgh meeting.

Bishop
N15 Chairman

Thorpe
Chairman INMM-2

Sorenson
Chairman INMM-14

Public Information Committee Report

We are devoting our space in this issue to the following article which illustrates best how INMM members can contribute to the effective communication we are fostering.

Herman Miller, Chairman
Public Information Committee
Mountain View, California

"Is Nuclear Power the 'Only Choice' for the Future?"

Between us, **Judith Viorst,** Redbook, February 1980

One of the very serious questions of the day is the continuously declining availability and increasing cost of energy. The times call for the very best in analyzing and discussing our restricted energy options and the effects they have on the American public. Therefore, the public needs the most responsible and the highest quality of journalism possible from the media. In our opinion the article by Mrs. Viorst doesn't measure up.

It is difficult for us to understand how Redbook, and what we perceive as a responsible person such as the author, could publish this article. It is a smorgasbord of facts woven into a story which supports the author's preconceived notions and emotions about nuclear power. There are also a number of points which are not true, and there are some omissions which we think will result in your integrity being questioned by your readers. The article develops little, if any, real or new perspective on the subject of nuclear power or the energy crisis. It simply perpetuates and appeals to fear, largely what seems to be the fear of technology. These fears are understandable if they are based on the misinformation the article repeats. Because of this we feel compelled to respond with this letter.

Research Effort

First, we question the quality of the research that went into the article. The author stated, "I decided that I would try to become informed." Then she says she found the answers to her questions "... in pamphlets, newspapers, magazines and interviews." We would not be able to write an accurate and factual article from those sources either. What has become so disturbing to us is that one incorrect media story breeds other incorrect media stories.

Throughout the article the references and quotes are vague and limited. None of the sources are listed. For example, we know of no knowledgable, responsible engineer who would say that they almost lost Detroit. The truth of this statement has been refuted.[1] The other accidents the author notes were all related to the defense nuclear program, but the author would have us believe that these are from or are typical of the commercial power industry. We believe that a responsible journalist would keep a clear distinction between defense nuclear programs and the commerical sector. By analogy one could easily prove that commercial aviation is unacceptably risky by citing the incidence of F-111 crashes. To put the accidents in perspective, the author could ask what other industry has a safety record comparable to the commercial nuclear industry. This ommission leaves us to question the actual intent of the writer. Incidentally, there have been accidents in the defense nuclear program other than those quoted in the article that more accurately demonstrate the lethal effects of high-level radiation exposure.

The writer quotes an out-of-date Atomic Energy Commission study (apparently WASH-740, 1967)[2] that is a partial consequence analysis of reactors. The part of the analysis that the author neglected to include was the probability of the event, which is sufficiently remote to eliminate the event from further consideration. This study has been superseded by others (e.g., WASH-1400, 1975)[3] which have been critiqued by the technical community of this nation, including some of those most critical of the nuclear option, and found to be a highly credible study[4] on the risk of nuclear reactors.

The risk of death to an individual in this country from the nuclear option is far more remote than being struck by lightning. Yet some people are killed by lightning, and someday some person (probably not a member of the public but a nuclear powerplant worker) will be killed at a nuclear facility. And someday there will be a partial fuel meltdown at a reactor; in fact, about once every 17 years (assuming 100 reactors are in service) is forecasted by the WASH-1400 study.[5] However, this is a partial meltdown and the public is not expected to be exposed. The Kemeny Commission, for example, concluded that even had the core at the Three Mile Island reactor melted, the public exposure would have been slight. The cost of replacement power can be a real impact, however, in such an accident. This is an issue that needs careful consideration.

Radiation

Woven throughout the article are words and expressions that engender a fear of radiation. None of the benefits of radiation are ever mentioned to put the subject in some reasonable perspective. The author's use of the expression "... life-destroying radioactive materials" leads the reader to overlook the life-saving virtues of radiation as constantly used in both medical treatment and diagnostics.

The fact that we have always lived in an environment of low-level radiation is never mentioned. Because of Denver's elevation and geology, every citizen receives more radiation in a year than the hypothetical person standing continuously at the fence of Three Mile Island during the March 1979 incident. Such data is apparently not presented because it does not contribute to the intended hysteria over radiation.

Radioactive Waste

The disposal of radioactive wastes is the most difficult issue to discuss. That's because most of us in the industry believe that from a technical point of view it has been solved for a long time. Most of what we see are the social and political issues around the question of waste — the location, medium, management, etc. The recent temporary closing of the U.S. low-level depositories highlighted the fact that nuclear waste from the medical community became the first pinch point. The public has just forgotten that the medical profession, in saving and extending life, is creating some of the waste.

We are again disturbed about the actual motives of the author when she says, "Thousands and thousands of tons of this waste must be safely stored for milleniums" and "... virtually every storage facility that our government has started has already suffered from radioactive leaks!" It has been demonstrated that high-level radioactive wastes can be managed, i.e., isolated from the biosphere. Further, the currently estimated times for isolation of high-level wastes are closer to 1,000 years. From then on they are of less risk than the ore bodies from which they originated.

As the effectiveness of the mechanical stabilization achieved with these wastes is realized, perhaps someday they will be utilized as energy sources and not buried. They can now be converted to a glass that is less soluble than Pyrex cookware; they are then double encapsulated in metal cans. There would only be enough of this high-level waste by the year 2000, if all electrical energy came from nuclear plants in this country, to fill a repository whose surface area would be about 3.5 square miles and the underground area no larger. Certainly, with quantities of material no more voluminous than this, the country has the capability to manage the waste with an effort that is small when compared to other industrial activities now routinely undertaken.

Proliferation

The reference to India's source of plutonium for exploding an atomic bomb is in error. Also, the statement "Peaceful reactors already have helped to build bombs" is incorrect. India's weapons material did not come from their power reactors. They have four light water power reactors and four power reactors under construction. India used heavy water provided by Canada in a "test" reactor to produce weapons material. The commercial nuclear power program in India did not produce weapons material. Further, we are not aware of any commercial nuclear power reactor program that was used to develop nuclear weapon capability. There are a number of good reasons for this, including economics. This country has reportedly demonstrated (exploded) a device assembled from reactor grade material, i.e., plutonium from a power reactor, instead of weapons grade material from a weapons reactor. However, it is much cheaper, quicker and more efficient (better weapons) not to involve commercial power reactors. Attempting to develop a weapons capability from a power reactor program is a costly and tedious process that has never been done to our knowledge except for the experiment by the United States mentioned above, long after we had nuclear weapons.

The article presents only one side of the proliferation concern. Nuclear technology is the proliferation issue, and considerable nuclear technology is indeed acquired by adopting energy production with nuclear reactors. But the genie is out of the bottle, and wishful thinking will not cast this capability out of the storehouse of human knowledge. Further, the article does not discuss the Nonproliferation Treaty and the International Atomic Energy Agency, and the prospects, hopes and definite limitations of these international programs in addressing proliferation. These are the *real* issues.

Conservation and Solar

What the writer implies about conservation and solar energy is greatly oversimplified. All of us support both the continued emphasis on conservation and the vigorous development of solar energy. From our point of view you don't have to argue the case, just present it fairly. Even though we support the development of solar energy, we clearly recognize that it has environmental consequences.[6] But then, we also recognize that the American public must come to terms with the fact that there is no free lunch.

The author does not identify the impacts, including costs and some disbenefits, of the various energy-saving and energy-producing alternatives. Many do have value, but her analyses are far too trivial (by omitting any concerns for the accompanying impacts) to assist in decision making. Her analysis of alternatives is simply a "wish" list.

Nuclear Option

No one who supports nuclear energy ever claimed that "nuclear power, ... is our painful but only real answer to the energy crisis." However, most of us believe that the inverse of the writer's statement is catastrophe. By closing the door on the nuclear option we are creating an energy crisis that will whiplash into every aspect of our lives — health, jobs, standard of living, economic and political stability — by adding to our shortfalls in energy sources.

We believe that we need all of our options, including nuclear energy. We can't afford to close the door on any of our alternatives. We need to be aggressive on all fronts.

Conclusions

We can understand the author's honest, gut reactions and concerns with nuclear power. We are, however, surprised and dismayed that the author and the editors of Redbook would include this article as a serious journalistic effort in these days when rational discussions with perspective are so important to the American people. There are so many ways to get information, and to have articles reviewed prior to publication, that what you have done, in our opinion, is not a service to your readers.

References

1. E. M. Page, *We Did Not Almost Lose Detroit.* Detroit Edison Company, May 1976.
2. *Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants,* WASH-740, U.S. Atomic Energy Commission, March 1957.
3. *Reactor Safety Study*, WASH-1400 (NUREG-75/014). U.S. Nuclear Regulatory Commission, October 1975.
4. Testimony of H. W. Lewis Before the Subcommittee on Energy and the Environment of the House Committee on Interior and Insular Affairs, February 26, 1979, *Congressional Record,* February 26, 1979.
5. *Reactor Safety Study,* WASH-1400.
6. Herbert Inhaber, *Risk of Energy Production,* AECB-1119, Rev. 2. Atomic Energy Control Board, P.O. Box 1046, Ottawa, Canada, KP 5S9. November 1978.

Miller

"IS NUCLEAR POWER THE 'ONLY CHOICE' FOR THE FUTURE?"

Reference: Our letter to you dated March 21, 1980

After sending you our letter last week, we noticed two points that need clarification. First, in the middle of the second page we imply something about deaths at commercial nuclear power plants which is not quite true. There have been industrial accidents resulting in deaths at operating nuclear plants. They were caused by such things as high pressure steam and falls. We are aware of more than two such accidents. However, most people limit these types of comparisons to accidents involving some radioactive aspect of the operating plant. That is what we were doing. That may not be a completely fair comparison.

Secondly, we noticed that our professional society stationery has no return address. That was an oversight on our part. We were not attempting to remain anonymous. Our addresses are:

Robert J. Sorenson
361 Breakwater Court
Richland, WA 99352

Robert G. Clark
1618 W. Clearwater
Kennewick, WA 99336

Saluting Jim Lee

By **John E. Barry**
Gulf States Utilities Company
Beaumont, Texas

On the eve of my becoming Chairman of this committee, it's reassuring to me to know that **Jim Lee**, retiring chairman, will continue to serve with us. A member of the INMM for over 13 years, he has directed membership activities for over six years. During his tenure the INMM has grown to nearly 700 members and assumed its international professional leadership role in nuclear materials management. He deserves our sincere thanks for all his efforts on behalf of this organization, most recently exemplified by his arrangement for this year's annual meeting in Palm Beach. With his continued participation on this committee and with the help of the other committee members **Vincent DeVito, Ed Owings, James Patterson** and **Tom Gerdis**, I pledge to work to continue his standard for excellence and accomplishment in future membership activities.

Help Us Promote Membership and Participation

My new administrative duties on the membership committee have made me more fully appreciate both the effort entailed in carrying them out and, more importantly, the communications they are triggered by or the responses they elicite. Strong interest in INMM membership and activities is evident from the applications being received from almost every area of the nuclear industry. A stronger response and involvement, however, continues to be sought.

For example, a new series of invitation letters has been drafted and reviewed and will be sent soon to specific groups within the electric utility industry such as those concerned with nuclear materials transportation and waste management. In these letters we point out the relevant issues addressed and standards work undertaken by the INMM.

As a follow up in the coming months we will seek to more energetically contact all potential new members especially whose names are furnished by present members and through application references. Therefore, if you have professional acquaintances or fellow workers who you feel would benefit from and be beneficial to the INMM, send us their names. We will invite them to join.

INET Corporation Formed

Herman Miller, Chairman of the INMM Public Information Committee, advises that he is now devoting increased effort to his new company, INET Corporation. INET was formed to provide business and technical services in energy related fields. INET activities are now directed to providing these services in nuclear operations, safety and safeguards. INET services will be provided to private and governmental groups in the U.S. and overseas.

Miller said, "Solving the world energy problem is one of the keys to our future well-being. Nuclear power is one very important part of the energy solution, and adequate safeguards are vital to public acceptance and use of nuclear power. INET will help in defining safeguards objectives and in solving the technical and administrative problems of safeguards application."

Miller has been an active participant in the development and use of non-destructive assay (NDA) equipment for over 10 years. During that time, he was a founder and President of National Nuclear Corporation (NNC). He has been an active member of the INMM. For several years he served as Chairman, Exhibits and currently he is Chairman, Public Information Committee. He is serving on the INMM Standards Committee and is a frequent contributor of papers for NDA and safeguards meetings. In carrying out his marketing responsibilities, he has visited laboratories and factories in the U.S. and overseas on a regular basis. He has assisted many laboratories and manufacturers in their NDA safeguards programs.

As part of an ongoing program, INET will continue to provide marketing services for NNC for overseas customers and for U.S. fuel fabricators. The new offices of INET are located in Sunnyvale, California.

Barry

Lee

Letter From Vienna

Our chapter continues to be a vigorous offshoot of the parent organization, albeit that our activities have more of a social than a scientific slant. We have been fortunate in discovering a pleasant room in a neighbouring restaurant in which to hold our luncheon meetings and have continued our policy of persuading distinguished and interesting personalities who are visiting Vienna to speak to us on these occasions. In February, **Mr. Hirata** gave us an interesting talk on the activities of the Japan Chapter and in March we were both instructed and entertained by **John Jaech** who addressed the topic "On Safeguarding Statisticans — the Non-proliferation Issue".

In April, a very successful "Heurigen" evening was held, which was attended by about 40 members, spouses and friends. We were honoured by the presence of Institute Chairman **Bob Keepin**; who spoke to us in his usual rousing style about the activities and achievements of the Institute. His talk was followed by an extempore address by **George Weisz,** Director of the DOE Office of Safeguards and Security, who provided a thought-provoking commentary on some aspects of international safeguards. Our special thanks are due to our Chapter Chairman, **Carlos Buechler**, who persuaded the "Herr Wirt" ("Mine host" in English) to open his establishment at Perchtoldsdorf (south of Vienna) especially for our meeting, and to Carlos' wife Lucy, who made the tables look so attractive with floral decorations and candles.

In May, at another luncheon meeting, we were delighted by the reminiscences of a man who was in at the very beginnings of nuclear energy — *Carl Bennett.* June brings the election of our new officers and committee, who I am sure will carry on the active policies which we have come to expect in our thriving young Chapter. We will take a break in our monthly meetings during the holiday months of July and August but hopefully these will resume in September when we will attempt to persuade further visiting celebrities to be our luncheon guest speakers. — *Donald R. Terrey.*

Bob Keepin leads informal discussion of INMM's expanding programs in the International area and its interactions with the International Atomic Energy Agency. L to R: Don Terry, Vice Chairman; Bob Keepin; Carlos Buechler, Chapter Chairman; Mrs. Buechler; and Mrs. Bernardino Pontes of IAEA.

George Weisz, Director of DOE Office of Safeguards and Security, addresses the well-attended meeting of the INMM Vienna Chapter in a heurige (traditional Austrian Inn) in the southern suburbs of Vienna on Wednesday evening, April 2.

Carlos Buechler, Chairman of the Vienna Chapter of INMM, introduces INMM Chairman Bob Keepin, who addressed the Vienna Chapter at a dinner meeting on Wednesday evening, April 2.

Among the nearly 50 attendees at the Vienna Chapter meeting on April 2 was Frank O'Hara, INMM Executive Committee member, and newly-appointed member of the IAEA Safeguards staff.

Report on Second Annual ESARDA Safeguards Symposium*

By **D. M. Bishop**
INMM Executive Committee
General Electric Company
San Jose, California
and
By **Dipak Gupta**
KFK, Karlsrue and Esarda

Note: Special thanks to Lou Doher (Rockwell International) who contributed the pictures accompanying this report.

ESARDA Report

1.0 INTRODUCTION

The objective of this report is to provide a brief review of the recent Second Annual ESARDA Symposium on Safeguards and Nuclear Materials Management held in Edinburgh, Scotland on March 26-28, 1980. This highly successful meeting was sponsored by the European Safeguards Research and Development Association (ESARDA). Chairman of the Symposium was Dr. **Dipak Gupta** (KFK, Karlsruhe) a long time INMM member. Other members of the Scientific secretariat which organized the meeting included **A.S. Adamson** (NMACT, AERE Harwell), **U. Ehrfeld** (KFK, Karlsruhe) and **L. Stanchi** (JRC, ISPRA).

The meeting was extremely well attended including over 266 safeguards professionals. Participants included representatives from national and international regulatory agencies, research and development laboratories and commercial processing facilities.

For those who may not be aware of ESARDA's overall scope and goals, a brief summary may be useful. ESARDA is an association of European organizations formed to advance and coordinate research and development activities in the safeguards area. It also provides a forum for the exchange of information and ideas between nuclear facility operators and safeguards authorities. Partners in the ESARDA organization currently include:

The European Atomic Energy Community

The Kernforschungszentrum Karlsruhe (KFK)-Federal Republic of Germany

The Centre d-Etude de l'Energie Nucleaire (CEN/SCK) Belgium

The Comitato Nazionale per l'Energia Nucleare (CNEN) I Italy

The Stitching Energie Onderzoek Centrum Nederland (ECN) — Netherlands

The United Kingdom Atomic Energy Authority (UKAEA) — Great Britain

Energistyreisen — Denmark

The specific objective of this second annual ESARDA symposium was to stimulate the exchange of information and ideas about safeguards implementation problems and safeguards concepts for different types of nuclear facilities. Areas of particular interest included nuclear plant operations, safeguards authorities and research organizations.

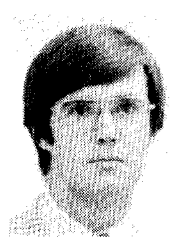
2.0 OVERVIEW

The principal subject of the meeting was experience in implementing IAEA safeguards requirements. This experience is directly applicable to US facilities about to come under IAEA safeguards. Additional emphasis was placed on explaining the results and impacts of the INFCE studies. Individuals from 16 countries and 2 safeguards organizations (IAEA and EURATOM) took part in the ESARDA symposium. One hundred (100) papers were presented from the following organizations:

IAEA and EURATOM	14
Operators and designers of facilities	12
National organizations (Nuclear Control Boards, Ministries, etc.)	15
Research Centers and Laboratories	59
	100

The papers and discussions covered seven major technical areas:

Areas	No. of Papers
1. Plenary Addresses	6
2. Plant Specific Experience	6
3. Accountancy, Material Control and Information	10
4. Data Evaulation and Methodology	16
5. Measurement Techniques, Standards (NDA and DA) Including Plant Specific Measurement Techniques	39
6. Containment & Surveillance Systems	14
7. Safeguards Concepts	9
	100



Bishop

Gupta

There was notable INMM member participation in the ESARDA sponsored symposium. Over two dozen INMM members participated in various phases of the technical program.

3.0 TECHNICAL SESSIONS

Highlights of the plenary, technical and panel sessions are summarized in the following discussion.

3.1 Plenary Papers

Papers presented at the invited sessions of the symposium provided the general background for the activities in the framework of international safeguards. Papers were presented by S. Ecklund (Director General, IAEA, Vienna), I.T. Manley (Head of Atomic Energy Division, Department of Energy, London), L. Williams (CEC) and G. Weisz (US DOE). Some of the more important points are summarized below:

a) INFCE investigations have indicated that a solution to problems associated with the proliferation of nuclear weapons is more influenced by political than technical factors. For a given framework of political conditions, international safeguards and institutional measures for the peaceful use of nuclear energy may contribute more to the solution of such problems than technical fixes.

INFCE work has also produced the suggestion that safeguards could be strengthened by the establishment of a system of plutonium storage. Under such an approach excess plutonium would be placed in the care of the IAEA and released only for specified peaceful uses.

b) The present day joint team activities between IAEA and EURATOM in the nuclear facilities of the European community have proven to be very successful. Sufficient funds should be made available to continue such activities.

c) R + D activities in the field of international safeguards are becoming more and more internationalized. National efforts have to be coordinated with the requirements of international safeguards. A typical example was given for the R+D activities of the United States in the field of international safeguards. It covered a wide spectrum of international and national cooperation.

3.2 Luncheon Address

INMM Chairman Bob Keepin (LASL) presented the luncheon address at the ESARDA symposium. The text of his address was presented in the last issue of the Journal (Volume 9, No. 1, pages 101 to 104). Keepin's address was entitled "Our Common Commitment to Safeguarding Nuclear Power." He stressed the basic nature of today's energy problem and the potential contribution nuclear power can play in resolving current technical and social issues. He stressed how safeguards professionals on both a national and international basis are working to help realize the full potentials of nuclear power. He also summarized current INMM programs which are focused on achieving this goal, including:

(1) Speakers Bureau
(2) Communication Bureau
(3) INMM News Bureau
(4) Education Programs
(5) N15 Standards Committee
(6) Certification Programs
(7) Technical Groups

Major emphasis was given to the need and importance of expanded cooperation between ESARDA and the INMM.

3.3 Plant Specific Experience

The papers discussed during this session and the panel discussion indicated that both the facility operators and the regulatory authorities have started getting valuable experience implementing IAEA Safeguard procedures. The discussions indicated that both regulators and operators are interested in providing solutions to the many problems which have beset implementation at new facilities. Safeguards experience at the following types of LWR facilities was highlighted.: low enriched uranium fuel fabrication facilities, mixed oxide fuel fabrication facilities, and reprocessing plants.

Key points included:

a) **Safeguards organizations:** The cooperation between the inspectors and the facility operators has been excellent. The "state" systems for accountancy and control in general require further improvement. The IAEA inspectors are required to carry out additional activities because of some insufficient capabilities (for example, lack of MUF evaluation procedures) at the state level.

b) **Facility operators:** Two problems were identified: (1) Frequency of physical inventory taking with washout and (2) the radiation dose received by inspectors. It was the opinion of the plant operators that the financial problems associated with physical inventory takings with wash-out can be alleviated by having running inventories every two weeks without wash-out or interrupting the facility. Safeguards organizations suggested that the problem of high radiation doses for the inspectors could probably be reduced by using better containment and surveillance measures.

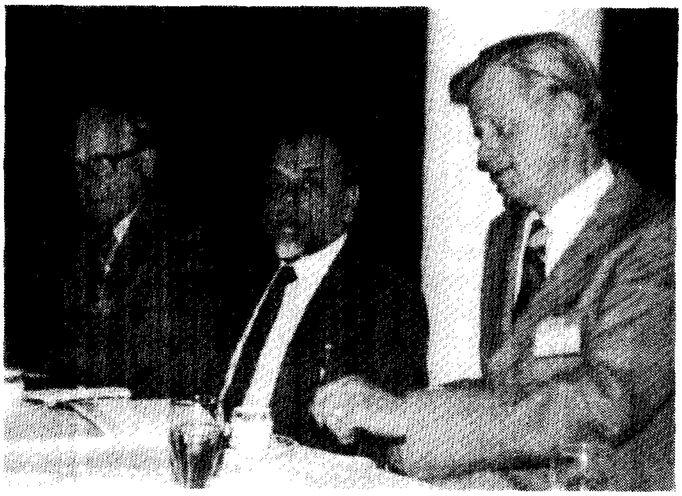
3.4 Accountancy, Material Control and Information Systems

The basic result emerging out of recent experience was that a number of computer based accounting systems are being designed and implemented in different facilities such as Zero Power Reactor, HTR reprocessing, plutonium reprocessing and nuclear research centers.

Both the facility operators and safeguards organizations are interested in using computerized accountancy and material control systems where practical. However, the important message was that less expensive computer systems are required which are easier to handle. They must also provide for the possibilites for transparent and simple verification. Some of the computer systems now in use have caused considerable problems in efforts to track the flow and inventory of nuclear materials.

3.5 Data Evaluation and Methodologies

a) A number of models for data evaluation and assessing the effectiveness of safeguards system have

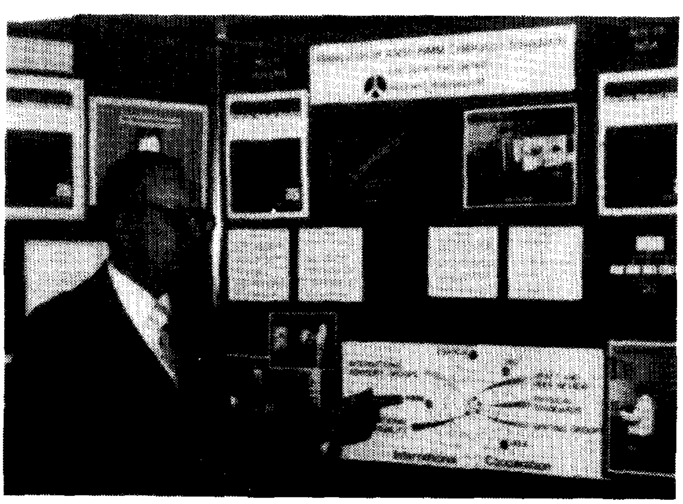


Sigvard Eklund (Director General, IAEA), Dipak Gupta (Chairman ESARDA), and G. Robert Keepin (Chairman INMM) share table and discussion at ESARDA luncheon.

D. M. Bishop (GE) and Marty Zucker (BNL) discuss NDA measurement applications during a coffee break between sessions.

Carl Bennett (BMI-PNL) and Bill Meyer (Sandia) during coffee break.

INMM Chairman Bob Keepin presenting luncheon address at ESARDA Symposium. Keepin stressed energy goals and INMM/ESARDA cooperation.



Lou Doher (Rockwell) during poster session on the application of INMM-N15 Safeguard Standards.

Tom Shea (IAEA), John Jaech (EXXON) and Bill DeMerschman (HEDL) during reception following the first day's technical sessions.

been developed and partly tested.

b) Models for accountancy of nuclear materials on both a conventional and real-time basis are among those being developed. Some of these (e.g. for establishing MUF and LMUF) have been tested in fabrication facilities. Both the plant operators and safeguards organizations are involved in the development and testing of these models.

c) Some of the statistical models to be used for data evaluation and effectiveness studies may have to wait before they can be used routinely. This delay results from the fact that the required data base may not be available in many facilities for some time to come.

d) Real-time accounting of nuclear material in-process has been analyzed and used by a number of facility oprators. Operators of fabrication facilities in Belgium, France, USA and UK and of reprocessing facilities in the UK are considering the possibility of use of real-time accountancy. Some of the models required for establishing inventory in process equipment have been tested under experimental conditions for reprocessing facility equipment.

3.6 **Measurement Techniques and Standards (NDA and DA)**

Significant contributions have been made in the area of measurement techniques. Several important features appear to have emerged from the presentations and the discussions:

a) The role of measurement standards particularly for NDA techniques appears to be more and more important. Significant international efforts are going into the specification, procurement and evaluation of such standards. A typical example is the joint effort in this area between NBS and ESARDA in the development of U enrichment standards.

b) Non-destructive methods are being routinely used in the area of international safeguards and plant operation. Examples are:

- Gamma absorption systems for uranium and plutonium concentration measurements
- K-edge y-spectrometry for the determination of U/Pu concentrations in solutions
- Use of Cerenkov's glow for establishing the presence of irradiated fuel elements in storage pools

c) The international cooperation in the framework of the TASTEX program (testing of different measurement systems and methods at the Tokai-Mura reprocessing facility) in Japan appears particularly fruitful in the area of measurement techniques.

d) Some interesting possibilities for chemical measurement systems were discussed. One example was the possibility of dissolution of a solid sample in the container in which it is shipped. This reduces possible Shipper/receiver differences.

e) An experimental investigation into the use and application of isotopic correlation systems was reported. Further experimental work will be required to clearly understand the possible use of this technique for safeguards purposes.

3.7 **Containment and Surveillance (C/S)**

Contributions on C/S techniques were received from international organizations, operators and safeguards organizations.

a) The C/S working group from ESARDA reported on the development of C/S hardware, theoretical investigations and the possibility of quantification of C/S systems. It was recognized that for advanced C/S systems in future facilities particular attention has to be paid to the different types of diversion strategies (internal/external). At the present time it appears to be rather difficult to justify C/S systems in a quantifiable cost-effective manner.

b) A number of facility operators reported on their experience with C/S systems in their facilities. A number of problems were also discussed.

c) The experience of the safeguards organizations with C/S measures were reported along with the results of a series of test programs.

d) A number of new possibilities were discussed for the use of C/S measures in international safeguards, including:

- Identification of fuel elements with eddy current and ultrasonic systems
- Laser surveillance technique for surveilling the presence of irradiated fuel elements in a storage pool
- Evaluation techniques for the performance of doorway-monitors
- Instant film development capability using new types of film camera systems

3.8 **Safeguards Concept**

a) The papers presented in this area provided a basis for lively and stimulating discussions. Safeguard concepts for enrichment and reprocessing facilities as well as for fast reactor systems were presented. The discussions revealed that, particularly in the area of concepts, close cooperation between safeguards organizations and the sponsoring parties is needed to arrive at a mutually acceptable safeguards system.

b) An analysis of the state's system of accountancy and control was also presented by the IAEA, and the point made that further improvement and development of such systems are a prerequisite for the effective functioning of international safeguards.

4.0 **PROCEEDINGS AVAILABLE**

Copies of the proceedings from the Edinburgh meeting can be obtained from the ESARDA Secretariat at the following address:

ESARDA Secretariat
Joint Research Center
I-21020 Ispra (VA)
Italy

Letter to Bob Keepin

Dr. G. R. Keepin
Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, N.M. 87545
U.S.A.

My dear Bob,

I would like to take this opportunity to thank you for your marvelous and stimulating speech during the official luncheon of the ESARDA at its 2nd Annual Symposium. Your speech was considered to be a very timely contribution to the controversial issue of nuclear energy and its future. I sincerely hope that the joint effort and cooperation which started during the last two years of our chairmanship of the INMM and the ESARDA, respectively, will continue to flourish in the future. It has been a great pleasure and personal honor for me to have you with us.

With warm personal regards,
Yours sincerely,
(D. Gupta)
Chairman, ESARDA

Address Changes

The following changes of address have been received by the INMM Secretariat (Phone 703-471-7880) at 11704 Bowman Green Drive, Reston, Virginia 22090.

E. R. Johnson
11702 Bowman Green Drive
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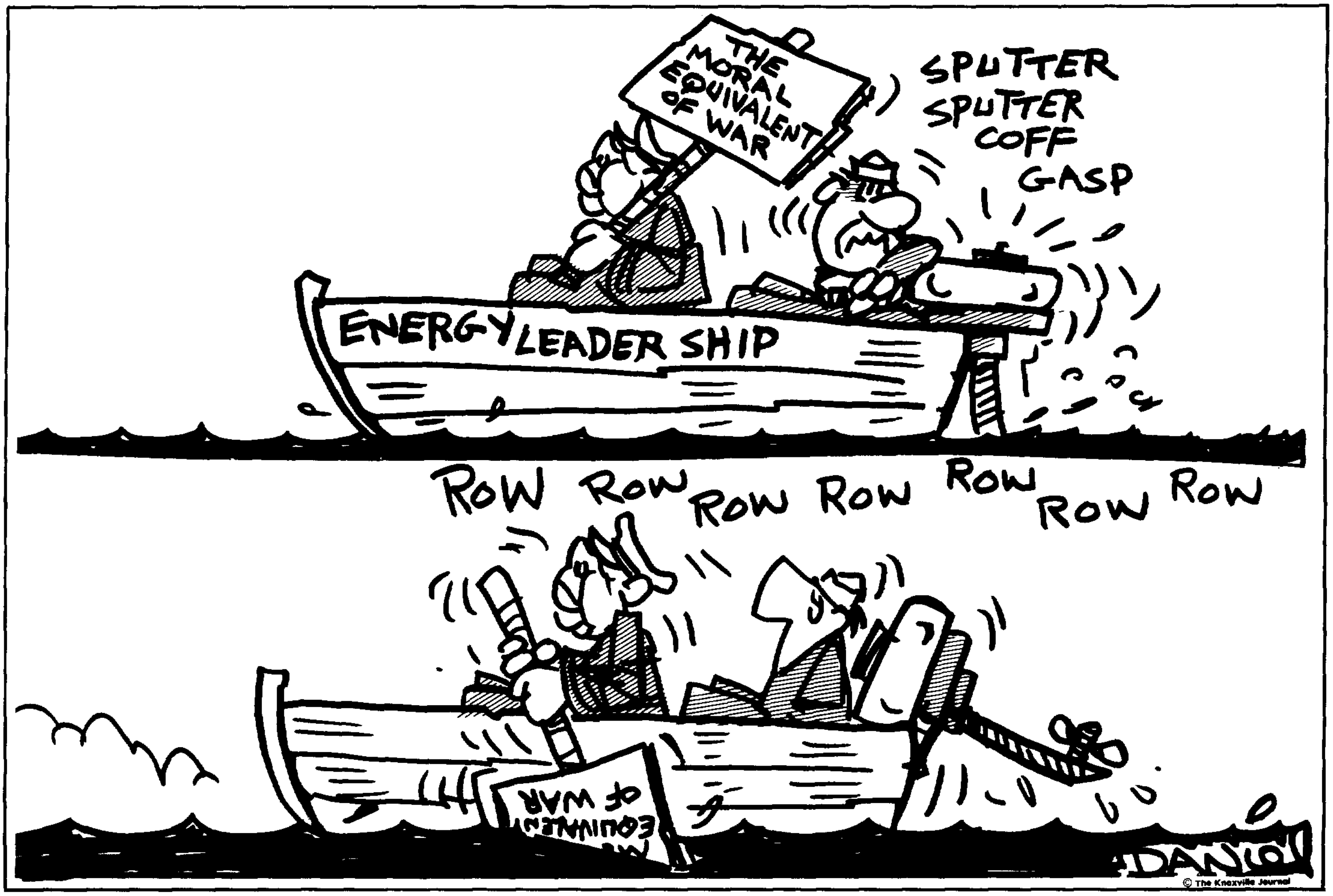
G. F. Molen
Savannah River Laboratory
Bldg. 773-11A
Aiken, SC 29810

Philip L. Schiedermayer
Profitect, Inc.
Professional Protection Consultants
3520 Golden Gate Way, Suite E
Lafayette, CA 94549

D. E. Six
Rockwell-Hanford
P.O. Box 800
Richland, WA 99352

Ms. Julia M. Smith
Brookhaven National Laboratory
Bldg. 130
Upton, NY 11973

Ms. Mary Alice Thom
EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, ID 83415



Student Award to Mohammed Sharafi and Meritorious Service Award to Douglas E. George

By **Dr. Ralph Lumb**
Awards Committee Chairman
NUSAC, Inc., McLean, Virginia

Most universities today are experiencing significant decline in the number of engineers enrolled in nuclear engineering. Nonetheless, the Awards Committee had a number of student papers to review for its annual Student Award. The paper entitled, "CIVEX Reprocessing Technique: Assessment of Technology and Institutional Problems," by **Mohammad Sharafi** was chosen for this year's annual Student Award. Mr. Sharafi has studied the CIVEX reprocessing scheme, evaluated it technologically, and concluded that it does have a certain proliferation resistance. He has analyzed the monitoring and measurement techniques that would be needed and concluded that considerable developmental work will be necessary for process control and waste management.

Mr. Sharafi also examined the institutional problems of deploying the CIVEX process. He concluded the CIVEX has a minor effect on proliferation and requires extensive international arrangements. He also concluded that the process has positive deterrants to diversion by subnational groups.

Mr. Sharafi is a Ph.D. candidate at Massachusetts Institute of Technology and this paper is a result of thesis work under the direction of Professor **David J. Rose** of the Engineering Department.

The Awards Committee also determined that this year's Distinguished Service Award should be granted to **Louis W. Doher.** For over 20 years, Lou has been employed at the Rocky Flats Plant of Rockwell International, a contractor to the U.S. Department of Energy. Lou has been a great booster of the Institute and for many years did an admirable job guiding its Standards activities.

The Awards Committee decided that this year there will be a Meritorious Service Award presented to **Douglas E. George,** for his many years of active service for nuclear materials management. For many years, Doug has worked quietly behind the scenes boosting the Institute of Nuclear Materials Management and generally making contritutions to the industry. Almost his entire professional life, over 35 years, has been devoted to the profession of nuclear materials management.

The recently-completed Topical Meeting on Intrusion Detection Techniques was a considerable success. Not only was there a substantial information transfer accomplished at the workshops, but the meeting was also a financial success. The success was largely due to the substantial effort put forth by **Tom Sellers** in organizing and conducting the meeting. Consequently, the Awards Committee has arranged for an award recognizing Tom's contribution to the Institute.

In the past, the Awards Committee has been concerned with the Student Award and Distinguished Service Award. However, it is apparent that there are other circumstances which warrant recognition by the Institute. Consequently, in the future the Awards Committee will be pleased to receive nominations from the membership for awards in recognition of unique service to the Institute. The Committee will process such nominations and, as appropriate, will recommend to the Executive Committee that the Institute recognize those unique services.

Bernie Gessiness, Willie Higinbotham, and **Ralph Lumb** constitute the membership of the Awards Committee. They would be pleased to receive nominations from any member of the Institute and would be happy to discuss a potential award at any time.

Dr. Ralph Lumb

Past Chairmen Lynn Hurst, Harley Toy, and Secretary Vince DeVito visited during a break at the "INMM Workshop on Impact of IAEA Safeguards" held in Washington, D.C. in December 1978.

Special Article

"On Safeguarding Statisticians — The Nonproliferation Issue"

By **John L. Jaech**
Exxon Nuclear Company, Inc.
Richland, Washington

Editor's Note: Remarks prepared for presentation at a luncheon meeting of the Vienna Chapter of the INMM, March 18, 1980.

It is with great pleasure that I speak to you today and bring you greetings from another successful chapter of the INMM — the Northwest Chapter in Richland, Washington. We have now met on three occasions and continue to draw between 50-75 to our dinner meetings. Now that this occasion marks the beginning of a speaker exchange program, we look forward to hearing from you members of the Vienna Chapter at future meetings of our Northwest Chapter.

I also appreciate this invitation to address the Vienna Chapter because it enhances my self-image; and these days, I need all the help I can get. To help you understand this remark, let me point out that when one has the profession of a **statistician,** with statisticians as a group often being regarded with suspicion, distrust, wariness, and a slight sense of discomfort, and when one furthermore is employed by a **major oil corporation,** which in the U.S. at least is synonymous with windfall profits, a dirty-word expression, and, finally, when one's field of application is in the **nuclear industry,** with its attendant less-than-desirable image in today's world, then his self-image needs to be bolstered occasionally. I hope you can sympathize with me and understand why, when someone asks me how I earn a living, I respond that "I am a mathematician for a struggling company engaged in energy conservation and production."

My topic is "On Safeguarding Statisticians — The Nonproliferation Issue." We are, of course, intimately associated with the words "safeguards" and "nonproliferation", and think immediately of those measures taken to assure that nuclear materials are restricted in their uses to peaceful purposes, those that will benefit mankind rather than harm him. It is exactly from that same point of view that I would like to speak to you with respect to the safeguarding of statisticians — to restrict their use such that mankind will benefit and not be harmed.

Now, I hope and think it will become clear that the safeguarding of statisticians as herein interpreted is largely a self-imposed responsibility. That is, it is largely up to the professional statisticians and to those engaged in statistical pursuits to safeguard themselves. However, those of you who are not so engaged are not free of responsibility here either — applications in statistics are often guided in part by the consultee who must work with the statistician in keeping the project on track.

So much for introductory remarks. In structuring my remaining remarks, let us address the topic of the rather widespread misconceptions that exist about the statistician and his contributions and try to explain why these misconceptions exist. In going through this exercise, we will identify by inference the safeguards that may be imposed (largely self-imposed) to restrict the statistician's uses to beneficial and not harmful purposes — with special emphasis on the field of application of nuclear materials safeguards.

The public generally believes that the statistician deals only with averages and with the normal distribution. When being introduced for the first time to someone, and upon being identified as a statistician, in my experience the odds are about 3 to 1 that this person will say, "Tell me, is it true that if you put your head in the oven and your feet in ice water, you'll be comfortable on the average?" My plea to you is, if you have made such remarks, please cease and desist.

As another example, say one has completed a round of golf, or a bridge game, or whatever, and the scorecard is given to the statistician with the remark, "Let Tom add it up, he's the statistician." That's bad enough, but then someone checks your addition and discovers a mistake! Actually, being poor in arithmetic is one reason for being a statistician — we don't have to get the exact answer, just getting within the confidence interval is close enough. As an aside, it is **especially** important in safeguards to be poor in arithmetic, since here the statistician is entrusted to come up with a value for MUF that no one will believe so that no action is taken. Being poor in arithmetic is helpful in this assignment.

Another misconception about statisticians is that they are miracle workers, and I mean this in a derogatory sense. There is a rather widespread belief that the statistician can perform some hocus-pocus statistical ritual that can turn an unacceptable data-based conclusion into an acceptable one. The consultee would like the statistician to assume the responsibility for discarding the 40% of the data that are outliers.

I'll touch on one more misconception, and that is the idea that the statistician carries in his head all sorts of statistics such as, "If the U.S. national debt were in dollar bills laid end-to-end, they would encircle the globe x times." These kinds of statements do not originate with statisticians, nor are we responsible for the statement, "If all the statisticians working on problems of nuclear materials safeguards were laid end-to-end . . . who would care?" I would care, and I might care a great deal, depending on what statisticians I were laid end-to-end with.

As a final note on the misconceptions about statisticians, it is especially appropriate for me to point out to this audience in which so many countries are represented that the rather negative attitude about our noble profession is apparently not restricted to the U.S. I offer a quote from an eminent statistician from the U.K., Professor Kendall[1], "Statisticians are regarded as living in a world of their own and possessing very few human attributes. Nothing is more devastating in a social gathering than to be introduced to a stranger as a statistician and to watch the dismay with which he, or . . . she wonders what you can possibly discuss on the ordinary social plane. That is not, I think, merely the laymen's natural distrust of numerical information. People appear to talk quite happily to actuaries and accountants or even to numerical analysts and mathematicians."

Now, my thesis is that the misconceptions about statistics, or, more generally, the prevailing negative attitudes about the statistician can be explained in large part as being the fault of the statistician — not solely the professionally trained individual, but including also the inadequately trained individuals engaged in statistical pursuits. However, this latter type individual is another matter, and I would like to restrict additional remarks to the professionally trained statistician. What mistakes have been made on his part to foster the negative attitudes previously discussed?

I will touch on five areas in considering this question. These areas relate to problems in communication, in being too academic while problem solving, in forcing problems to fit favored statistical techniques, in placing undue reliance upon the computer, and finally, in the fact that statisticians are often in disagreement among themselves.

Consider the communications problem. Our final product is a report, possibly oral but often written. It does very little good if the results of a statistical study, important though they may be, and perhaps representing an excellent analysis with considerable original thought, are not communicated in an understandable and timely way. Kendall, previously quoted, maintains that the statistician is often undervalued because of his inability to convey ideas, especially in writing. His philosophy, is and I quote, "If someone fails to understand me I regard the fault as mine, not his."[1] The temptation to include complicated derivations and equations in a report is strong; the temptation to purposely obscure in order to impress is very real. But these temptations must be avoided if the statistician is to be safeguarded.

Thus, conclusion number one is: You, the statistician, keep your reports simple and understandable. You, the consultee or the user, if you do not understand the report, seek *clarification*. If that happens often enough, the statistician will, hopefully, in the future, simplify his writings and hence enhance his usefulness. I must, in this regard, quote to you from an article I read on the airplane while traveling to Vienna. The quote is, "The older I grow, the more clearly I perceive the dignity and winning beauty of simplicity in thought, conduct, and speech, a desire to simplify all that is complicated and to treat everything with the greatest naturalness and clarity." The quote is from Pope John XXIII.[2] Point number two: The statistician has erred in not avoiding the temptation to be too academic in his approach to problem solving. This could be a difficult subject to deal with because it is clearly dangerous to base results on analyses that are mathematically unsound. However, the subject simplifies immediately when we recognize that it is one thing to deal with practical problems on a sound mathematical basis, keeping in mind that it is the **problem** that is important, and quite another to dwell on the mathematics, regarding the problem itself as something to be endured but of no interest beyond that.

When working on problems of nuclear materials safeguards, we cannot, in my opinion, afford to expend a significant proportion of our energy in pursuing the intellectual pleasures of pure mathematics — except as a hobby. Again Kendall, a brilliant mathematician I should make clear, speaks to this issue[1], "Nowadays there is a brand of mathematician who is a danger to our subject, or at least, to the acceptance of our subject in the worlds of science and business . . . there is a place in the world, even in the world of experimental science, for the scientist who is mainly interested in **studying his own mind.** Where we have gone too far, I think, is in allowing him to acquire pecking order over the scientist who is interested in dissecting and reducing to order the external world. The intricacies and austerities of mathematical statistics are such as to encourage intellectual arrogance on the part of their practioners. I do not think we should let them get away with it."

The third problem area is somewhat related — it is not uncommon for the statistician to have become familiar with, and perhaps even developed in part, some technique that he is eager to apply. When this happens, the whole problem of applied statistics gets turned around: instead of searching for a technique to solve a given problem, one either searches for a problem to fit the technique, or else twists a given problem to fit the technique in question. At times, this takes a lot of twisting. Professor Anscombe says it well[3]: "What is important is that we realize what the problem really is and solve that problem as well as we can, instead of inventing a substitute problem that can be solved exactly, but is irrelevant."

As a case in point, consider the Kalman filter. Here we have a rather elegant mathematical technique (rather, a computing algorithm that permits efficient application of a technique similar to one that's been around in safeguards applications for many years)[4], and this has led to individuals running hither and yon, consuming valuable energy, not to mention tax dollars, looking for an application. (This valuable energy might *better be expended in seeking to improve the quality of* the data base.) The first profound conclusion reached by the proponents of the Kalman filter to my knowledge, was that it is superior to the single-balance-period MUF in detecting trickle diversion. I think we all knew that, nicht wahr? Anyway, the net result of all that frenzied energy is, I think, pre-ordained; namely, it is hard to improve on the simple cumulative MUF when taking into account the MUF over more than one material balance period. (Again, **simplicity!**)

Turning to the next problem area, while without question the age of computers has, in balance, been beneficial to statistical development and application, yet there are some potential hazards. To identify them quickly, the existence of so many package routines may, if one is not careful, replace the thought process and lead to problems of poor correspondence between reality and the model on which the analysis is based. Secondly, again if care is not taken, we may lose the "feel" of the data through over-reliance on the computer. The computer, if used correctly, can supply a large part of this feel through data plots, data screening, data ordering and the like, but in this process, the user must maintain control of the computer, and not vice-versa. One last problem with the computer age — I am troubled by the occasional over use of computer simulation in solving problems. Granted that simulation **is** needed to handle many otherwise unsolvable problems, yet the fact remains that simulation is at times used when less expensive and more exact mathematical techniques are readily applicable. We as members of God's creation[5] are still able to reason; let's not let the computer get all the credit.

Statistics and statisticians are sometimes maligned because we don't always agree with one another. Those who would like to downgrade the contributions of statistical thought capitalize on these disagreements, arguing that until we agree among ourselves, why should any of us be listened to?

Those who would argue this way tend to forget two important points. First, many quite vocal areas of disagreement affect in no way the results of an analysis but may be quite academic. As a case in point, I call your attention to a publicized running battle that I have had in and out of print with a statistician friend of mine on the distinction, if any, between a bias and a systematic error. Now, when it gets right down to cases, this disagreement is quite unimportant. (I point out that it is quite unlikely that the disagreement will even be resolved; my friend is too stubborn to admit he is in error; I, on the other hand, am correct in my position.)

I think it's important to broadcast the message that disagreements among members of the statistical profession are to be expected. If I may quote from Kendall[1] this one last time, "The statistician . . . is rarely sure about anything. Ours is a logic of uncertainty. We make almost all our statements in terms of doubt, of expectation, of chances in favor. And rightly so, because that is what life is like."

In closing, I hope that these remarks will stimulate those of you engaged in statistical pursuits to become more self-disciplined and impose on yourselves the safeguards necessary to enhance your effectiveness. I also hope that the others of you will, having heard the problems faced by members of the statistical profession, become more charitable in your dealings with us ever keeping in mind the thought that, "There, but for the grace of God, go I."

REFERENCES

1. Kendall, Maurice, "Statisticians — Production and Consumption," The American Statistician, **30,** No. 2, May, 1976.
2. Pope John Paul XXIII, "Journal of a Soul," (unknown date).
3. Anscombe, F. J., "Rectifying Inspection of a Continuous Output," JASA, **53,** p. 702-19, 1958.
4. Stewart, K. B., "Some Statistical Aspects of B-PID's and Ending Inventories," TID-7581. USAEC Div. of Tech. Information, p. 148-60, 1959.
5. Moses (By inspiration), The Bible, Genesis.

Jaech

Veterans of INMM activities talk over institute changes during 20th Anniversary Celebration. Left to right are John Ladesich, Southern California Edison, Armand Soucy, Yankee Atomic Electric (Former INMM Chairman), Ed Johnson, E. R. Johnson Associates, Inc. (Former INMM Chairman), Jerry Johnson, and Harley Toy, Battelle Memorial Institute, (Former INMM Chairman).

Safeguards Engineering: A New Profession...

Editor's Note: The following article, "Safeguards Engineering: A New Profession," is reprinted with the permission of the American Nuclear Society. It appeared on pp. 48-49 of the May 1980 issue of **Nuclear News.** Reference is made to this article in Dennis M. Bishop's technical summary of the recent ESARDA conference this past March in Edinburgh, Scotland *(see pp. 23-26 of this issue).

Development of procedures and technology for nuclear materials safeguards may have been neglected in the 1960s and early 1970s, but if proof were needed that this field of activity is now receiving adequate attention, it is the fact that the specialists are being institutionalized. At a luncheon address to a large international gathering at the second annual symposium of the European Safeguards Research and Development Association (ESARDA), in Edinburgh, Scotland, March 26-28, **Bob Keepin,** who is the leading light of the Institute for Nuclear Materials Management (INMM) in the United States, reported that good progress was being made toward the formal certification of safeguards engineers. INMM has completed the formulation of subjects to be covered in examination questions and will be holding its first examination conference in West Palm Beach, Fla., this June. And there was a good deal of talk during the meeting of ESARDA and INMM operating as sister organizations on either side of the Atlantic to establish a professional status for safeguards engineering.

The International Nuclear Fuel Cycle Evaluation (INFCE) has provided a strong endorsement of the importance of safeguards in support of a nonproliferation regime, but, at this stage, it is probably worth issuing a warning against the generation of excessive self-importance among the people who, for years to come, will have to cope with the sensitive day-to-day tasks of policing the nuclear industry.

At the present time, when safeguards procedures and techniques are being developed, there is certainly plenty of intellectual and scientific challenge for the professionals involved. This was quite apparent at the Edinburgh meeting in the lengthy discussion of organizational arrangements for materials accountancy and in the detailed descriptions of development of specialized instruments. But neither the rather boring details of procedural arrangements nor the complicated characteristics of the technology are going to make a substantial contribution to the task of showing politicians and the public that effective safeguards can and are being applied.

In establishing their new engineering discipline, INMM and ESARDA should perhaps be giving some thought to a future when politicians, no doubt spurred on by nuclear opponents, have turned their attention to other issues; when procedures have become dull routines and instrument design has been broadly standardized; and when operators of nuclear facilities, who have absolutely no inclination to divert nuclear material, are becoming irritated by the disruption of safeguards inspections.

At present, few people would argue with the importance of safeguards being seen to be applied universally; for this reason, Britain and the United States are currently involved in voluntary implementation of International Atomic Energy Agency safeguards at their civilian nuclear installations. These gestures are certainly going to cost a lot of money. Describing the application of IAEA safeguards in the United States, **Robert F. Burnett,** U.S. Nuclear Regulatory Commission director of safeguards, referred to a study of likely cost to the commercial industry that suggests that the one-time implementation cost will be between $1.9 million and $7.2 million and that the annual cost to the industry of maintaining the program is expected to be between $600,000 and $1.5 million. One cannot help wondering whether the safeguards engineer of the future will start to feel that there is a certain futility in pursuing his profession in weapon states and in those western European states where North Atlantic Treaty Organization nuclear weapons are already deployed.

IAEA Director General **Sigvard Eklund** told the Edinburgh meeting that the annual IAEA budget for safeguards has risen from $1 million in 1970 to $20 million in the present year — but not without generating considerable criticism from the so-called "group of 77" nonaligned countries, who would rather see this — and more — money spent in constructive aid programs to make the benefits of nuclear energy available to the developing nations. Eklund repeated his now familiar warning about mounting political pressures within the IAEA, and he stressed the importance of making progress with the implementation of both Article 4 of the Nonproliferation Treaty, which covers the application of international safeguards, and Article 6, which calls for reductions in the levels of nuclear armaments. "If we fail to do this," he said, "it will erode confidence in the NPT."

From the outset, those involved with the implementation of international safeguards have striven to minimize the potential nuisance to normal operation of nuclear facilities. Participants at the meeting in Edinburgh were told of a recent effort in this direction: the introduction of joint Euratom/IAEA teams of inspectors for plants in European Economic Community countries, where operators are subject to the earlier system of Euratom controls, as well as to IAEA safeguards. At the same time, operators have shown a fair degree of philosophical tolerance toward the requirements of international safeguards. But the potential for friction is not far below the surface, and attendants at the meeting were warned that safeguards would fail in their objective of making the peaceful uses of nuclear energy widely available if their imposition were to become the last straw in the already heavy burden of regulation and were to cause utilities to decide against investment in nuclear plants.

An example of significant disruption of normal operations due to safeguards was given by **Vandem Bemdem,** the general manager of a small plutonium fuel fabrication plant in Belgium (NN, April 1979, p. 59). In spite of the joint team concept, there is still a need for two 100-percent physical inventory controls each year to meet Euratom and IAEA requirements. This involves a cleaning out of all sections of the plant and a work stoppage of 2.5 weeks each time. A further requirement for inventory inspections every 2 weeks causes some disruption of operations approximately equivalent to a further stoppage of 2 to 2.5 weeks per year. In all, these inventory controls are estimated to cause a 15 percent reduction in plant capacity.

Another apparent source of irritation is the use of remote sealed cameras for surveillance of such facilities as spent fuel ponds or pressure vessel heads. The fact that people do not like the remote eye watching them was demonstrated during the luncheon at the ESARDA meeting. The manufacturer of a safeguards camera unit had set up an example of its product to view one of the tables, but the people sitting at that table quickly turned the camera in a different direction — as chance would have it, toward the attractive representative of the manufacturing company. Whether because of the camera or the haggis served by the Scottish hosts, she did not seem to be entirely at ease during the luncheon.

The meeting did, however, highlight an area where the safeguards engineer can make a contribution that will please everybody. This is the development of principles and guidelines that will allow safeguards requirements to be incorporated at the design stage of new plants. It was pointed out that, at present, there is no document that a person can take into a design office to explain what safeguards are all about. If ESARDA and INMM can do something to make good this deficiency, they may well justify the status of worthwhile professional institutions.

Book Review

"Fission, Fusion and the Energy Crisis", S. E. Hunt, Pergamon 2nd Ed. 1979

By **Anthony Fainberg**
Brookhaven National Laboratory

It is always interesting to read a non-U.S. point of view on the whole energy question, since we, like many other nationalities, I suppose, are so steeped in our domestic arguments on the topic, that we may lose sight of some broader issues. In any case, most of us gain perspective by being exposed to a (for us) fresh outlook even if we don't agree with it, and this, in itself, should encourage us to look around before freezing our opinions in concrete. In fact, what U.S. nuclear people will find interesting is a strongly pro-nuclear position, which, at the same time does not approve of PWR's at all.

S. E. Hunt has written a short basic text entitled "Fission, Fusion, and the Energy Crisis". There are less than 170 pages, and, of course, the title cannot really be lived up to in such a brief volume. The book is the second edition, with some updating over the first edition, which was published in 1973. In the preface to the first edition, the author tells us that the book is intended for the undergraduate student, as well as for the non-scientist and the layman. In fact, the level of technology is too elementary for the scientific undergraduate, as it must be, if laymen are to be reached by the same material. The author wishes to outline the technical elements involved in the production of energy, as a basis for the social decisions of how to arrange an optional energy strategy. Hunt correctly remarks upon the strong interrelationship of the technological, social, enonomic,and ecological aspects of the energy problems. In developing his arguments, however, he shows himself strongest in the first aspect, weakest in the others.

The descriptions of fundamental nuclear physics, and the development of the application of theory to reactors, are done in excellent, brilliantly clear fashion. Hunt clearly has a remarkable ability to impart basic physics and engineering to a non-technical audience. Chapters 2 through 5 deal with the technology. Natural uranium reactors (MAGNOX, CANDU) are covered before the enriched (AGR, PWR, BWR, HTGR, Steam Generating Heavy Water Reactor, and various fast breeders). All are quickly and efficiently described with their principal features and diffferences clearly highlighted. The control and safety chapter comes next. First, the vital role of delayed neutrons in reactor control, is delineated, with a good discussion of the dependence of reactor power-doubling time on reactivity.

Then Hunt briefly compares different reactor types as regards safety. Not surprisingly, perhaps,the British Magnox and AGR's are found to be safer than American PWR's (BWR's are not discussed). Hunt expresses skepticism about the adequacy of the emergency core cooling system and the ability of the pressure vessel to resist a catastrophic fracture. He also is concerned over the high energy densities of LWR's relative to other reactors. Maybe he's right. Nevertheless, after the Windscale Wigner release, one is not necessarily convinced that British reactors are really inherently safer than American ones. He also seems quite sanguine about safety problems in fast breeders, and dismisses these concerns in a brief arm-waving paragraph which is as uninformative as it is unconvincing.

Strangely, given the fact that the book is supposed to be updated, (being a second edition) there is a paragraph which regrets that the USAEC both promotes and regulates nuclear power. Since the NRC has been in existence for quite a few years now, this error is not easily forgivable — in fact, it casts doubt on the whole updating job. With this level of updating, maybe Hunt would have done better not to have put out a newer addition at all.

One has the feeling, as regards LWR's, that Hunt's dislike of them may possibly have a chauvinistic component. Nevertheless, it is well-worth thinking, in retrospect, that perhaps LWR's were pushed too rapidly for the wrong reasons (convenience, with technology and experience already developed in the naval reactor program). It is not beyond the realm of possibility that heavy water moderated or gas-cooled reactors would have been recognized as safer and thus been more acceptable to the public. This lesson should be applied to choice of the optimal fusion reactor in the future, although it is probably too late to apply it to fission in the U.S.

In discussing the economics of reactors, again, much work is outdated. Future projections of uranium demand and supply are outlandishly high, and used to support arguments for a quick introduction of breeders. It is now realized that a large-scale breeder option could be easily postponed for 20 years, and possibly for decades beyond either considering the U.S. alone, or the non-Communist bloc as a whole. Hunt examines costs of nuclear vs. oil or coal, and concludes that it is "clear that . . . nuclear is appreciably cheaper". There are quite a few experts who are not so sure of the clarity of this assertion (which, it would be if there were no reprocessing or breeders; such analysis then does depend on which country and which policy is in question).

All through the book, when dealing with questions of social effects, safety, and economics, Hunt finds himself easily convinced of the strongly pro-nuclear point of view. This is well and good. However, in a book which is designed to inform, and, at least by implication, persuade, the author should be aware that the confident assertion of a hypothesis is no substitute for documented proof, or even, for that matter, for a plausibility argument.

For example, in the very beginning, we find the assertion that for the standard of living to remain acceptable, it is impossible to reduce per capita energy consumption. This point of view is hard to credit — particularly when several European countries have higher per capita incomes and far lower per capita energy consumption than the U.S. World energy demand can certainly be cut by a significant fraction if only the U.S. reduced its per capita energy demand to that of, say, Sweden or West Germany. Hunt's rejection of the value of conservation in developed countries forms one basis for his assertion that "the world's need for nuclear power in the long term appears to be inescapable". Renewable sources? " . . . It seems unlikely that the renewable energy sources can be developed to meet a large fraction of the demand . . . " No supporting data, just the blanket assertion. The statement may, after all, be true (in fact, the recent CONAES report tends to confirm it). But the author owes the reader a bit more on what is, after all, the very core, the central question of the energy debate. It should be noted that there is a chapter on renewable energy, consisting of 6 pages of text. Justice is not done to the topic. Everything mentioned is done so only cursorily. An interesting note is that the U.K. spends only 4% as much on renewable energy research as on nuclear power, much less than in the U.S. Maybe Hunt's parochial attitude on the subject is somewhat conditioned by the general feeling in the U.K., which seems reflected in funding. But, to be fair, many of us may suffer from similar parochialism.

Hunt does present good chapters on the various national nuclear programs around the world and gives an excellent summary of the different approaches to controlled fusion reactors. In fact, his forte is presenting highly technical topics in an extremely clear and comprehensible way. If he had stuck to doing this, the book would have been a success. As it is, in trying to write a text on the whole energy crisis, in all its complexity, and, in addition, in trying to do it in less than 200 pages, the book is a failure. It is superficial and, I am afraid, will only reinforce the feelings of those anti-nuclear people who express their disbelief at the repeated smug declarations of the nuclear establishment. What is needed by the pro-nuclear forces now is reasoned and cogent argument based on fact rather than on sleight-of-hand. There are good arguments for rates from coal-fired plants relative to nuclear. But, on the whole, this book is only useful in conjunction with others. No one who is not already convinced will be persuaded by Hunt, whether on the subject of the necessity of nuclear power, the putative inferiority of LWR's, the need for breeders, or the inability of renewable resources to satisfy the world's energy needs, in the long term. Finally, I am puzzled that the publisher, Pergamon, would want anyone to discuss such a difficult problem as the energy crisis in such a miniscule tome.

Fainberg

Special Article

The Sun Is A Nuclear Reactor: A Solar Advocate Looks at Nuclear Energy

(EDITOR'S NOTE: The attached article was written by Los Alamos Scientific Laboratory employee Fred Marsh, speaking as a concerned citizen and not as a representative of the Laboratory. Marsh, an analytical chemist, is a proponent of solar energy research, and in his article calls for an understanding of nuclear research as one of the issues in this nation's energy debate. He is asking for an opportunity to address some of the charges leveled against nuclear energy. Marsh's article is not an official position paper of the Los Alamos Scientific Laboratory, but the Laboratory offers it as the statement of a private citizen who also has many years of experience in nuclear research and who feels that the positive, as well as the negative, side of nuclear energy should be told.)

Most nuclear critics share a genuine concern for the future of mankind and our environment. I feel the same way. But I do object when the opposition is based on misconceptions and emotions, rather than on adequate understanding of the issues.

As an enthusiastic supporter of solar energy who has spent two decades in the nuclear industry, my perspective encompasses both fields and, I hope, bridges the gap between them. While it's quite fashionable to oppose nuclear energy, I feel that it has an important role in our nation's attempt to free itself from dependence on Iran and other foreign energy sources. Therefore, I requested this opportunity to address a few of the most frequent charges leveled against nuclear power.

CHARGE #1 NUCLEAR ENERGY IS UNNATURAL

Nuclear energy not only is natural, it is the basis of life as we know it. Thermonuclear reactions power our sun and the stars. Radioactivity is a natural component of our bodies and our planet and always has been. Because radionuclides decay exponentially with time, natural radioactivity levels at any time in the past were higher than they are now.

The two major natural radionuclides in our bodies, carbon-14 and potassium-40. subject the average person to an annual dose of about 25 millirems.[1] Currently there is much interest in geothermal as a "natural" energy source. Much of the heat within the earth has been generated from the decay of naturally occuring radionuclides that have been a part of this planet since creation. Most forms of energy used by man are derived from the sun. These include gas, oil, coal, wood, wind, hydroelectric, tidal (partially), and of course solar energy itself. Because the sun is a thermonuclear reactor, all of these forms of energy are merely transformed nuclear energy!

The 93-million-mile distant nuclear reactor that we call the sun emits a wide spectrum of radiation. In addition to the visible portion that we are most familiar with we also receive invisible higher-energy radiation ranging from ultraviolet to extremely energetic radiations from cosmic particle interactions. These higher energy radiations from the sun, while capable of damaging the human body, are just another part of the natural radiation background. An average person living near sea level receives about 45 millirems per year of potentially damaging solar radiation.[1] Those of us who live at the high altitudes of northern New Mexico receive approximately twice this dose.

Natural reactors exist not only millions of miles out in space, they also have existed right here on earth. A fascinating discovery made in 1972 led to conclusive evidence that a natural fission reactor had existed in what is now the African Republic of Gabon.[2] Approximately two billion years ago, uranium-235, the fissionable isotope of uranium, had an abundance more than four times higher than it is today. (The natural enrichment then was higher than that used in present-day thermal power reactors.) Unique geologic conditions at that time caused uranium to be leached from a large surrounding area and transported by groundwater to one particular area where it was redeposited. When sufficient uranium had collected to sustain a fission chain-reaction and when water accumulations were adequate to moderate neutron energies as required, a natural reactor began to operate. As the heat of the nuclear reaction boiled away the water, the reaction stopped, only to restart when water returned.

Undeniable evidence shows that this natural reactor continued operating in its oscillating mode for at least 150,000 years, during which time appreciable amounts of uranium were converted to plutonium that also fissioned. The total power produced was equivalent to about four years of continuous operation of a large nuclear power plant. There is no indication that an explosion, or anything other than a gentle percolating reaction ever occured. The fact that such an event could have happened on our prehistori earth is fascinating.

Of practical importance, however, is the fact that most of the nuclear waste from this natural reactor remained in place for 1.5 billion years until its recent discovery. This is encouraging news for our modern society that is concerned with the problem of long-term nuclear waste storage.

CHARGE #2 NUCLEAR POWER IS DANGEROUS

Fission reactors involve highly energetic reactions that produce intensely radioactive products as waste. Because this has been a recognized fact of life since the inception of the nuclear age, the industry has "grown up" with an incredible array of safeguards, regulations, and restrictions. Consequently, in spite of the potential hazards, the nuclear power industry has a safety record unmatched by any other industry; there has never been a nuclear-related fatality at a commercial nuclear power plant during the more than twenty years that nuclear power has been generating electricity.

During that same period, for the sake of comparison, more than one million persons have been killed on our highways, thousands have been killed in aviation accidents, and hundreds of thousands have been evacuated from their homes because of releases of "conventional" chemicals such as that from the recent derailment near Toronto.

A bright side of the nuclear waste picture is the fact that the waste is highly concentrated and therefore requires little storage space. In fact, the total amount of nuclear waste expected from all operating reactors in the United States by the year 2000 would cover a single football field to a depth of only six feet.[3] In spite of the much-publicized need to store nuclear wastes safely for periods of "hundreds of thousands of years", Alvin Weinberg, the former Director of the Oak Ridge National Laboratory, reminds us that 800 years after these wastes are created, their toxicity has fallen below that of the original uranium that produced them.[4]

Three Mile Island has been much in the news lately. A serious accident, the worst ever encountered in the nuclear industry, occured because of multiple human errors. Two emergency cooling systems had been manually valved off during reactor operation, in direct violation of regulations, and thus were unable to operate as they otherwise would have. Additional emergency cooling systems that were automatically activated and did feed water to the core, were manually turned off by members of the confused reactor crew.

The accident need not and would not have happened if existing regulations had been followed. Much has been learned from this accident and many changes in design and operating procedures already have been instituted to ensure that it will not happen again. Nevertheless, there were no injuries, no fatalities, and no serious overexposures to radiation. An amount of radioactivity, small when compared to our exposure to natural radioactivity, was released.

The recent report of the President's Commission on Three Mile Island estimated that this release will cause between zero and 1.5 additional cancers in a population that is expected to sustain 365,000 cancers from other causes. In other words, any additional cancer risk from this, the worst nuclear power accident ever, is statistically insignificant and absolutely undetectable.

That is not to say that people living near Three Mile Island have not been damaged, for they have. Many residents of the area have suffered moderate to severe psychological trauma. These people were victims, not of what happened, but of what they were told had happened.

Commissioner Anne Trunk of the President's Commission on Three Mile Island was particularly critical of press coverage during the accident. Ms. Trunk, in a supplemental report, wrote, "Too much emphasis was placed on what if rather than what is. As a result, the public was pulled into a state of terror, of psychological stress. More so than any other normal source of news, the evening national news reports by the major networks proved to be the most depressing, the most terrifying. Confusion cannot explain away the mismanagement of a news event of this magnitude."

The intentional fearmongering and terrorizing tactics of some nuclear opponents was exemplified by Ernest Sternglass, who as shown on the evening news scurrying around with radiation meter in hand, telling everyone within earshot that they were going to get cancer. If Sternglass actually believed what he was saying, he would have stayed as far away as he could.

A recent news item[5] notes that realtor reports and county assessment records show no decline in property values in the immediate vicinity of Three Mile Island. Even in the month immediately after the accident, virtually every sale resulted in a substantial profit, with many in the 20 to 75 per cent range.

CHARGE #3: CONVENTIONAL FUELS ARE CLEANER AND SAFER

Fossil fuels are scarce and will grow ever more scarce (and more expensive). Substitute fuels therefore will be needed; the only question is when. Every delay in replacing fossil fuels ensures that more of this nonrenewable resource will literally go up in smoke. Fossil fuels that required 600 million years to be produced will be consumed in only a few centuries. These materials have great value as feedstock for many chemical processes and will soon become much too valuable to burn.

Coal is the most abundant fossil fuel in this country; unfortunately, it also is the dirtiest. Coal scars the land where it is mined, fouls the lungs of those who mine it, and pollutes the air where it is burned.

A report issued this year by the government's Office of Technological Assessment states that more than 14,000 coal miners are disabled and another 120 are killed in a typical year.[6] Coal contains many toxic materials that are discharged to the atmosphere. Arsenic, antimony, cadmium, and lead in coal plant fly ash concentrate in the smaller particles that are least efficiently removed by electrostatic precipitators.[7] Unfortunately, these same small particles provide the most efficient means of respiration into the lungs.

The high levels of sulfur released into the atmosphere by the combustion of coal and oil, amounting to 18.6 million tons of sulfure dioxide in 1972, is the principal cause of acid rain. Acid rain has destroyed fish in hundreds of lakes in upstate New York and threatens fish life in thousands of Canadian lakes.[8]

A recent news article[9] reported that the acidity of rain in the Los Angeles area reaches 1000 times normal and has averaged 50 times normal for the past two years. The acid rain generated in California reaches the Colorado Rockies with increasing frequency, according to this same article. In the most extreme example yet recorded - a storm in Scotland during 1974 - the rain exceeded the acidic equivalent of vinegar.[10]

Perhaps the most remarkable and under-publicized fact relating to conventional fuels is that many coal-burning power plants discharge more radioactivity to the environment than a comparable size nuclear power plant.[11] This is caused by trace levels of natural radionuclides in coal and the vast amounts of ash, which concentrates these trace elements, that are discharged to the environment.

Even if fossil fuels were plentiful and free of pollutants, they still would contribute to a problem of growing concern. All fossil fuels contain carbon that is converted to carbon dioxide under ideal combustion conditions. Carbon dioxide in the upper atmosphere is transparent to incoming solar radiation, but absorbs a portion of the infrared radiation that leaves the earth. Thus, higher levels of carbon dioxide retain more heat via a "greenhouse" effect.

This warming effect is magnified in the polar regions, such that substantial melting of the polar ice caps could result. The consequent rise in the ocean level could flood many heavily populated coastal regions of the world. Unpredictable changes in global weather patterns are another likely result. Major problems are forecast within a century if present trends continue.[12]

CHARGE #4 RADIATION IS ALWAYS HARMFUL

As discussed earlier, natural radiation has always been with us at magnitudes that far exceed manmade sources. (See table.) We frequently are reminded that radiation causes cancer, yet we easily forget that radiation therapy also cures cancer. We easily forget the value of medical x-rays and the many radionuclides that aid modern-day medical diagnosis by concentrating in particular organs or abnormalities of the body.

We also need to be reminded that the dose that we receive from the naturally occuring radionuclides within our bodies is nearly 10,000 times greater than the external radiation dose due to nuclear power plants. (See table.) This information does not deny the problems of nuclear energy, but it does put them into proper perspective. Radiation, like fire, can serve or destroy man. Like all powerful tools and forces, it must be used wisely.

TABLE. ESTIMATED ANNUAL RADIATION DOSAGE PER PERSON IN THE UNITED STATES*

	Source		Average annual dose. millirems
Natural:	environmental, cosmic		45
	terrestial		60
	internal		25
		Subtotal natural	130
Manmade:	global weapons fallout		4
	nuclear power plants		0.003
	medical		73
	occupational		0.8
	miscellaneous		2
		Subtotal manmade	80

*Ford Foundation Nuclear Energy Policy Group, "Nuclear Power: Issues and Choices," p. 163 (1977).

CHARGE #5: PLUTONIUM INGESTION GUARANTEES CANCER

Plutonium is a highly toxic material and is treated as such by the nuclear industry. Nevertheless, minor accidents cannot be totally prevented and a small number of persons have ingested significant amounts of plutonium, especially during the hectic years and primitive working conditions that accompanied this nation's nuclear development efforts during World War II.

For the 224 persons with the highest plutonium ingestions since 1943, the Los Alamos Scientific Laboratory has maintained complete medical records. Within this group there have been 32 deaths, compared to 61 deaths expected from a comparable group from the general population. There have been seven cancers, compared to eleven cancers predicted for a comparable group with no plutonium exposure.[13] The often repeated charge that any plutonium ingestion guarantees cancer and an early death, like the famous obituary published about the then-living Mark Twain, "seems greatly exaggerated."

In summary, commercial nuclear power plants consume no irreplaceable fossil fuels, release no toxic metals or sulfur or carbon dioxide to the environment, release less radioactivity than most coal-burning power plants, and have an absolutely unmatched safety record of zero fatalities. Yet nuclear power receives notoriously bad press. Why is this?

The unfavorable publicity may be due, in part, to the suspicion with which many people view any new technology. Part may be due to the fact that nuclear weapons were built and used to kill people. (The fact that many more people were killed by fire-bombing raids during World War II has not led, to my knowledge, to any demands that fire be outlawed.) Part may be due to the fact that radiation cannot be seen, smelled, tasted, or felt. (It can, however, be detected at extremely low levels with relatively inexpensive and unsophisticated instruments.)

The major reason for the bad publicity may simply be fear of the unknown. When people don't know whom to believe, they often believe those who shout the loudest. And the loudest shouters often are the least reliable sources of information.

Factual input and reason seem to have a minor role in deciding nuclear issues these days. Political decisions appear to be influenced instead by such things as how many people attend rock concerts staged by nuclear opponents. Anthony Roisman, former attorney for the anti-nuclear Natural Resources Defense Council, admitted as much recently[14] when he described the public outcry over nuclear safety as "an irrational, nonfactual response." The question this response poses, he said is whether "there is a way to get the decisions about nuclear power back into the area of rational discussion."

"I will not be satisfied," Roisman continued, "if nuclear power is killed because

200,000 people in New York could scream louder than the utility executives. It would be just as wrong as it would be for nuclear power to succeed on the basis of money over facts." These words, I emphasize, are those of an outspoken and articulate antinuclear spokesman.

I conclude with a quotation from A. S. McLean, Director of England's National Radiological Protection Board, made during a speech to a Swedish seminar on risk assessment.[15] McLean said, "The impression conveyed was that informed and impartial politicians ought to regard a democratic society's <u>evaluation</u> of risk perception as even more important than qualified, objective risk.

"This is tantamount to saying that it is more important to consider the number of people who would be frightened than the number who would be killed. The conclusion is that we should favor energy production from fossil fuels, which kill more people, rather than from nuclear energy, which frightens more people."

McLean goes on to say, "I can see why short-sighted politicians might approve of this view, assuming that the fears of the public will last at least until the next election. Dead people don't have votes. Frightened people do!"

ABOUT THE AUTHOR

Fred Marsh is an analytical chemist at the Los Alamos Scientific Laboratory and has worked in the nuclear industry for 21 years. He is an active member of the New Mexico Solar Energy Association. He recently modified his conventional home to make it more energy-efficient and installed a woodburning stove, resulting in a two-thirds reduction in natural gas consumption. Marsh was the invited speaker on the subject of woodburning stoves at the 1978 Energy Fair in Los Alamos, sponsored by the League of Women Voters.

The Los Alamos Scientific Laboratory is operated by the University of California for the Department of Energy.

REFERENCES

1. Ford Foundation Nuclear Energy Policy Group, "Nuclear Power: Issues and Choices," p. 163 (1977).
2. G. A. Cowan, "A Natural Fission Reactor," Scientific American, Vol. 235, p. 36 (July, 1976).
3. Time Essay, "The Irrational Fight Against Nuclear Power," Time Magazine, September 25, 1978, p. 71.
4. A. Weinberg, Nature, Vol. 281, p. 335 (October, 1979).
5. Associated Press release, "Three Mile Island Homes Still Selling at Big Profits," Albuquerque Journal, p. B-11, August 23, 1979.
6. Science and the Citizen, "Coal; Prospects and Problems," Scientific American, Vol. 241, p.72 (July, 1979).
7. R. Boulding, "What is Pure Coal?," Environment, Vol. 18, p. 12 (January/February, 1976).
8. L. J. Carter, "Uncontrolled Sulfur Dioxide Emissions Bring Acid Rain," Science, Vol. 204, p. 1179 (June 15, 1979).
9. Los Angeles Times release, "Acid Rain Being Found in Many Western States," Albuquerque Journal, P. A-2, October 6, 1979.
10. J. P. McBride, R. E. Moore, J. P. Witherspoon, R. E. Blanco, "Radiological Impact of Airborne Effluents of Coal and Nuclear Plants," Science, Vol. 202, p. 1045 (December 8, 1978).
11. G. E. Likens, R. E. Wright, J. N. Galloway, T. J. Butler, "Acid Rain," Scientific American, Vol. 241, p. 43 (October, 1979)
12. M. Glantz, "A Political View of CO_2," Nature, Vol. 280, p. 189 (July 19, 1979).
13. G. Voelz, The ATOM, Los Alamos Scientific Laboratory, July/August, 1979, p. 24
14. news item, Nucleonics Week, Vol. 20, No. 40, p. 13 (October 4, 1979
15. news item, "Next Election the Real Risk," Nuclear Industry, May, 1979, p. 29

Reports of Activities Of INMM Members

Ed Kinderman is still at SRI International (formerly Stanford Research Institute). His activities are not now closely related to national safeguards, although he has participated in two proliferation studies recently. Since returning from a two-year resident assignment in England (with travel over the rest of Europe), he has concentrated on studies of markets for new energy technologies and on general energy planning.

E.A. (Ed) Kohler has been employed by Union Carbide Corporation Nuclear Division, at the Paducah Gaseous Diffusion Plant since 1952. Ed has been supervisor of the Uranium Control Accounting group of the Materials Management Section of the Operations Planning Department since June 1976. Prior to that time, Ed served in various positions within the Uranium Control group. Uranium Control is responsible for all actions necessary to assure that all nuclear materials are properly identified and accounted for. In addition to accomplishing the basic accounting function, Uranium Control is responsible for coordinating NM movements and inventories at the request of the Paducah Materials Manager, and entering all required data to the Nuclear Materials Management and Safeguards System (NMMSS) on a timely basis.

B.T. (Bill) Kraemer is employed by Union Carbide Corporation at the Paducah Gaseous Diffusion Plant in Paducah, Kentucky. As supervisor of the Materials Management Section of the Operations Planning Department, he is responsible for the accounting and safeguarding of all nuclear materials at the Paducah Plant. Prior to assuming responsibilities for the Nuclear Material Accounting Section in 1970, Bill had 15 years experience in the Production Engineering and Cascade Operations areas. In 1978 he served as coordinator in the preparation of the IAEA Design Information Questionnaire for the Paducah Gaseous Diffusion Plant. He has been a member of the INMM for 10 years and currently serves on the INMM 8.1 subcommittee for UF-6 mass measurements.

Frank Martin is a member of the technical staff of Sandia Laboratories in the Safeguards Evaluation Division. Frank was recently Technical Manager and Lead Instructor for the 2nd International Training Course on the Physical Protection of Nuclear Facilities and Materials conducted for DOE by Sandia in December, 1979. Frank is a physicist and was formerly with DOE's office of Safeguards and Security as Chief Inspector and later Chief of the Plans and Analysis and Safeguards Implementation Branches. Frank retired from the U.S. Navy as a commander in 1976.

Haruo Natsume is Deputy Head, Division of Chemistry, of the Japan Atomic Energy Research Institute (JAERI).

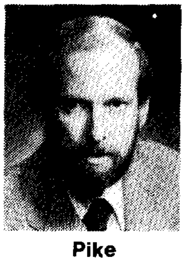
David H. Pike (Ph.D., Industrial Eng., University of Florida, 1970) is the section head of the Systems Analysis Section in the Computer Sciences Division of the Oak Ridge National Laboratory. Prior to assuming this position, he was an Associate Professor of Industrial Engineering at the University of Tennessee. His current research efforts are in the areas of system modeling and time series analysis. His publications have appeared in Trans. of A.N.S., Management Science, I&EC Process Design and Development, and the Journal of the INMM.

Julia M. Smith of Brookhaven National Laboratory has transferred within the Department of Nuclear Energy to the Reactor Engineering Analysis Group. Her primary involvement will be the application of reliability analysis and risk assessment methods to nuclear power plants. Prior to joining BNL in October, 1977 as a statistician in the Technical Support Organization for Nuclear Safeguards, Julie was the statistician in Nuclear Materials Management at General Electric, Wilmington, N.C. and for the U.S.A.E.C. Division of Nuclear Materials Safeguards, Washington, D.C. She has an M.S. in Statistics from Virginia Polytechnic Institute and State University. Julia attended her first annual meeting in 1975 in New Orleans and has been an INMM member since the Cincinnati meeting in 1978.


Kinderman


Martin


Natsume


Pike


Smith

G. Anthony Adams is with the Westinghouse Electric Corp., Advanced Reactors Division, Cheswick, Pa. He has been with Westinghouse for seven years and is presently working in accountability and safeguards. At the present time, he is involved in decontamination and decommissioning of the Plutonium Fuel Development Laboratories. All fuel left at the facility is in shipping containers and ready to be shipped when a DOE site is selected. He is also a member of News Bureau of the INMM Public Information Committee. He has also been nominated for a position with the IAEA in Vienna.

Geoffrey R. Cullington is an Euratom Safeguards Inspector with the Commission of European Communities in Luxembourg. He works in the Basic Concepts Division and is involved in Procedures and Training for Safeguards Implementation. Before joining Euratom in 1974, he worked for the UKAEA on the Dragon high temperature reactor and the Dounreay Fast Reactor before that.

Robert U. Curl has recently completed a two-year assignment as a Safeguards Inspector with the International Atomic Energy Agency, Vienna, Austria. In addition to carrying out safeguards inspections in Western Europe, Bob's responsibilities included functioning as negotiations officer for the United Kingdom offer to come under IAEA Safeguards. Additionally, Bob was involved in negotiating the IAEA Safeguards provisions for a number of western European facilities. Upon returning to the United States last October, Bob accepted a position with EG&G Idaho, in Idaho Falls, Idaho, as Manager, Safeguards and Materials Management Branch. While Bob enjoyed the application of Safeguards at the international level, he is glad to be back and is looking forward to renewing old acquaintances in West Palm Beach.

Dr. **Paul De Bievre** is heading the Mass Spectrometry Laboratory of the European Commission at Geel, Belgium and has been coordinating CBNM's involvement in Safeguards which is mostly related to Reference Materials and Measurements. His main field of activity is in development and application of precise and accurate isotopic measurement techniques. With his team, he developed an accurate assay method for fissile isotopes in undiluted inputs of reprocessing plants and works on Isotopic Reference Materials for the European Community. He chairs the ESARDA Working Group on Destructive Analysis, a forum where almost all European Laboratories measuring U and Pu regularly meet. He is also Chairman of IUPAC's Subcommittee on the Assessment of the Isotopic Composition of the Elements (SAIC) and a titular member of IUPAC's International Commission on Atomic Weights. He has a Ph.D. in Chemistry from Gent University and teaches at Antwerpen University.

John C. Chinault is a quality assurance engineer in the Westinghouse Nuclear Fuel Division's fuel fabricating site at Columbia, S.C. His primary responsibilities are in the measurements control program, safeguards and statistics. He has a physics and math background and did his graduate work at Brown University.

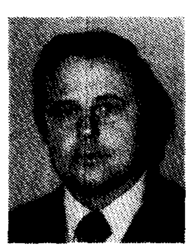
Mitshu Hirata is a nuclear scientist with the Japan Atomic Energy Research Institute, Tokyo in the Program Planning Office, and serves as the Associate Director. His primary activities have been in support of domestic and international safeguards systems analyses at the Institute. He has been an advisor for the Science and Technology Agency of INFCE studies. He is also Secretary of the Japan Chapter of the INMM.

Robert J. Gregg is Quality Assurance Manager of UNC Recovery Systems, a Division of United Nuclear Corporation, located in Wood River Junction, Rhode Island. Bob has spent over twenty years in the nuclear industry, with extensive management experience in process and development engineering, project management, quality control and nuclear materials. In his current position, he is responsible for all quality assurance programs at UNC Recovery Systems, including all aspects of nuclear material management.

Etienne A. A. Van der Stricht is with one of the inspectors' divisions of the European Community Safeguards Directorate in Luxembourg. He joined the Euratom Safeguards in 1970 after having been active in the field of environmental radioactivity measurement and evaluation since 1962 at the Joint Research Centre of the Commission in Ispra, Italy and at the Brussels headquarters. Present assignments are focused on safeguards implementation in fuel fabrication plants. He has also been involved in training of inspectors, health physics for inspectors, installation of safeguards equipment in the facilities, evaluation of material balances and evaluation of the results from the chemical analysis. Before joining the Commission of the European Communities, he worked for six years at the Belgian Research Centre in Mol, mainly on radioactive fallout. Although a chemist, his personal interest is statistical evaluation of data and use of statistics in safeguards.

Adams

Cullington



Curl

De Bievre

Hirata

Members of INMM Executive Committee Take Special Safeguards Tour of GE-Wilmington

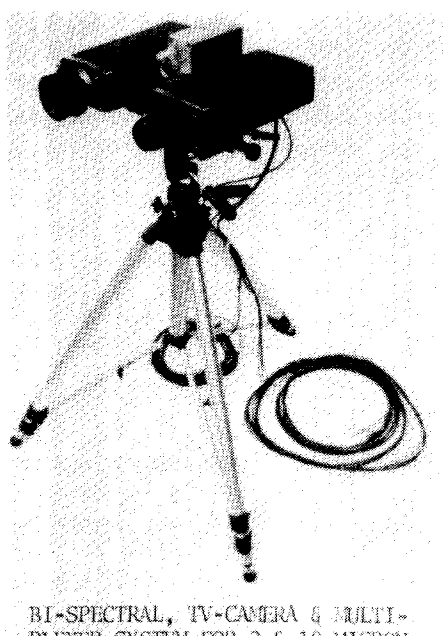
Six members of the INMM Executive Committee, the Chariman of its Pacific Northwest Chapter and the Editor of this Journal were given a special safeguards tour on April 17 of the nuclear fuel fabrication plant operated by the General Electric Company Nuclear Division at Wilmington, North Carolina.

The tour which followed the regular two-day meeting (April 15-16) of the INMM Executive Committee was given by four GE safeguards professionals — **Ron Church, Wally Hendry, Charlie Vaughan** and **Fred Walker.** Mr. Hendry gave an overview presentation of the MICS (Manufacturing Information Control System) which includes some 90 terminals on which to track the flow of nuclear materials through the plant. The key points of his talk were:

- The system provides a common data base for all manufacturing functions.
- Interactive terminals minimize operator input errors.
- System logic prevents operational (e.g. quality, SNM inventory control) problems.
- Real time system assures up-to-date information.
- Synergistic effect of multi-functional use results in an excellent overall safeguards system.

The INMM contingent — **Bob Keepin, Gary Molen, Ed Owings, Roy Cardwell, Yvonne Ferris, Frank O'Hara, Roy Nilson** and **Tom Gerdis** — were given a factory tour which concentrated on operation of the safeguards system. Those who took the tour were very impressed with the quality of the safeguards system and the practical safeguards expertise at GE-Wilmington.

Bi-Spectral Video Imager



BI-SPECTRAL, TV-CAMERA & MULTI-PLEXER SYSTEM FOR 2 & 10 MICRON WAVEBAND SERVICE

Unique spectrographic detail may be obtained from a bi-spectral video-scanning view of close up or distant phenomena when the presentation is made at common scale on a synchronous time base. A family of video imaging cameras, manufactured by Image Technology Methods Corp. of Waltham, MA 02154, provides spectrally-filtered, synchronous TV-pictures for any two wavebands from 0.2 to 40 microns.

Spectral data, from a dual camera facility, is adjusted to common scale and multiplexed into a standard video cassette recorder and dual TV-monitor facility. Demultiplexing provides superimposed, side-by-side and individual channel viewing under manual switch command.

Analyzer and image digitizer modules for densitometric film and scan recording analyses and for multispectral, thermographic and spectrographic emissive imaging applications are described together with filterable video scanning sensors in the company's short form catalog, PD-110-4.

Technical Assistance to IAEA Safeguards: The Canadian Program

C. W. Zarecki, R. M. Smith, D. A. Head, R. M. Duncan

INTRODUCTION

For many years the policy of the Canadian government has been that the export of nuclear material, facilities, and equipment is conditional on an agreement between Canada and the receiving State which prohibits military uses. When the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was established in 1970, Canada was one fo the first to ratify it and to accept the International Atomic Energy Agency (IAEA) inspection at its nuclear facilities. As a member of the Nuclear Suppliers Group, Canada supports and enforces the requirement for the application of safeguards to all exported strategic nuclear materials, facilities, equipment, and technology. Canada now requires that agreements for such exports be made only with countries which are signatories of the NPT or which accept equivalent full-scope safeguards.

It is recognised that these policies place considerable reliance upon the IAEA. As these policies were being established, Canada appreciated that the IAEA's Department of Safeguards would need new equipment and techniques to be able to effectively apply the required safeguards, and that the IAEA's financial and manpower resources were insufficient to apply effective safeguards to all types of nuclear facilities in a reasonable time. Thus, for the past five years, Canada has been assisting the IAEA in the development of safeguards schemes, equipment, and techniques relevant to the CANDU and other Canadian-designed reactors. The provision and installation of equipment, the supply of technical experts on a cost-free basis to the IAEA, and investigations of safeguards problems have also been included in the support given. This technical support is carried out under the umbrella program known as "Canadian Safeguards Research and Development in Support of the IAEA" (1). The program is jointly run by Atomic Energy of Canada Limited (AECL) and the Atomic Energy Control Board (AECB).

SCHEMES

As a very effective part of the program, assistance in the development of nuclear facility safeguards schemes has been given by a Canadian expert to the staff of the IAEA at no cost to the Agency. Throughout the terms of the Program, Canada will continue to make cost-free experts available, as required.

In the implementation of an international safequards system, material accountancy is considered to be the most important safeguards measure, with containment and surveillance as important complementary measures. The IAEA has had, for a number of years, a scheme by which safeguards can be applied to LWR reactors. More importantly, the equipment to implement the scheme is, generally speaking, available. The CANDU reactor differs from the LWR reactor in many ways, and in the safeguards sense the most important difference is on-power refuelling. On-power refuelling and the resultant use of small easily-handled fuel units created many unique problems for instrumented safeguards. Generally speaking, the equipment to implement the scheme was not available. One of the first requirements in assisting the IAEA to develop effective safeguards for the CANDU system was, therefore, to develop a safeguards scheme which could be implemented using equipment that is available now or which could be developed in the near term.

In CANDU stations the fuel is packaged in units, known as bundles, each of which is relatively small (about 20 kg). Because of their small size, the throughput of fuel bundles must be large to maintain the station at its rated power (for example, at one 2000 MW station approximately 1000 fuel bundles are discharged each month). As well, the spent fuel storage bays of commercial CANDU power stations typically have a capacity of tens of thousands of fuel bundles, and the bays of some large multi-unit stations can contain hundreds of thousands of bundles. These large numbers have important implications for instrumented safeguards and material accountancy, as follows:

i) The fuel bundles are essentially identical and each contains approximately the same amount of natural uranium. Under these conditions, material accountancy can become item accountancy, which can simplify the safeguards task to one of counting and attribute verification of the items. This must, however, be done for the throughput on a continuous basis and for the inventory on an annual basis.

ii) The amount of plutonium contained in the irradiated fuel can be estimated from the data on the power history of the bundles. The material accounting records for unirradiated fuel can be verified by counting the number of bundles in storage and checking some on a random basis by non-destructive analysis. The records for irradiated fuel must be verified by counting the number of bundles removed from the reactor, and again counting the bundles stored in the irradiated fuel bays.

iii) Relief must be provided to the problems of counting a large number of bundles. Sealing the fuel in the irradiated fuel storage bay can provide this relief. If the inventory is divided into a few blocks and each block is sealed using a seal that has both identity and integrity functions, later verification of the seal would then constitute an adequate verification of the contents of the inventory block.

In conjunction with the IAEA, Canada developed the general concept of CANDU safeguards at the Douglas Point Nuclear Generating Station in Ontario. This part of the program included the development of prototypes of the equipment needed to show the concept was practical. This scheme and the equipment are described in reports prepared jointly by IAEA, AECL and AECB staff (2, 3). Important features of the concept include:

i) on-line counting and recording of the net flow of irradiated fuel from the core;

ii) surveillance of areas within the station where nuclear material is handled and/or stored;

iii) sealing of the stock of irradiated fuel in the storage bay, and

iv) overlap of systems in such a way that redundancy is obtained.

Based on the work done at Douglas Point, a detailed scheme was devised for safeguarding the nuclear material within the 600 MW CANDU generating stations, a model presently under construction in Canada and abroad. The greatest emphasis is placed upon the irradiated fuel, since it contains plutonium, but safeguards are also planned for the fresh natural fuel. The scheme was developed in collaboration with the IAEA, and has been accepted by the Agency as one way in which safeguards can be adequately applied in the 600 MW CANDU.

Work on scheme development continues in the program, but the focus of attention has shifted to the large multi-unit power stations now in operation in Canada. This is an area of considerable interest to the IAEA since there are two multi-unit stations now in operation (2000 and 3000 MW, respectively) and three under construction (one 2000 MW and two 3000 MW). The IAEA has taken the lead in conceiving cost-effective ways of implementing adequate safeguards, and Canada is providing the technical and engineering resources with which options and needs are analyzed and feasibilities are considered.

EQUIPMENT

Although the equipment needed to implement the basic concepts had been demonstrated in the Douglas Point program, the prototypes did not have the reliability or level of performance required to give the IAEA the high degree of assurance which it subsequently identified (i.e. 95% confidence that the system is capable of detecting diversion).

For the 600 MW CANDU, it was necessary to bring these prototypes to a very high level of reliability, to design for ruggedness of construction, and to ensure they met the relevant safety standards. In addition, modifications were required to adapt the instruments to the particular features of the 600 MW. Once this work was completed, production models were manufactured for use in the CANDU 600 MW reactors. Some of this equipment is described below:

a) **Film Surveillance Camera**

In the 600 MW stations, film cameras are required in the fresh fuel loading area to detect, by the use of a radiation level triggering mechanism, any attempt to divert irradiated fuel through this room. Film cameras which require motion detection capability are needed in the irradiated fuel storage area.

The CANDU film surveillance camera was developed by Atomic Energy of Canada Limited Engineering Company and produced by G. Kelk Ltd., a Canadian Engineering firm. It uses a Minolta Super 8 camera as the heart of the system with a number of peripheral features, the most unique of which include a date/time display on each frame, a choice of random or fixed interval time triggers, a motion-detection trigger, and a gamma radiation field trigger. It was decided to develop this camera since the models available to the IAEA did not have these very useful features.

The camera was designed to meet the following tests and specifications:

i) high temperature test to 50-55 degrees C;

ii) humidity test — 21 degrees C and 95% humidity for 4 hours; 480 hours in 20 cycles up to 95% humidity and 50-55 degrees C;

iii) seismic tests;

iv) Mean Time to Failure (MTTF), 10,000 hours.

(b) **Closed Circuit Television (CCTV)**

The 600 MW scheme calls for surveillance in the reactor vaults, the fuelling machine rooms, and the storage bay. The first two of these areas present significant difficulties because of high radiation fields and inaccessibility during reactor operation. Other requirements are a high-capacity picture storage, on-the-spot review capability, high system reliability, and high tamper-resistance.

To meet these criteria the CCTV system was developed and produced by a Canadian engineering firm, working under the direction of Atomic Energy of Canada Limited Engineering Company.

The high reliability criterion reflects the requirements of unattended operation, with intermittent visits by the IAEA inspector to review results at intervals that may be as long as 100 days. The overall reliability goal required the entire system to have a reliability of 90 percent for any 100 day period (i.e. MTTF is about 850 days). This level of reliability is achieved by using a micro-computer to monitor each function or subsystem. When a failure is detected, it can either switch to a back-up component or by-pass the function, as required. There is a back-up unit available for each type of equipment in the system, including the disc recorders, the videotape recorders, the motion-detectors and the micro-computer. The only exceptions are the video cameras where reliability is obtained by using high quality units and preventive maintenance.

Difficulties with high radiation fields are overcome by using radiation-resistant cameras containing the minimum number of electronic components. Wherever possible, electronics and control functions are removed from the camera and placed in the central control station.

The system is capable of recording 100,000 pictures (frames) between inspection visits, and these can be reviewed in-situ at the central control station by the inspector. Alternatively, the videotape can be removed and returned to Vienna for review.

This CCTV system was developed because it was felt the CCTV system in use by the IAEA would not meet the requirements for reliability or radiation resistance.

(c) **Bundle Counters**

The concept of a device to count and record the net flow of fuel bundles discharged from the reactor core and sent to the storage bay predates this program. The first instrument capable of doing this was a prototype built by Sandia Laboratories installed in the Pickering Generating Station of Ontario Hydro under the old TRUST program of the early 1970's. While this prototype demonstrated the concept, the ease of its operation and its maintenance required upgrading for an operational safeguards instrument. A second Sandia prototype installed at the Douglas Point Station showed that there were solutions to problems involving its use. It was for the 600 MW CANDU that we developed the first industrial, highly tamper-resistant and tamper-indicating instruments. The 600 MW bundle counter was developed and produced at Chalk River Nuclear Laboratories. The counting is accomplished by Geiger tubes located near the fuel flow path close to the point where the fuel bundles are discharged from the core. Signals from these tubes are taken to a remote electronics package, located in an area which is accessible even when the reactor is at power. The electronics package includes logic functions which analyse the signals from the tubes (i.e. duration of signals and order of appearance) and decide whether the transfer is normal, the number of bundles transferred, and the direction of transfer. All this information is recorded along with the date and time of the transfer. Using information from this log, the IAEA inspector can independently verify the operator's fuelling records. A small "watchdog" source is placed near each Geiger tube so as to continuously monitor the condition of the connecting cables and the Geiger tubes.

(d) **Containment-Sealing Equipment**

As indicated above, sealing of the irradiated fuel in-place in the storage bay is an important part of the safeguards scheme. Two techniques have been developed for sealing. In the first, an expanded metal mesh cage is used as a box into which the trays or baskets containing the irradiated fuel bundles are placed. Once full, a top can be applied to the cage and a seal applied. The second concept uses the fact that, in some tray designs, the stack of trays itself forms a containment shell. In such cases a rod fixed to the bottom of the stack reaching up to a cover placed on top of the stack is used to lock the stack together to prevent the undeclared removal of fuel bundles. A seal can be applied to the locking mechanism to ensure the integrity of the containment shell.

The seal used must be capable of being applied and of being verified underwater at depths of about four metres, as the top bundles in the stack are stored under this depth of water. The seal under development for this task is a cap-and-stud type containing an ultrasonically readable zone — it is being developed by Atomic Energy of Canada Limited Engineering Company, in cooperation with the Joint Research Centre of the Commission of the European Communities at Ispra, Italy. The seal has several features including relative ease of application, and the fact that verification of the identity includes verification of the integrity. Production models of the equipment described above have been built or are nearing completion for use in the four 600 MW stations presently under construction in Canada and abroad. In-situ testing of the various pieces of equipment in a 600 MW station is scheduled for this fall.

Training programs have been, or are being, conducted in Vienna. These programs include equipment demonstration as well as equipment operation and maintenance training. We feel that training is an essential part of the equipment acceptance procedure as it ensures that the equipment will be maintained and operated in the manner for which it was designed.

A number of other types of equipment are under development, including devices for measuring some attributes of irradiated fuel. At the present time, two types of attribute verifiers of irradiated fuel are being examined. One device uses gross gamma measurements, while the other uses Cerenkov radiation measurements. The development is not complete, but present tests indicate that there should be no major difficulty in producing the operating equipment. However, we expect that for many of these devices the success of its application will depend on the ingenuity with which the concept is applied to the civil and mechanical details of the particular plant. Our experience has been that at least half the problem (and cost) is involved in applications engineering.

SAFEGUARDS STUDIES

At the request of the IAEA, various studies have been, or are being, undertaken. Some of these are:

Study of Cerenkov Radiation as an Attribute Test for Identifying Fuel Bundles as Irradiated Fuel.

Study of the Non-Destructive Analysis of Irradiated Fuel and Determination of Fissile Contents.

Study of Methods of Uniquely Identifying Fuel Bundles.

Study of Methods of Applying Safeguards to Heavy Water in Nuclear Generating Stations.

Study of the Use of Reactor Operating Records for Verification of Reactor Core Inventories.

INTERACTION WITH THE IAEA AND OTHER ORGANIZATIONS

As is the case with many interorganizational programs, success or failure depends upon establishing both effective communications and a spirit of cooperation among the groups. In terms of working with the IAEA, it is imperative that we obtain advice and opinions from safeguards staff members in both the operations and development divisions. The operations staff have a wealth of information on the practical problems involved in the implementation of safeguards. During the development phase when obtaining operational equipment, it is particularly useful to expose a prototype of the device to the IAEA for its evaluation.

We have found that communication with the Agency can be effective if there are intermittent contacts at the technical level, as required, coupled with semi-annual formal meetings for review of the total program. Additionally, the operational viewpoint is obtained through a formal consultation procedure now in place between the IAEA and AECB operations groups in which all aspects of safeguards implementation problems are discussed.

Wherever practical, Canada maintains liaison with other foreign organizations involved in the development of safeguards equipment, such as the U.S. International Safeguards Project Office, Sandia *Laboratories*, Joint Research Centre of the Commission of the European Communities at Ispra, Italy, and the European Safeguards Research and Development (ESARDA) Containment-Surveillance Working Group. This avoids duplication of effort and ensures that all organizations concerned reap the benefit of research done by others.

CONCLUSIONS

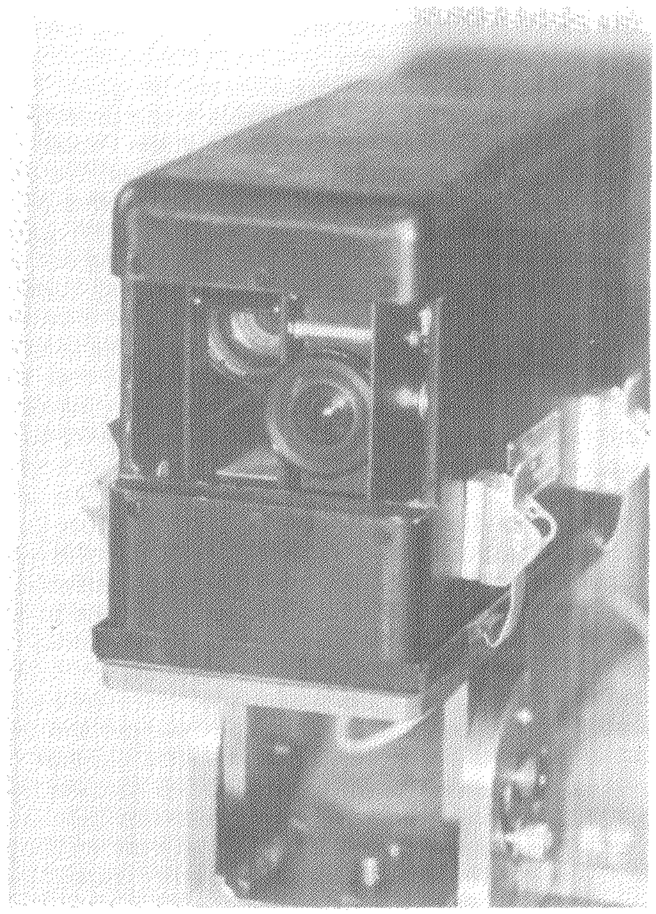
The application of effective safeguards by the IAEA is essential for the peaceful development and use of nuclear energy. Canada, together with other nations, recognizes the need to assist the IAEA In the development and provision of safeguards equipment required for effective safeguards. Canada's program of assistance to the IAEA currently meets this need in the form of technical expertise, equipment development, purchase and installation, and a continuing research and development program in support of improved equipment and procedures.

REFERENCES

(1) "Canadian Safeguards Research and Development in Support of the IAEA: Program Document" outlining the tasks which comprise the Program, D. A. Head, AECB-1136, Rev. 1. 1980 January.

(2) "Safeguarding On-Power Fuelled Reactors — Instrumentation and Techniques", A. Waligura et al, AECL-5712. 1977 May.

(3) "A Safeguards Scheme for 600 MW CANDU Generating Stations", D. Tolchenkov et al, IAEA-SM-231/109. 1978 October.



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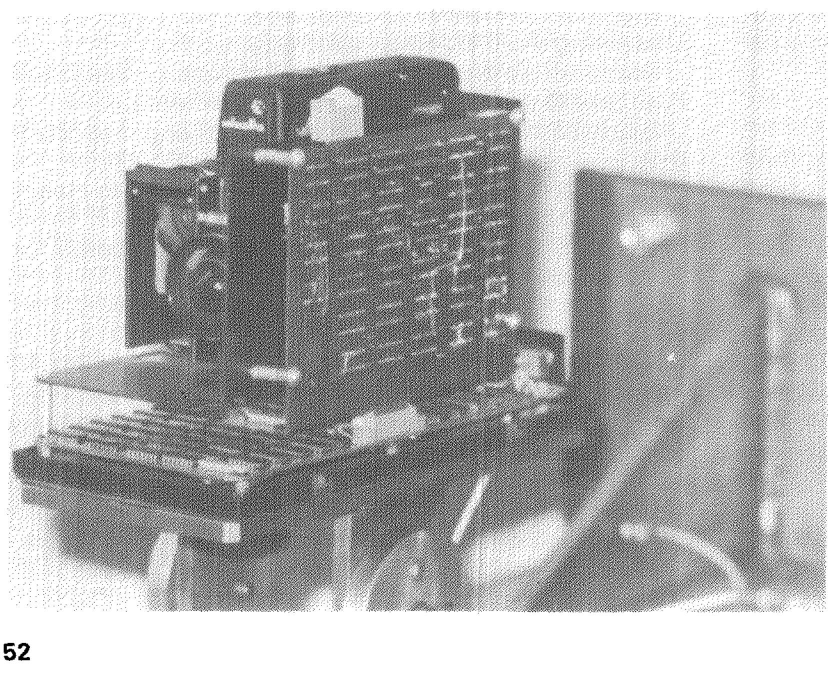

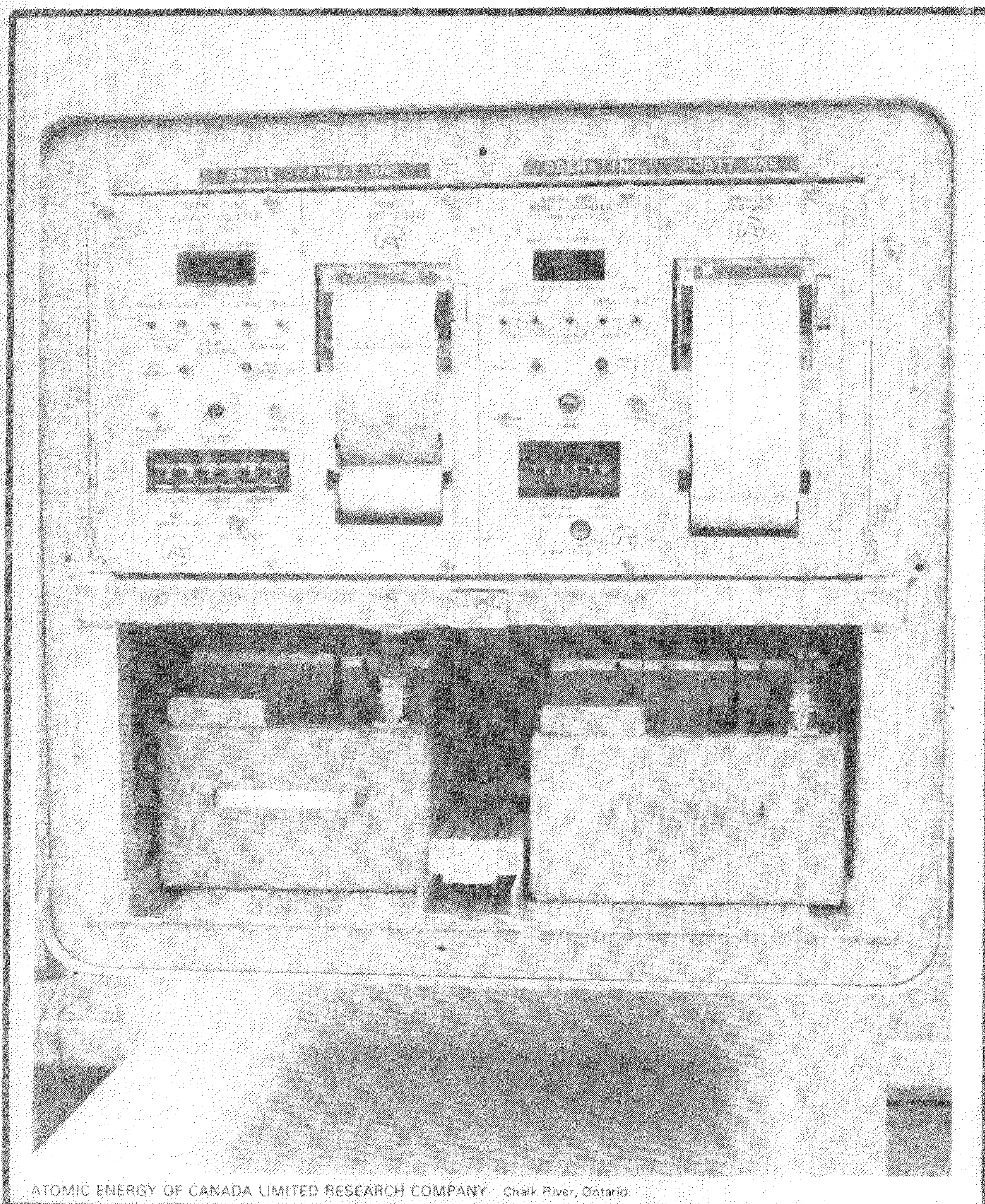

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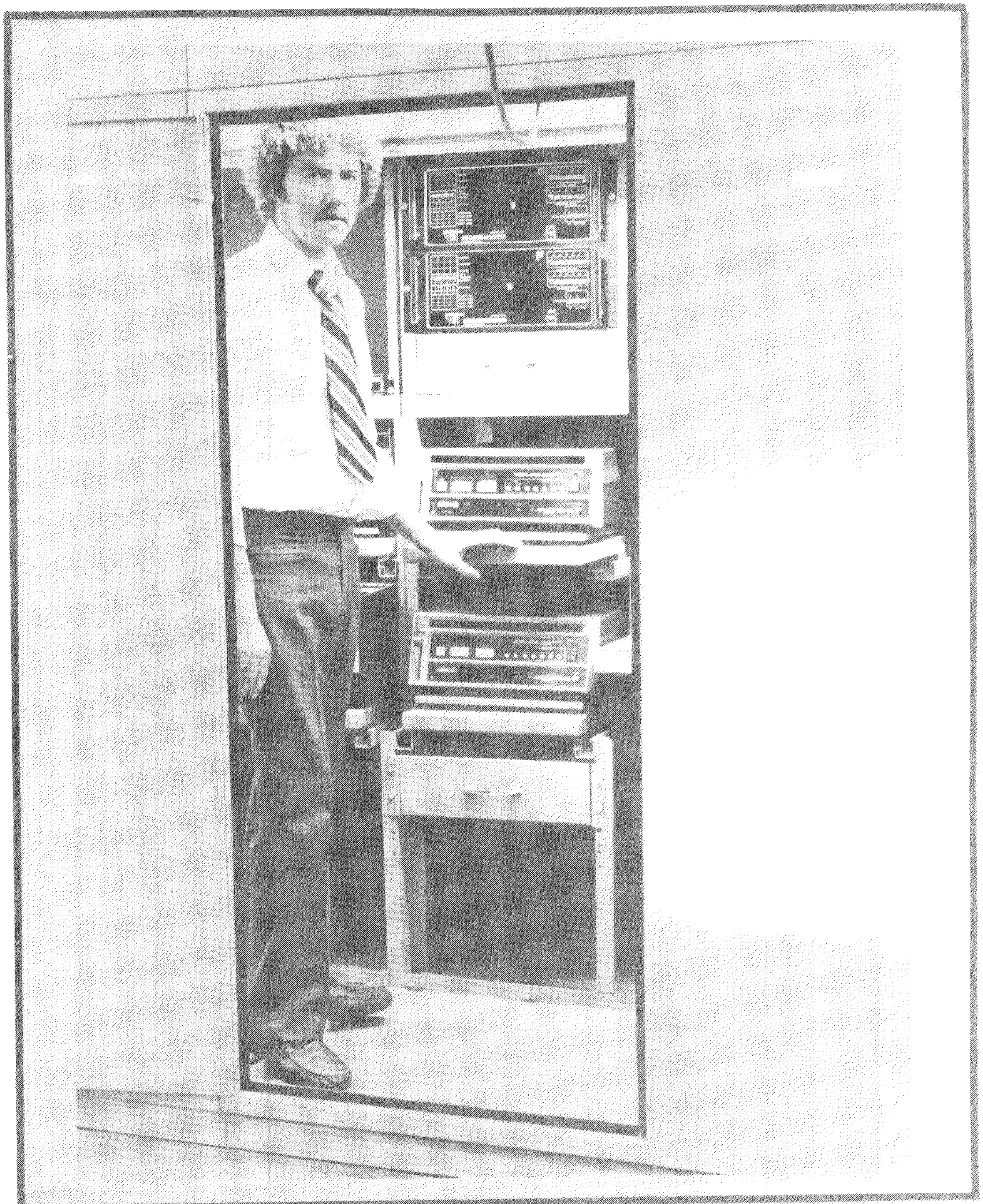
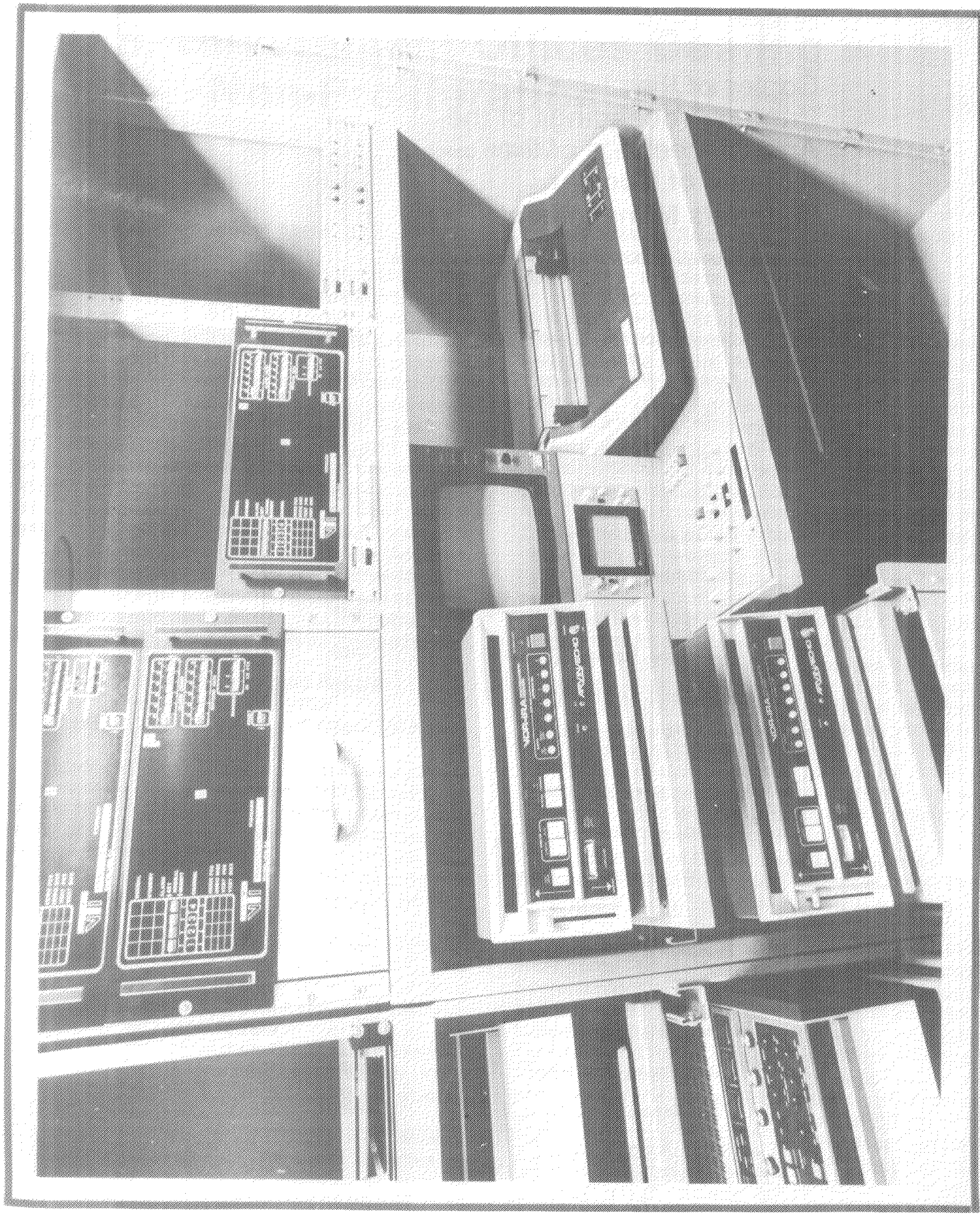


CCTV SYSTEM CONTROL ROOM



EQUIPMENT IN CCTV CONTROL ROOM

U.S. Government Offices Dealing with Non-Proliferation Matters

Joerg H. Menzel

Department of State

The focus of U.S. non-proliferation policy is provided in the Office of the Secretary of State by the Ambassador at Large and Special Representative of the President for Non-proliferation Matters **Gerard C. Smith** and in the Bureau of Oceans and International Environmental and Scientific Affairs by Assistant Secretary **Thomas R. Pickering.** Principal support on non-proliferation matters comes from the Deputy Assistant Secretary for Nuclear Energy and Energy Technology Affairs and the four offices under his direction. Additional support is provided by one of the offices in the Bureau of Politico-Military Affairs as well as designated staff members in the Secretary's Policy Planning Staff (S/P), the office of the Under Secretary for Security Assistance, Science and Technology (T), the office of the Legal Advisor (L), the Bureau of Intelligence and Research (INR), the Bureau of International Organization Affairs (IO), and others as the need arises.

Ambassador at Large and Special Representative of the President on Nonproliferation Matters (S/AS)

Ambassador at Large and Special Representative of the President for Non-proliferation, Gerard Smith, has a mandate from the President, under the direction and authority of the Secretary of State, to coordinate and guide U.S. efforts internationally to carry out non-proliferation policies and to be responsible for negotiations to that end. He is further responsible for general co-ordination and development of U.S. non-proliferation policy. He is also U.S. Representative to the International Atomic Energy Agency (IAEA), and was U.S. Representative for the recently concluded International Nuclear Fuel Cycle Evaluation (INFCE). Gerard Smith was previously a member of the Washington law firm of Wilmer, Cutler and Pickering. From 1969 to 1972, he was Director of the U.S. Arms Control and Disarmament Agency (ACDA) and chief of the U.S. SALT delegation.

S/AS is in the Office of the Secretary of State. It consists of the Ambassador and three Deputies — **George Rathjens** (Professor of Political Science at MIT), and **Frank Hodsoll** and **Allen Locke** (career State Department officials). Messrs. Rathjens and Hodsoll have concentrated on INFCE and general non-proliferation policy. Mr. Locke has concentrated on bilateral issues.

Assistant Secretary, Bureau of Oceans and International Environmental and Scientific Affairs (OES)

In addition to his responsibilities as head of the Bureau of Oceans and International Environmental and Scientific Affairs, Assistant Secretary Thomas R. Pickering is the Chairman of the National Security Council (NSC) Ad Hoc Group on Non-Proliferation. In that capacity, Mr. Pickering assumed the functions performed by Dr. Joseph Nye at the start of the Administration and is charged with coordinating interagency implementation of U.S. non-proliferation policy. Mr. Pickering draws his primary support from the offices listed above plus the Bureau of Non-Proliferation in the Arms Control and Disarmament Agency.

Mr. Pickering is a career diplomat who was appointed as Assistant Secretary of OES in 1978. Previously he was the U.S. Ambassador to the Hashemite Kingdom of Jordan, served as Special Assistant to the Secretary of State and the Executive Secretary of State, and was Deputy Director of the Bureau of Politico-Military Affairs. From 1961-1964 he served as political adviser of the U.S. delegation to the Eighteen-Nation Disarmament Conference in Geneva. Mr. Pickering's educational background includes Masters Degrees from the Fletcher School of Law and Diplomacy and from the University of Melbourne.

Bureau of Oceans and International Environmental and Scientific Affairs, Nuclear Energy and Energy Technology Affairs (OES/N)

The Deputy Assistant Secretary for Nuclear Energy and Energy Technology Affairs reports to the Assistant Secretary for Oceans and International Environmental and Scientific Affairs (OES) and provides principal support in the Department of State to the Assistant Secretary and to the President's Special Representative for Non-proliferation in the areas of non-proliferation and nuclear export policy. He is responsible for supervising the activities of the Offices of Non-Proliferation and Export Policy, Nuclear Technology and Safequards, Nuclear Export and Import Control, as well as the Office of Energy Technology Cooperation. In addition, under the delegation of authority under procedures implementing the Nuclear Non-Proliferation Act of 1978 (NNPA), he is responsible for co-ordination of Executive Branch review and recommendations to the Nuclear Regulatory Commission of all nuclear export license applications. He also has principal responsibility for renegotiation of over 20 existing agreements for nuclear cooperation and all new agreements in accordance with the requirements of the Nuclear Non-Proliferation Act.

The Deputy Assistant Secretary for Nuclear Energy and Energy Technology Affairs is Mr. **Louis Nosenzo** who joined the Department of State in 1973 and has served in his current position for over three years. Prior to that, he was Director of Nuclear Policy and Operations in the Bureau of Politico-Military Affairs. Before coming to the Department, his professional background included extensive technical and management experience in system analysis of strategic and tactical warfare, and in ballistic missile and space systems planning. Mr. Nosenzo's educational background includes a Bachelor of Electrical Engineering degree from Cornell University, graduate work in Meteorology, and a Masters Degree in Aeronautics and Astronautics.

The **Office of Non-Proliferation and Export Policy (OES/NEP),** as its title implies, is responsible for policy development and execution in the area of nuclear non-proliferation. Among its major tasks is to renegotiate over 20 international agreements for nuclear cooperation to incorporate requirements of the NNPA and the Administration's non-proliferation policy. The office also handles specific non-proliferation problems, oversees policy aspects of U.S. international cooperation in the peaceful uses of nuclear energy, and develops export policy governing supply of nuclear materials, equipment, and technology abroad. The Director of NEP is **Michael Guhin,** who spent six years on the National Security Countil staff covering nuclear energy, science and technology, and arms control issues, and two years at NRC as the first Assistant Director for Export-Import and International Safequards.

The **Office of Nuclear Technology and Safeguards (OES/NTS)** is responsible for policy and program development in the areas of international nuclear technology cooperation, nuclear safeguards, physical security of nuclear facilities and materials, and all matters involving the nuclear fuel cycle. This includes policy and measures to deal with sensitive technologies (e.g., reprocessing, enrichment, and heavy water production) and international issues related to spent fuel storage and waste management. U.S. support for IAEA safeguards and the follow-up work to the International Nuclear Fuel Cycle Evaluation (INFCE) are the responsibility of this office, as is foreign policy input to budgetary decisions related to the U.S. nuclear program and U.S. participation in other international fora dealing with nuclear energy. The Director of NTS is Dr. **John Boright,** a physicist who has worked on nuclear and non-proliferation policy issues since 1970, in the State Department, ACDA, and at the U.S. Mission to the IAEA.

The **Office of Nuclear Export and Import Control (OES/NEC)** carries out the export licensing responsibilities that were specified for the Secretary of State by the Nuclear Non-Proliferation Act of 1978 (NNPA). The Act requires the Department of State to coordinate the Executive Branch position on export license requests and to make a determination that the license, if issued, meets the criteria of the NNPA and is not inimical to the common defense and security. This involves close collaboration with the Departments of Commerce, Defense, and Energy, the Arms Control and Disarmament Agency, and the Nuclear Regulatory Commission. The Director of NEC is **Gerard Helfrich,** a nuclear engineer who has over 25 years experience in senior positions with DOE and its predecessor agencies ERDA and AEC, including 4 years as AEC Scientific Representative in Tokyo.

The **Office of Energy Technology Cooperation (OES/NTC)** serves to round out U.S. international energy strategy by (1) establishing cooperative energy technology development projects with other industrialized countries for the purpose of reducing medium-term and long-term reliance on oil imports; (2) forging links between oil exporters and importers by using the intellectual and financial resources of both sides to work on the energy technology problems of the future; and (3) meeting the energy needs of the energy deficient developing countries through programs to adapt existing technology and develop new technologies specifically directed at their needs. The office provides foreign policy guidance for the collaborative technology development work taking place in the OECD's International Energy Agency, works with the Department of Energy in setting up new cooperative activities with countries of special interest, and develops new proposals and programs that provide assistance to developing countries whose economic growth has been slowed by high-cost oil imports. The Director of NTC is **Martin Prochnik,** a geologist by training who has been involved in international energy activities since 1971.

Bureau of Politico-Military Affairs, Office of Non-Proliferation Policy (PM/NPP)

This office specializes in the arms control and national security dimension of the nuclear proliferation problem as distinct from its scientific, technological, and energy-related aspects. For example, in cooperation with the other eight offices in the Bureau of Politico-Military Affairs, PM/NPP pays particular attention to the role of our alliance relationships and security assistance programs in our non-proliferation policy. In addition, this office has the lead in formulating State Department policy regarding the NPT and the non-proliferation aspects of other arms control agreements, such as the Comprehensive Test Ban currently under negotiation.

PM/NPP's participation in nuclear export control policy includes primary responsiblity within State for issues related to the Nuclear Suppliers Group. The office also works on the international transfer of conventional weapons munitions using nuclear source material (e.g., depleted uranium).

Other responsibilities of this office include: the international transfer to non-NATO countries of advanced civilian or military technology which could be used for developing or delivering nuclear weapons; the international aspects of the nuclear testing programs of the U.S. and of our allies; and international nuclear incidents, such as accident or theft, involving

U.S. deployed nuclear weapons.

The Director of PM/NPP is **Marvin Humphreys,** a career foreign service officer with experience in politico-military and arms control matters at both the State Department and ACDA.

U.S. Government Offices Dealing with Non-Proliferation Matters: Arms Control and Disarmament Agency

Halting the acquisition of nuclear weapons by additional countries is one of the most important arms control objectives of the international community and of the U.S. Government. Nuclear non-proliferation is an essential element of U.S. national security and of the desires of many nations to reduce the risks of nuclear war. For these reasons, efforts to deal with proliferation risks are among the highest priorities of the Arms Control and Disarmament Agency whose Director is, by law, the principal adviser to the Secretary of State, the National Security Council, and the President on arms control and disarmament matters. Activities in this area of arms control are centered in the Non-Proliferation Bureau of ACDA.

The Bureau of Non-Proliferation (ACDA/NP)

The Bureau of Non-Proliferation, one of four Bureaus in ACDA, has technical and policy responsiblitities with respect to curbing the proliferation of nuclear weapons and explosives. It has operational responsibilities for negotiation in this area, and interacts with other U.S. agencies on non-proliferation issues. The Bureau is also responsible for the formulation and management of external research projects in support of these activities. The bureau is headed by the Assistant Director for Non-Proliferation, appointed by the President and confirmed by the Senate. This position is held by Mr. **Charles Van Doren,** a lawyer who has dealt with non-proliferation matters at ACDA since 1962. The Deputy Director is Dr. **Robert Rochlin,** a nuclear physicist, who has worked on nuclear arms control matters at ACDA since 1963.

The organizational units within the Bureau of Non-Proliferation are the Nuclear Exports Division, the Nuclear Safeguards Division, and the Nuclear Energy Division. The staff consists of foreign affairs officers and physical scientists who work closely together on the range of complex technical and policy issues.

The **Nuclear Exports Division (NP/NX)** provides advice, assessments, and policy recommendations on the international relations aspects of non-proliferation. The Division is responsible for U.S. bilateral initiatives concerning countries of particular non-proliferation interest; for multi-national initiatives, including supplier country policies; for encouraging additional adherence to the Non-Proliferation Treaty and nuclear free zone agreements; for non-proliferation aspects of related arms control measures such as testing limitations; for participation in the negotiation of U.S. bi-lateral nuclear agreements for cooperation; for preparation of Nuclear Proliferation Assessment Statements pursuant to the Nuclear Non-Proliferation Act of 1978; and for development of U.S. nuclear export policies and procedures, including the application of physical security provisions. Mr. **Richard Williamson,** a former Foreign Service Officer, is the Division Chief.

The **Nuclear Safeguards Division (NP/S)** provides scientific and technical analysis, advice, and policy recommendations on matters related to the safeguards system of the International Atomic Energy Agency (IAEA) and to the safeguards aspects of nuclear fuel cycles, facilities, equipment, and materials. The Division seeks to strengthen the effectiveness of the IAEA safeguards system by affecting relevant agreements, procedures, and national support and by assuring adequate IAEA safeguards criteria, resources, evaluation procedures, implementation, and reporting. In support of international safeguards objectives, the Division also manages the major portion of the Bureau's external research program. The Division Chief is Dr. **Joerg Menzel,** who started work on safeguards in 1968 at Los Alamos Scientific Laboratory and served at IAEA before joining ACDA in 1976.

The **Nuclear Energy Division (NP/NE)** provides scientific, economic, and technical analysis, advice, and policy recommendations on domestic and international questions affecting non-proliferation. The division assesses the arms control implications and fosters the development of proliferation resistant alternatives for nuclear fuel cycles and advanced nuclear technologies. In addition, the Division provides technical support to the Nuclear Exports Division on matters concerning U.S. nuclear exports and to the Nuclear Safeguards Division on characteristics of the nuclear fuel cycle which affect international safeguards. The Division also manages a comprehensive external research program in support of these activities. The Division Chief is Dr. **O. James Sheaks,** formerly Associate Professor for Nuclear Engineering at the University of Maryland and consultant to NRC on LWR safety.

Editor's Note: The above descriptions of the offices and individuals associated with non-proliferation matters in The Department of State and ACDA, were kindly submitted by Dr. Joerg Menzel and his associates in ACDA. The Department of Energy and the Nuclear Regulatory Commission play supporting roles and the Office of the President plays a key role in developing non-proliferation policies. In a future issue, we hope to publish a paper or papers describing the roles of these other government agencies.

Views on International Safeguards at Uranium Enrichment Plants

Joerg H. Menzel (Arms Control and Disarmament Agency),
John P. Boright (Department of State), and
Leonard M. Brenner (Department of Energy)

I. Introduction

US views on international safeguards at uranium enrichment plants have evolved over a number of years. This paper attempts to assemble in a concise manner the pertinent elements as they have been stated previously. The focus of the paper is on the initial steps required, in our view, to facilitate the preparations for effective implementation of IAEA safeguards at uranium enrichment plants, while taking into account the need to avoid compromise of sensitive information. For completeness, Sections II and III of the paper review international safeguards concerns and goals as applied to uranium enrichment plants.

II. International Safeguards Concerns

At uranium enrichment plants declared to be for the production of low enriched uranium (< 20% U-235), the IAEA should be able to detect in a timely manner the diversion of uranium, including the production of uranium in excess of or at an enrichment level higher than that declared, particularly high enriched uranium (≥ 20% U-235).

For a US facility, the US is examining alternative access levels for IAEA inspectors including controlled access to and exclusion from certain areas and/or equipment, and, for the latter case, the use of one or more special material balance areas (MBA) for a "process step involving commercially sensitive information."[1] In accordance with INFCIRC/153 and with understandings reached at IAEA Advisory Group Meetings, if a special MBA were requested, the US would permit compensatory measures, including inspection effort in excess of the maximum routine inspection effort, as well as the extensive use of Containment/Surveillance (C/S) measures to supplement the inspection effort.

The US has to take into account the need to avoid compromise of US "Restricted Data" and other sensitive technology.

III. International Safeguards Goals

The stated objective of IAEA safeguards "is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."[2]

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1 The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected), Paragraph 46 (b) (iv), IAEA (June 1972).

2 Ibid., Paragraph 28.

Safeguards agreements do not specify what is meant by timely detection or significant quantities, and because of the diversity of circumstances under which safeguards are applied, no single set of values for these terms is likely to be appropriate for all circumstances. Nevertheless, quantitative goals are needed by the IAEA for the purposes of planning and assessing safeguards approaches, implementation and accomplishments. Accordingly, the United States has worked with other countries and the IAEA in attempting to develop such goals. While international discussions of these goals are expected to continue, the IAEA has adopted for current use certain values as guidelines.[3] It should be stressed that these values are guidelines and not requirements.[3]

The Significant Quantity (SQ) values in use by IAEA relevant to uranium enrichment plants are an amount of low enriched uranium (LEU) containing 75 kg of U-235 and an amount of high enriched uranium (HEU) containing 25 kg of U-235. The relationship between SQ relevant to a State and detection goal quantities for an individual facility is complex and only partially investigated to date. Preliminary studies indicate that in many circumstances goals for a facility as derived from SQ values are not greatly less than the SQ values. For these reasons, as an interim approach until the nature of this relationship is better understood, the US views as appropriate the current IAEA practice of setting the inspection goal quantity for a facility equal to the SQ, or smaller, taking into account facility size and measurement uncertainties.

The timeliness goal for detecting the diversion of a goal quantity of LEU is of the order of one year. On the other hand, at uranium enrichment plants declared to be for the production of LEU, the US supports a safeguards approach designed to be able to detect the fact of HEU production, should it occur, within one to three weeks after a goal quantity of HEU might have been produced.

Where quantification is possible, the US supports a probability goal of 90 percent for detecting, during any one year period, the diversion of a goal quantity of LEU, and a probability goal of 95 percent for detecting, during any one year period, the production of a goal quantity of HEU. The probability goal of incorrectly concluding that a diversion has occurred should be less than 5 percent. Where quantification is not possible, the IAEA will need to provide a "high level of assurance" that the diversion strategies of concern would be detected.

While recognizing that there may be difficulties in meeting the goals mentioned above in all situations due to a variety of factors, the US believes that through appropriate improvements it would be possible for the IAEA to achieve these goals in the majority of facilities now under safeguards. The safeguards agreements call for the IAEA to use material accountancy, containment and surveillance, but also to take full account of technological developments in safeguards in their implementation. With respect to future facilities, taking[3] safeguards into account in the design of these facilities will be increasingly important.[3]

IV. Development of an International Safeguards Approach

Any international safeguards approach at an enrichment plant must take into account concerns with respect to sensitive technology and should give the IAEA reasonable assurance that it can detect and thereby deter the diversion of LEU and HEU, with the goal of achieving appropriate timeliness, sensitivity, and probabilities of detection. The approach should efficiently utilize the resources required by the IAEA and the State involved.

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[3] Houck, F.S., IAEA Safeguards from a United States Perspective, INMM Proceedings, Vol. VIII, pp. 391-397 (July 1979).

The approach should be based on verified design information and should include verified nuclear material accountancy and C/S measures. The particular combination of these measures necessary to achieve an effective safeguards approach at a facility depends to a large extent on the plant's capacity, the site-specific and technology-specific design, and the agreed degree and type of access. The combination should permit the efficient application of safeguards and avoid undue interference in the State's peaceful nuclear activities and, in particular, in the operation of the uranium enrichment facility.

The US is analyzing several parameters pertinent to international safeguards approaches in terms of how tradeoffs among them, particularly for different degrees of plant access, will affect all the others. These include:

(1) Safeguards effectiveness,

(2) Risk of technology compromise,

(3) Facility access,

(4) Resources required by the IAEA, and

(5) Costs to the host country.

The access levels being generally considered include (1) access to the feed and withdrawal (F/W) station plus specified limited access to the cascade halls, or portions thereof, during different stages of construction and operation, and (2) access to the F/W station but not inside a perimeter around the cascade halls or the perimeters around individual cascade halls.

The following activities inter alia are viewed as being vital to the preparation for efficient and effective implementation of IAEA safeguards at uranium enrichment plants:

- Design of the plant layout, equipment and operation so as to facilitate IAEA safeguards and so as not to preclude, a priori, specified options for safeguards approaches;

- Provisions of design information within the IAEA's Design Information Questionnaire (DIQ) format as soon as physical layout and operational parameters are available;

- Consultation with IAEA on safeguards measures during the early phases of site preparation and plant construction (this may include site visits and demonstration of equipment and procedures for weighing and sampling, nondestructive assay methods, C/S measures, and chemical/mass-spectrometer analysis);

- Negotiation of a Facility Attachment at least 12 months prior to the introduction of nuclear material into the process buildings in order to provide time for finalized inspector and operator resource planning as well as construction, installation, and calibration of safeguards relevant equipment;

- As required, verification during the various stages of construction of that design information pertinent to the safeguards approach agreed upon.

In addition to the above, it is important to provide appropriate training to IAEA inspectors on analytical and calculational techniques with respect to material accountancy and statistics, any C/S measures utilized, interaction with the State System of Accounting for and Control of nuclear materials (SSAC) and physical security measures, as well as on health and safety.

V. Specifics on Design Information

Pursuant to the US/IAEA Safeguards Agreement now being considered by the US Senate, and subject to the US need to avoid compromise of "Restricted Data" and other sensitive technology, the US would provide design information in accordance with the IAEA's Design Information Questionnaire (DIQ), including safeguards-relevant design and construction drawings.

The design information described below contains elements whose value depends on the agreed access level and the safeguards strategy which would be finally agreed to by the IAEA and the US. For example, verification of some particular piping runs may or may not be relevant depending on whether the pipes cross material balance area boundaries, which in turn may depend on the particular inspection strategy. On the other hand, utilization of a procedure which could detect HEU production directly could have an impact on the role and deployment of C/S measures at the F/W and process buildings. The design information provided to the IAEA for its consideration on specific safeguards strategies would include certain data falling within the following elements:

a. Plant site activities
- site layout including all buildings and portals;
- exposed and underground lines and conduits with special emphasis on those which are connected to the F/W and process buildings or which cross the designated safeguards perimeter(s);
- details of daily traffic patterns for personnel, equipment, vehicular or rail traffic movements into and out of the F/W and process buildings or across the designated safeguards perimeter(s).

b. Uranium handling and flows
- overall process flows;
- the primary UF_6 piping system including safeguards relevant details of the F/W building and its interconnections with the process buildings;
- machine areas, traps and sampling points, if any, in the process buildings;
- sampling lines to measurement rooms;
- feed, product and tails buffer and permanent storage areas and inventories;
- details of handling, sampling, measurement and measurement accuracy, transfer and storage of UF_6;
- uranium flows and packaging of wastes or other discards;
- records, reports and material accounting procedures, forms and equipment.

c. During construction the IAEA would be afforded adequate opportunity to verify safeguards relevant, non-sensitive points of the process systems including:
- access to exposed and underground lines;
- access to the building;
- access to process buildings before specific sensitive components are installed.

During construction the IAEA could compare design drawings with the as-constructed facility. This would help to provide assurance that IAEA knowledge of uranium flows was complete. In the case of a non-access area, all non-uranium handling penetrations of the non-access area boundary would be known and appropriately secured where pertinent. All uranium handlings systems would be identified and could be traced, including the process header equipment inside the process buildings leading up to the cascades. Key measurement points, other strategic points, and other aspects of the safeguards strategy would be defined on this basis.

VI. Related R&D Projects

R&D projects are underway in the US on a variety of perimeter monitoring techniques and equipment such as personnel portal monitors, vehicle monitors based on neutron detectors, UF_6 flow monitors, and monitors to assure zero-uranium-flow. Although specific pieces of this type of equipment look feasible and operationally possible, there still remains the task of integrating these components into a comprehensive safeguards system which would provide a reasonable degree of assurance.

Considerable practical experience has been obtained in the US at an operating enrichment plant with in-line NDA equipment measuring U-235 enrichment and neutron levels related to the U-234 fraction in liquid UF_6 product. Additional systems are expected to be installed. In addition, R&D projects have been initiated to provide instrumentation for similar NDA measurements for UF_6 feed and tails lines.

Preliminary calculations and experiments have been initiated recently to investigate the possibility of using NDA instrumentation installed in or around cascade halls for the direct detection of HEU production. One of these approaches is based on the continual monitoring of neutron levels in close proximity to the cascade areas and the principle of correlating increased neutron levels with the increased U-234 (and U-232, if present) concentrations associated with HEU production.

GE's Norm Hall (left) and Dean James contemplate a safeguards licensing question.

Mr. Vince DeVito and his wife Jeanne shown here with Mr. Yoshio Kawashima at the 1978 Annual Meeting in Cincinnati, Ohio.

Optimization of Measurement Control

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I. INTRODUCTION

Keeping materials-balance variances within acceptable limits requires some form of measurement control. For processes operating near steady-state with small fluctuations in inventory (the desired case in high-throughput commercial facilities) the net transfer measurement errors soon become the dominant component of the materials balance variance.[1] Controlling the net transfer measurement error so that systematic errors do not propagate over long time intervals is possible through judicious recalibration of the transfer measurement instrument. However, if the process contains many such instruments, with a variety of error variances and calibration costs, then the best allocation of limited recalibration resources may be uncertain. This paper proposes a simple method for allocating resources that is optimal in the sense of achieving the minimum net transfer variance within a resource constraint. Use of the method requires only a common measure of recalibration costs and the knowledge of systematic error variance of each instrument.

This method allows: a proposed process to be analyzed for the minimum net transfer variance attainable at any level of recalibration resource investment, an existing process to be analyzed for the impact on the net transfer variance of proposed instrumentation changes, and specific instrument recalibration schedules to be developed for use in process simulations. The utility of the method is illustrated by an example drawn from a commercial reprocessing plant in which reductions in the net transfer variance attained with an optimal recalibration strategy are compared with some other intuitively reasonable strategies.

II. NET TRANSFER VARIANCE PROPAGATION

Measurement error models for a single instrument include both additive and multiplicative forms.[2] Although the measurement control methods developed in this appendix apply equally to either model, we have assumed for this purpose, the multiplicative form

$$M = M^a(1 + \varepsilon + \eta) \quad , \tag{1}$$

where M is the measured value, M^a is the actual value, ε is the random error component and η is the calibration error component. Using this model, the variance of the sum of N transfer measurements made with the instrument is[1]

$$\sigma_T^2 = Nb^2\left(\sigma_\varepsilon^2 + \sigma_\eta^2\right) + b^2\,\sigma_\eta^2 \sum_{k=1}^{K} n_k\left(n_k - 1\right) \quad , \tag{2}$$

where K is the number of recalibrations, n_k is the number of batches between the k and (k+1)st recalibrations, and b is the batch size (here assumed constant).

The second term in Eq. (2) represents the contribution to the transfer variance of correlations between measurements made with the same unrecalibrated instrument. This is the component of Eq. (2) that is reduced by more frequent recalibrations, while the first term remains unchanged. If there is more than one materials transfer stream to be measured, then σ_T^2 is the sum of terms of the form Eq. (2), one term for each instrument used in a transfer measurement, assuming that each instrument is dedicated to one materials transfer stream. Efficient recalibration allocations are obtained by minimizing the sum of these terms and choosing an appropriate number of recalibrations K for each instrument.

III. RECALIBRATION STRATEGIES

A recalibration strategy is an assignment of a specified number of recalibrations to each instrument over some time interval. Such a strategy is said to be optimal if it minimizes σ_T^2 under a given resource constraint. By modifying the form of Eq. (2), some standard mathematical methods can be applied to solve for an optimal strategy. It is shown in the appendix that, for a fixed number of recalibrations K, the net transfer variance in Eq. (2) is minimized by choosing a uniform spacing between recalibrations, i.e., the n_k of Eq. (2) should be chosen as nearly equal as possible. It follows (see appendix) that a good approximation to the transfer correlation term in Eq. (2) is

$$b^2 \sigma_\eta^2 N(N/K - 1) \quad . \tag{3}$$

Clearly, increasing K, the number of recalibrations, will reduce σ_T^2.

If two instruments have systematic error variances σ_1^2, σ_2^2 and costs per recalibration C_1, C_2, the expression in Eq. (3) allows the problem of finding an optimal strategy to be formulated as

$$\text{minimize } b^2 \sigma_1^2 N(N/K_1 - 1) + b^2 \sigma_2^2 N(N/K_2 - 1) \tag{4}$$

subject to the constraint

$$K_1 \times C_1 + K_2 \times C_2 \leq C \quad . \tag{5}$$

Here K_1 and K_2 are the number of recalibrations for each instrument that must be solved for, and C is an upper limit on recalibration costs. The problem in Eqs. (4) and (5) is solved by standard optimization methods. A program, RECAL, that incorporates a dynamic programming algorithm was written to solve problems of the form of Eq. (4), and was applied to data from a commercial reprocessing plant.

IV. EXAMPLE PROCESS

The process used for illustrating selection of optimal strategies is the Allied-General Nuclear Services reprocessing plant. This plant processes irradiated power-reactor fuel using the Purex recovery process that produces nitrate solutions of plutonium and uranium. A detailed description of this process is found in Ref. 3.

For the purpose of calculating the net transfer variance of the plutonium measurements, consider only the material input to the accountability tank and material output through the surge tank; although other output sidestreams exist, they are of significantly lower magnitude and are therefore neglected. The average batch size of the plutonium is about 20 kg processed over a period of 9.6 h.

The amount of material in the accountability tank is estimated by a volume measurement and a wet chemistry concentration measurement. Material output through the surge tank is estimated by a flow rate measurement and densitometer concentration measurement. Instrument precision for these measurements is summarized in Table I.

Recalibration costs for each instrument are referenced to the cost of recalibrating one NDA instrument. In the absence of precise cost estimates, values of 100 units for the volume instrument, 10 units for the wet chemistry instrument, 5 units for the flow meter, and 1 unit for the densitometer are assumed.

Optimal strategies generated by RECAL using the above cost and precision data were compared with two other strategies that seem reasonable. These strategies are

A. Allocate recalibration of the wet chemistry instrument, the flow meter, and the densitometer in inverse proportion to their recalibration cost.

B. Same strategy as A except make allocation proportional to instrument precision.

Assuming a recalibration resource of 1 unit per batch, Figure 1 compares the net transfer relative standard deviation attainable with strategies A, B, and the optimal strategy over a

TABLE I

INSTRUMENT PRECISION

Measurement Point	Measurement Type	Relative Standard Deviation	
		Random	Systematic
Accountability Tank	Volume	3.0×10^{-3}	1.0×10^{-3}
	Concentration	1.0×10^{-2}	3.0×10^{-3}
1BP Stream	Flow Rate	1.0×10^{-2}	5.0×10^{-3}
	Concentration	1.0×10^{-2}	3.0×10^{-3}

period of 100 batches. As expected, the optimal strategy performs better than A and B, reaching an improvement of about 15% at 100 batches.

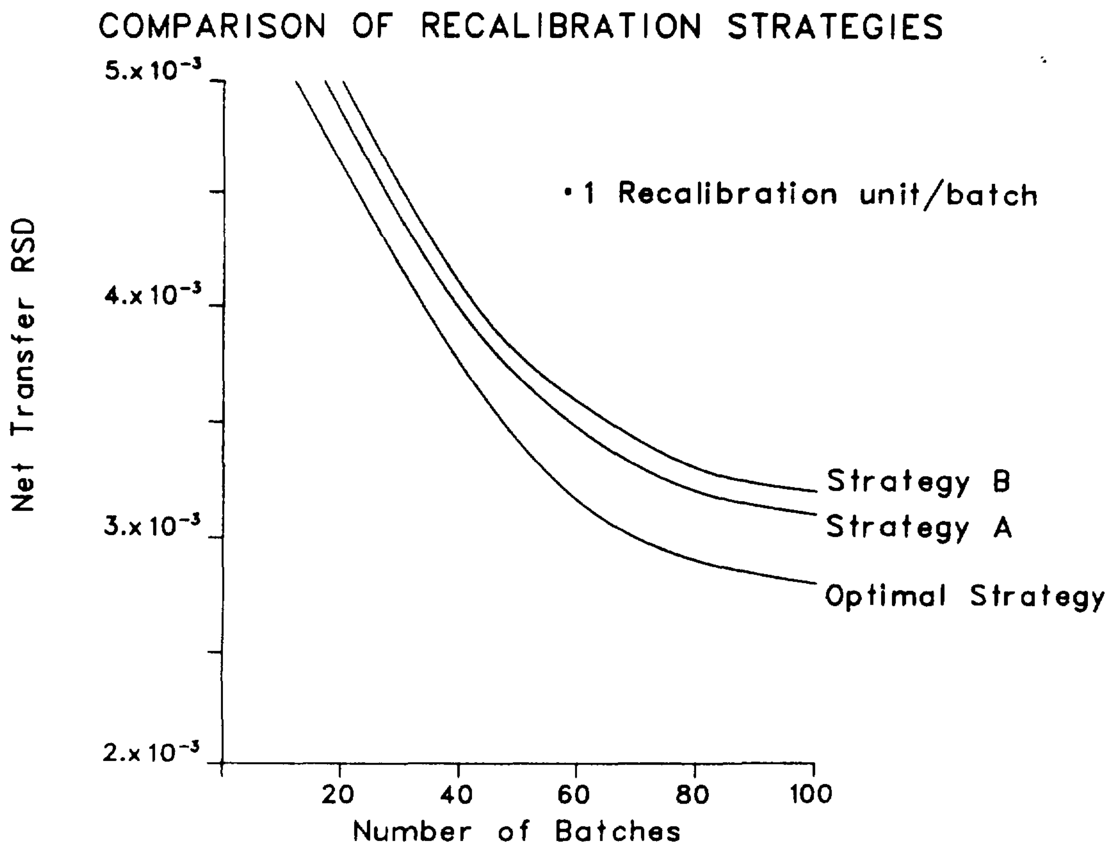

FIG. 1

V. WORTH OF INSTRUMENT IMPROVEMENTS

In the reprocessing example, the optimal strategy did not select any recalibrations of the volume measuring instrument because of its high 100 unit cost per recalibration. Indeed under the assumption of 1 recalibration unit per batch and 100 batches, no volume recalibration is selected in an optimal strategy until the volume cost is reduced to 20 units per recalibration. Thus a reduction in volume recalibration cost is not useful unless this lower threshold is reached. This example illustrates another use of this method in examining the sensitivity of σ_T^2 to changes in either the recalibration cost or precision of an instrument. Using σ_T^2 as a measure of effectiveness, one can rank proposed instrumentation improvements according to their efficacy in reducing the materials balance variance.

REFERENCES

1. H. A. Dayem, D. D. Cobb, R. J. Dietz, E. A. Hakkila, J. P. Shipley, and D. B. Smith, "Dynamic Materials Accounting in the Back End of the LWR Fuel Cycle," Nucl. Tech. 43, 222-243 (1979).

2. J. L. Jaech, "Statistical Methods in Nuclear Material Control," TID-26298, Technical Information Center, Oak Ridge, Tennessee (1973).

3. E. A. Hakkila, D. D. Cobb, H. A. Dayem, R. J. Dietz, E. A. Kern, E. P. Schelonka, J. P. Shipley, D. B. Smith, R. H. Augustson, and J. W. Barnes, "Coordinated Safeguards for Materials Management in a Fuel Reprocessing Plant," Los Alamos Scientific Laboratory report LA-6881, Vol. I (September 1977).

APPENDIX

OPTIMAL RECALIBRATION INTERVAL

To show that the expression

$$\sum_{k=1}^{K} n_k \, (n_k - 1) \qquad \text{(A-1)}$$

constrained by

$$\sum_{k=1}^{K} n_k = N \qquad \text{(A-2)}$$

is minimized by choosing the n_k equal, use the method of Lagrange multipliers. Define the relation

$$L = \sum_{k=1}^{K} n_k (n_k - 1) + \lambda \left(\sum_{k=1}^{K} n_k - N \right) ,$$

where λ is an undetermined multiplier, K is fixed and known, and n_k are the problem unknowns. Then a necessary condition for n_1, $n_2, \ldots n_k$ to solve the problem of minimizing Eq. (A-1) subject to Eq. (A-2) is that the n_k be a solution of the equations

$$\frac{\partial L}{\partial n_k} = 0 \qquad k = 1, 2, \ldots K$$

and

$$\sum_{k=1}^{K} n_k = N \quad .$$

Since for each k,

$$\frac{\partial L}{\partial n_k} = 2n_k + \lambda - 1 = 0 \quad ,$$

it follows that $\lambda = 1 - 2n_k$, and therefore that $n_1 = n_2 = \ldots n_K$, so the best strategy is to recalibrate at regular intervals.

Equality of the n_k and the constraint (Eq. (A-2)) imply that $n_k = N/K$, $k = 1, 2, \ldots K$, so that the expression in Eq. (A-1) becomes

$$N(N/K - 1) \quad . \qquad \text{(A-3)}$$

In practice only natural number solutions for the n_k are useful. While Eq. (A-3) is not exact under this condition, it has been found to be a good approximation to Eq. (D-6) when N is greater than about 2 x K.

A High-Abundance Sensitivity Mass Spectrometer for the International Atomic Energy Agency's Safeguards Analytical Laboratory*

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Abstract

Oak Ridge National Laboratory (ORNL) recently built for the International Atomic Energy Agency (IAEA) a high abundance sensitivity, tandem mass spectrometer equipped with a pulse counting detection system. This instrument has been installed in the IAEA's Safeguards Analytical Laboratory. This paper gives a brief description of the physical design and operating characteristics of the instrument.

Introduction

Monitoring various nuclear facilities for Safeguards purposes requires a mass spectrometer capable of precise and accurate isotopic measurements on a large number of samples of uranium and plutonium. The health hazard involved in handling plutonium and transportation regulations restricting quantities that may be shipped make very desirable the availability of a mass spectrometer capable of analyzing submicrogram quantities. In addition, the possibility of future need for isotopic correlation calculations made it desirable

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for the IAEA to obtain an instrument of high abundance sensitivity to allow precise and accurate measurement of minor isotopes.

ORNL was asked to build for the IAEA an updated version of the tandem pulse-counting mass spectrometers ORNL has had in operation for 20 years. The instrument should be capable of operating at pressures below 6×10^{-6} Pa, be able to run at least ten samples in an eight-hour day on a routine basis, to have an abundance sensitivity of $\geq 10^{6}$, and be able to analyze nanogram-size samples of uranium and plutonium.

The instrument installed by ORNL at the IAEA's new Safeguards Analytical Laboratory at Seibersdorf, Austria, meets or exceeds all of the above requirements. This paper is a brief description of the instrument and its capabilities.

Description of the Instrument

To produce a mass spectrometer capable of precision isotopic measurements on nanogram quantities of uranium and plutonium, a number of mechanical design parameters had to be met. Among these parameters are the following:

1) Base instrument pressure less than 10^{-6} Pa;
2) Accurately aligned ion optics;
3) Ease and rapidity of sample changing;
4) Extreme sensitivity for the ion detection system; and
5) Modern, stable operational electronic components.

Figure 1 shows the physical layout of the system; Table 1 contains an explanation of the coded labels. It consists of two 90 degree sector magnets with 30 cm radii. The vacuum system is of all-metal construction, and ultimate pressures are below 10^{-7} Pa.

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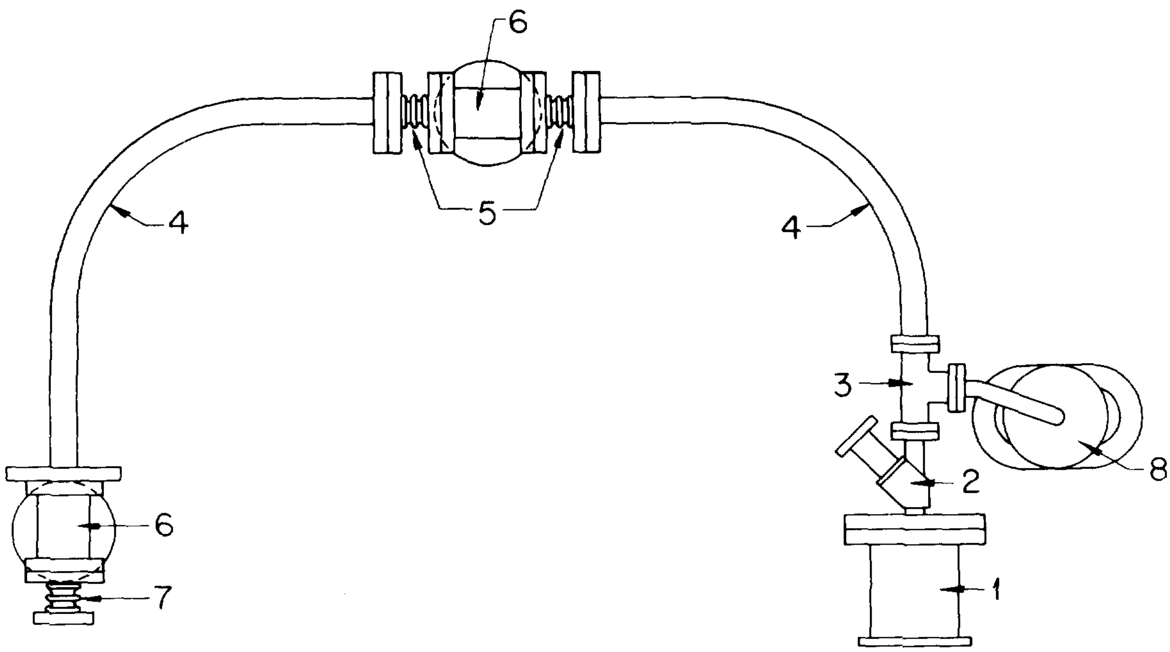

Figure 1: Physical layout of the vacuum system.

Table 1

Key to Figure 1

No.	Description
1.	Source housing.
2.	Isolation valve.
3.	Tee.
4.	Flight tube: Copper wave guide with 90° angle.
5.	Bellows to reduce alignment problems.
6.	Adjustable slit housings.
7.	Detector housing.
8.	Ion pumps -- one under each slit housing in addition to the one shown.

There are ion collimating slits at the focal points of each magnet. These slits are continuously adjustable to allow setting for optimum instrumental performance. The slit after the first magnetic analyzer serves to ensure that ions of only one mass-to-charge ratio enter the second magnetic stage at any one time. The second magnet removes momentum-degraded ions, thus enhancing the abundance sensitivity to $\geq 10^6$. Abundance sensitivity is defined as the intensity of the ion beam at mass M divided by the scatter from this beam one mass unit away. For example, abundance sensitivity in the uranium region is obtained by dividing the intensity of the $^{238}U^+$ peak by the intensity of the beam at mass positions 237 or 239. We use mass 237 for this measurement because more ions lose energy (and thus appear on the low mass side of their parent peak) through gas phase collisions than gain energy. From the analytical point of view this means that correction to the $^{236}U^+$ ion intensity for scatter from the $^{238}U^+$ beam is well under 1 ppm. We usually make no scattering correction to this mass position.

The ion source used in this spectrometer is a modification of the thick-lens type developed by Nier.[1] We have modified this source to allow 15 kilovolt operation. Besides strong focusing action, the source provides for electrical deflection of the ion beam in both the horizontal and vertical planes to optimize focusing conditions. The sample changer which operates in conjunction with this source has been described.[2] It is basically a wheel upon which can be mounted six sample filaments. Samples are positioned from outside the vacuum system by a rotary motion feedthrough. The assembled multiple-filament wheel is shown in Fig. 2. Thin, stainless-steel, rectangular cross-section shields prevent cross contamination of samples during analysis. The filaments are of rhenium in a canoe configuration which will accommodate approximately 1 μl of solution; resin beads are also mounted in these filaments.

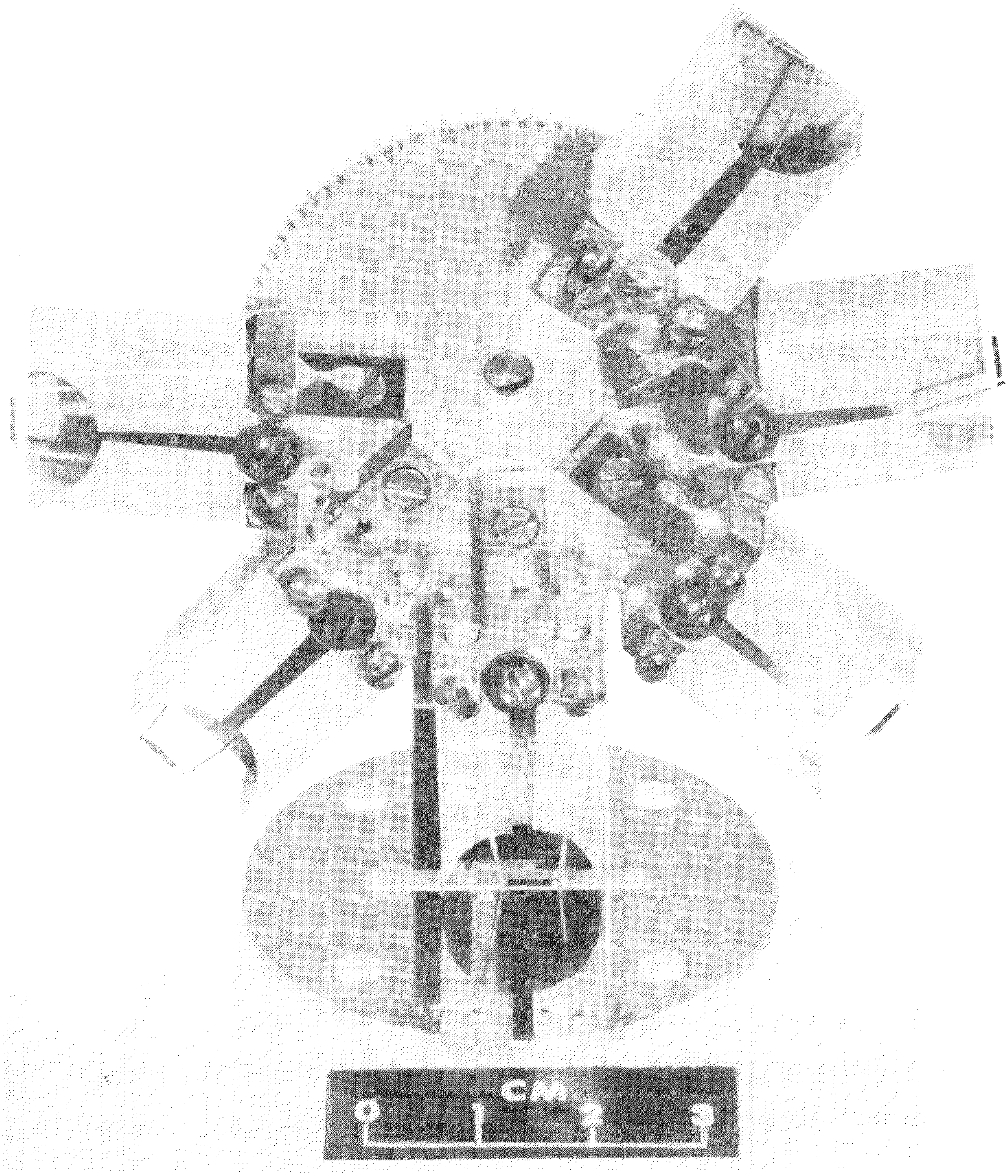

Figure 2: Sample wheel with six filament assemblies mounted.

Fig. 3 is a block diagram of the electronic components used with the instrument. Mass scanning is performed by stepping the accelerating voltage under computer control. To allow analysis of subnanogram samples of uranium and plutonium, a pulse counting detection system is required. Our collector is a 14-stage electron multiplier. Pulses created by individual ions are passed through a preamplifier, a discriminator, and a scaler before being sent to appropriate monitoring and storage devices. The pulse pair resolving time of the system is about 20 nsec, allowing count rates

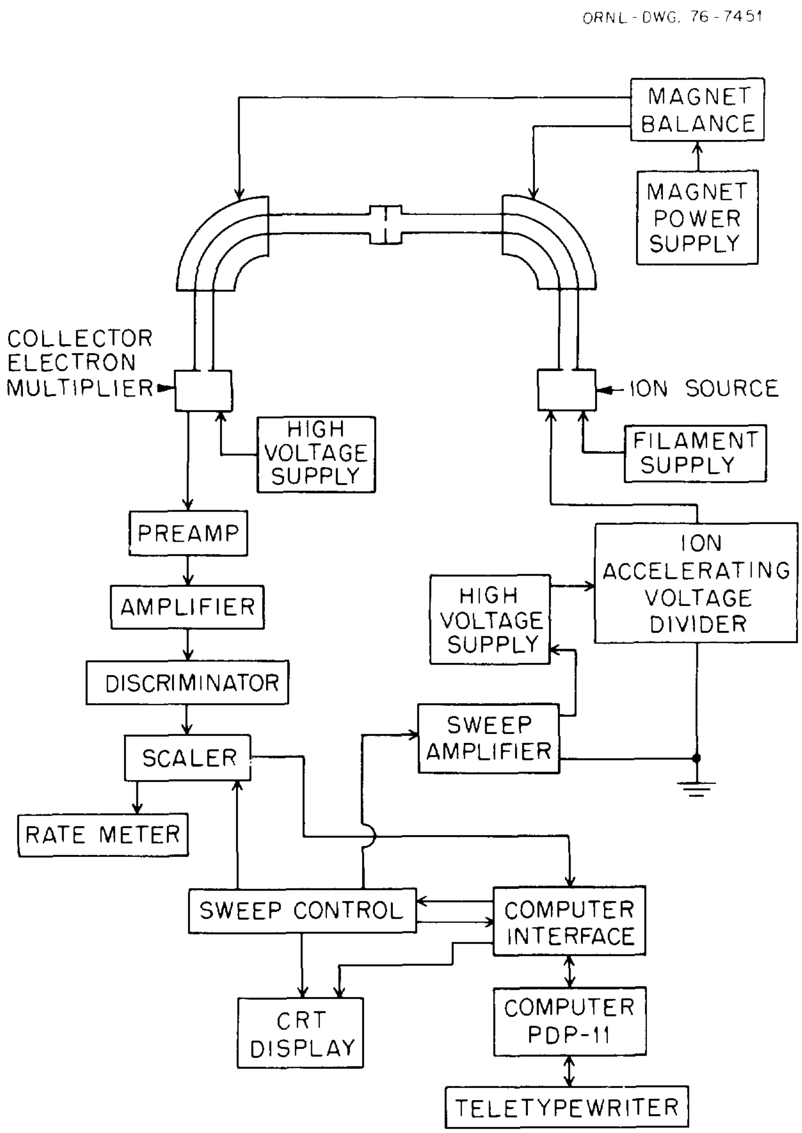

Figure 3: Schematic diagram of electronic components.

of 300,000 counts per second to be used without requiring excessive correction. All these operations are controlled by our ORNL-designed sweep control panel. Further details of the system, many of whose components are of ORNL design, and complete operational procedures for the instrument have been published.[3]

<u>Sample Handling</u>

There are two principal techniques for introducing samples into the mass spectrometer in a form suitable for analysis: as solutions and on resin beads.[4-6] The major concern in either technique is to locate the sample so as to optimize ion optical geometry and to have the sample present in chemically reduced form to prevent excessive loss as oxides.

Samples are run from a single rhenium V-shaped filament (Fig. 4), and ions are formed thermally by heating the filament resistively to a high enough temperature (1500-1700°C for Pu; 1700-1900°C for U). Samples are loaded as solutions by introducing 1 μl of dilute nitric acid solution containing 10-100 ng of U or 5-20 ng of Pu into a Re filament. A full wheel of six samples (Fig. 2) is mounted in the mass spectrometer, and the instrument is evacuated to about 1.3×10^{-3} Pa. Benzene vapor is introduced into the source chamber via a controlled leak until the pressure is about 7×10^{-2} Pa. Each filament in turn is heated to 1400°C (for U) or 1200°C (for Pu) and held at that temperature for 30 seconds. This treatment chemically reduces the sample on the filament and ensures a stable metal ion signal.

The resin bead sample loading technique, developed at ORNL, has been described, both as to general principles and as to practical problems.[4-6] Several advantages accrue when resin beads are used to load samples: 1) Vastly simplified chemistry. No chemical separations are required; resin beads are allowed to soak for 16-24 hours in an 8 N HNO_3 solution containing the sample and are then loaded directly on the filament. 2) Improved sensitivity, partially due to the sample now being very close to a point source for the ion optics; in contrast, solutions spread from one end of the filament to the other. U samples of 1 ng and Pu of <1 ng can be reliably analyzed. 3) The ability to run Pu and U from a single filament loading. 4) Elimination of the need for benzene reduction. The bead itself acts as the

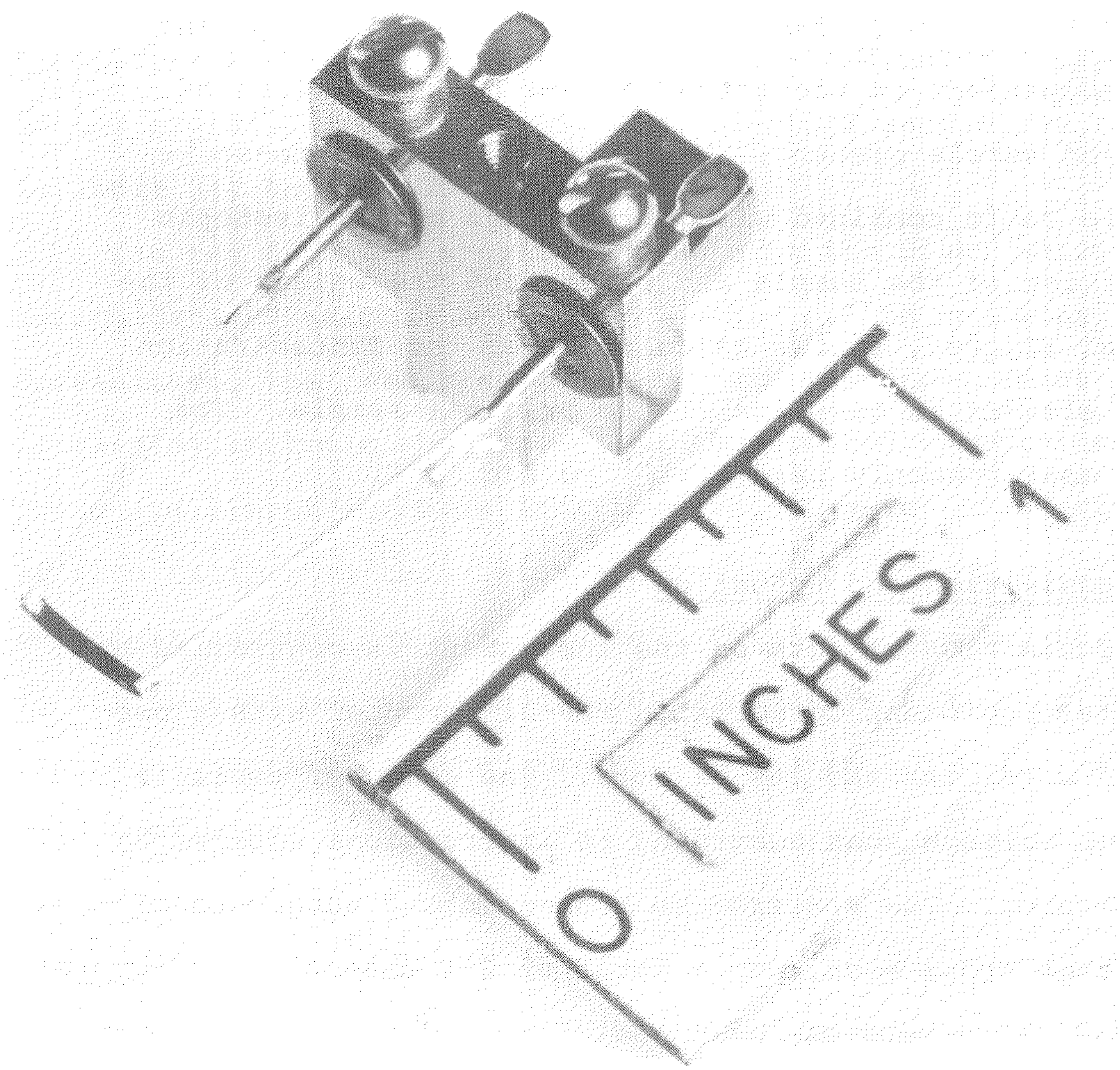

Figure 4: Filament assembly.

chemical reducing agent when the filament is heated. Ten to 12 samples can be analyzed in an eight hour working day.

Details of the technique and its advantages are discussed at some length in References 4 and 6.

Quantitative determination of Pu and U is achieved through the technique of isotope dilution. In this technique, a known amount of an isotopically enriched spike of known isotopic composition is added to an aliquot of the sample. The two are equilibrated through appropriate mixing and valence adjustment. After equilibration is achieved, it is unnecessary to obtain quantitative recovery of the elements at any step; the determination of quantity is now a function only of the ratio of sample isotope to spike isotope and thus independent of the actual amount of the mixture of spike and sample present. Measuring the sample-to-spike isotopic ratio combined with a knowledge of the isotopic composition of the sample and spike, and the weight of the original aliquot, allows calculation of the concentration of the element in question in the original sample. The spikes most commonly used are ^{242}Pu and ^{233}U.

Data Acquisition and Reduction

Acquisition of data on the instrument is controlled by a Digital Equipment Corporation PDP-11 computer with a one-million word disk and 16K of core. The computer controls the high voltage scan according to instructions entered by the operator. The spectrum is broken into 8 subgroups of 32 voltage steps each, for a total of 256 channels. Each subgroup represents one mass position, and the entire spectrum of 256 channels is repetitively scanned 50 to 150 times to constitute one run. Ten such runs constitute an analysis. The scan is programmable so that statistics on minor isotope measurements can be improved by scanning the appropriate peaks more often than the major ones. A background position is also scanned to allow correction for detector noise. A typical scanning scheme, which can be altered at will, for U would be:

Mass	233.5	234	235	236	238
No. of scans	1	16	2	16	1

Thus, for 10 runs of 50 scans each, the minor isotopes will be scanned 8000 times, the 235 1000 times, and the 238 500 times; the scan of each peak consists of 32 separate samplings of the signal. Uncertainty for minor isotope abundances (<100 ppm) is about 3%, and for 235 is about 0.5%.

The raw data are stored in a file on the disk, which can accommodate 20 samples of 19 runs each. At the operator's convenience, the data are processed, and an output sheet containing isotopic abundances and atom ratios is obtained. These are listed for each individual run. Weighted averages of each ratio with their standard deviation and composition in weight percent are also listed. These results are stored in a file that can accommodate 500 samples. Details of the computer programs and the statistical routines applied have been published.[3,7,8]

Summary

A mass spectrometer and data system have been built for the IAEA to serve specifically safeguards purposes. The sensi-

tivity of the instrument allows analysis of sub-nanogram samples of Pu and U loaded on resin beads. Isotope dilution is used to measure concentrations of these two elements.

References

1. A. O. Nier, Rev. Sci. Instr. 18, 398 (1947).
2. W. H. Christie and A. E. Cameron, Rev. Sci. Instr. 37, 336 (1966).
3. D. H. Smith, H. S. McKown, W. H. Christie, R. L. Walker, and J. A. Carter, ERDA Report ORNL/TM-5485, June, 1976.
4. R. L. Walker, R. E. Eby, C. A. Pritchard, and J. A. Carter Anal. Letters 1, 563 (1974).
5. R. L. Walker, C. A. Pritchard, J. A. Carter, and D. H. Smith, ERDA Report ORNL/TM-5505, Oak Ridge, Tennessee, July, 1976.
6. D. H. Smith, R. L. Walker, J. A. Carter, J. of Institute of Nuclear Materials Management 8(4), 66 (1980).
7. D. H. Smith, USDOE Report ORNL/TM-7002, Sept., 1979.
8. D. H. Smith, Chem. Biomed. Environ. Instrum., in press.

Use of Isotope Correlation Techniques to Determine ^{242}Pu Abundance*

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ABSTRACT

Gamma-ray spectrometry is a very desirable technique for determining plutonium isotopic abundances because it is nondestructive and adaptable to making rapid in-line analyses. However, the technique has had the shortcoming of not being able to determine the abundance of the ^{242}Pu isotope. Here we describe a way around that shortcoming: a very linear and reactor-independent correlation for calculating the isotopic abundance of ^{242}Pu from the measured abundances of ^{239}Pu, ^{240}Pu, and ^{241}Pu.

INTRODUCTION

An accurate measurement and a strict accounting must be made of plutonium wherever it is produced, stored, or used. This is because two of its isotopes, masses 239 and 241, are very fissile and hence very valuable. Since not all of the plutonium isotopes are of equal value, it is necessary to measure not only the total elemental amount of plutonium but also the abundance ratios of all the plutonium isotopes.

Isotopic abundance ratios are traditionally determined using mass spectrometry, sometimes in conjunction with alpha pulse height spectrometry. Although this method is very reliable and accurate, it is a destructive technique having several limitations, particularly with respect to speed of analysis and use for in-line measurements.

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We have developed and are continuing to improve the technique of using gamma-ray spectrometry[1,2] to measure plutonium isotopic abundances. This technique is made practical because each plutonium isotope emits a set of x-rays and gamma-rays whose energies and intensities form a unique pattern that is characteristic of only that isotope. These patterns are distinguishable when detected by modern gamma-ray spectrometers employing germanium detectors and computer-based analyzer systems.

The principal difficulty in the determination of the isotopic abundances of plutonium by gamma-ray spectrometry is the determination of ^{242}Pu. Although its radiations are unique and distinguishable, their emitted intensities are too weak to be observed from a sample containing a mixture of plutonium isotopes because the ^{242}Pu half-life is relatively much longer than the other isotopes. Fortunately, the ^{242}Pu abundance in plutonium produced in PWR and BWR reactors is small and usually does not exceed 5% even when high burnup is achieved. For this reason, a highly accurate determination of the ^{242}Pu abundance is not required since even a $\pm$10% error in its value would generally propagate less than a $\pm$0.5% error in the total plutonium measurement that includes all of the isotopes.

Since the mass 238 to 241 isotopes of plutonium can now be determined to within $\pm$0.5% using gamma ray spectrometry, we have been looking for a satisfactory method for determining the ^{242}Pu abundance to complete the analysis. One promising technique that would make use of available information is based on the well-known fact[3,4] that certain correlations and abundance ratios exist among the various uranium and plutonium isotopes in the fuel stemming from the isotope production process. These correlations have been the subject of several studies[5,6] made for various purposes, but we are not aware of any detailed investigation made to find a good correlation for predicting the ^{242}Pu abundances.

In this paper we report some of the studies we have performed and present one correlation for calculating the abundance of ^{242}Pu based on measured abundance values for the ^{239}Pu, ^{240}Pu, and ^{241}Pu isotopes.

BASIS OF CORRELATION TECHNIQUES

The detailed process whereby the isotopes of plutonium are produced and destroyed is very complex and perhaps cannot be rigorously determined because of unknown or poorly characterized neutronics history of the fuel. Therefore, for this study we develop only some very simple relationships based on the following principal path for the production of the various isotopes of plutonium:

$$^{238}U \xrightarrow{k_1} {}^{239}Pu \xrightarrow{k_2} {}^{240}Pu \xrightarrow{k_3} {}^{241}Pu \xrightarrow{k_4} {}^{242}Pu.$$

To a first approximation the production rate for each isotope from its precursor is given by a first-order rate equation having a rate constant k_i that is the product of the time-integrated neutron flux and the cross section[7]:

$$\frac{dN_{i+1}}{dt} = \underbrace{k_i\ N_i}_{\text{production term}} - \underbrace{k_{i+1}\ N_{i+1}}_{\text{destruction term}} \qquad (1)$$

where N_i and N_{i+1} are the amounts of parent and daughter isotopes and k_i is a constant governing the transformation rate.

Initially, we can begin with the very simple premise that the destruction rate is small compared with the production rate. Then one derives that

$$N_{i+1} = k_i\ N_i\ t\ . \qquad (2)$$

Using Eq. (2), one can now develop a number of correlations involving the ratios of isotopes. For example, one correlation involving the abundance (N) of ^{242}Pu atoms would be

$$\frac{N_{242}}{N_{241}} = C_1 \frac{N_{240}}{N_{239}}\ ,\ \text{or}\ N_{242} = C_1 \frac{N_{240}\ N_{241}}{N_{239}}\ . \qquad (3)$$

Another would be

$$\frac{N_{242}}{N_{240}} = C_2 \left(\frac{N_{240}}{N_{239}}\right)^2,\ \text{or}\ N_{242} = C_2 \frac{(N_{240})^3}{(N_{239})^2}\ . \qquad (4)$$

Since the isotopic abundances are generally reported as weight or atom percentages* of the total rather than as atoms or grams, it is more convenient to use percent abundance values in the above equations. This can be easily done by noting that the weight fraction of the ith isotope equals $(N_i/\sum N_j)$.

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*For our present purposes, the difference is negligible and will be ignored.

Using brackets to denote weight percentages, one can rewrite Eqs. (3) and (4) as

$$[242] = C_1 \frac{[240] \quad [241]}{[239]} \tag{5}$$

and

$$[242] = C_2 \frac{[240]^3}{[239]^2} \; . \tag{6}$$

In the following section, we report on the fitting of published data to these and other isotopic functions we have investigated. Nearly all of the data used in this study were taken from a listing[8] of the Battelle Pacific Northwest Laboratory data bank. Table 1 summarizes the reactor origin of the measurement values used. Because of the large number of data sets available on plutonium generated by the Yankee Rowe and Dresden power reactors, we frequently studied these sets separately. In other studies, the data sets were separated according to reactor design, that is, PWR, BWR, or CANDU. In all cases, the ^{241}Pu abundance values were decay-corrected to the reactor fuel discharge time.

ISOTOPIC CORRELATIONS

Intuitively, one would assume that the best correlation for determining ^{242}Pu abundance would involve the ^{241}Pu abundance, since ^{241}Pu is the immediate precursor in the the formation process. Therefore, correlations predicted by Eq. (5) were first investigated. A plot of $[240][241]/[239]$ vs $[242]$ is shown in Fig. 1. The data show a strong correlation that appears to be nearly independent of reactor origin. However, it should be noted that the relationship is not linear, and that the nonlinearity becomes more pronounced with burnup or total reactor power output.

We have not been able to explain in detail the reasons for this nonlinearity. However, we recognize that the production process is complex and that our development of Eqs. (5) and (6) ignored many factors that should be considered. For example, the destruction term in Eq. (1) was ignored in deriving Eqs. (5) and (6). Inclusion of this destruction term should lead to a more rigorous set of equations, although in preliminary investigations of this question we found that including only the ^{239}Pu destruction term did not produce a significant change in the form of the final equations. Perhaps of greater importance is that our development assumed the production rate constants (cross

TABLE 1. Summary of the reactor data used in this study and the results obtained in fitting the data to the expression [242] = C [240][241]/[239]^2, where [242] signifies weight percent of ^{242}Pu. Isotopic data are mass spectrometric values taken from the Battelle Northwest data bank.[8]

Reactor	Power (MW)	Number of data	Correlation constant, C: Mean value	Standard deviation	Std. dev. (%)	Range of C	Deviation from mean (%)	Corresponding range of ^{242}Pu abundance
PWR Reactors:								
Yankee Rowe	185	97	54.4	2.6	4.8	60.4 48.5	+11.1 -10.8	0.12 5.68
Indian Point	275	20	56.1	1.44	2.6	58.6 53.3	+4.6 -5.1	1.07 2.42
Sena	325	26	52.0	0.96	1.8	53.5 49.5	+1.5 -2.5	1.04 2.04
Trino	257	31	52.6	2.03	3.9	57.7 49.4	+9.5 -6.2	0.84 2.42
Robinson	772	3	49.7	--	--	49.8 49.6	+0.1 -0.2	4.18 5.97
All PWR data	--	177	53.8	2.55	4.7	60.4 48.5	+12.2 -10.0	0.12 5.97
BWR Reactors:								
Dresden	210	62	49.3	2.97	6.0	55.5 45.3	+6.2 -4.0	0.37 5.79
Big Rock Point	75	14	51.2	2.35	4.6	47.2 54.2	+11.2 -7.8	1.95 2.93
Garigiano	160	31	53.0	1.46	2.8	57.7 49.6	+8.8 -6.5	1.83 3.33
Humboldt Bay	65	20	50.5	1.76	3.5	55.4 48.4	+9.7 -4.2	0.316 2.12
KBR	250	13	49.6	1.32	2.7	53.3 48.6	+7.4 -2.1	0.96 2.10
Dodewaard	54	6	50.3	1.20	2.4	51.9 49.0	+3.2 -2.5	2.18 2.76
All BWR data	--	146	50.5	2.71	5.4	57.7 45.3	+14.2 -10.4	0.37 5.79
CANDU Reactor:								
NPD	25	9	55.6	3.66	6.6	63.0 52.8	+13.3 -5.1	0.68 1.13
All Reactor Data	--	332	52.4	3.2	6.0	63.0 45.3	+15.8 -14.0	0.12 5.97

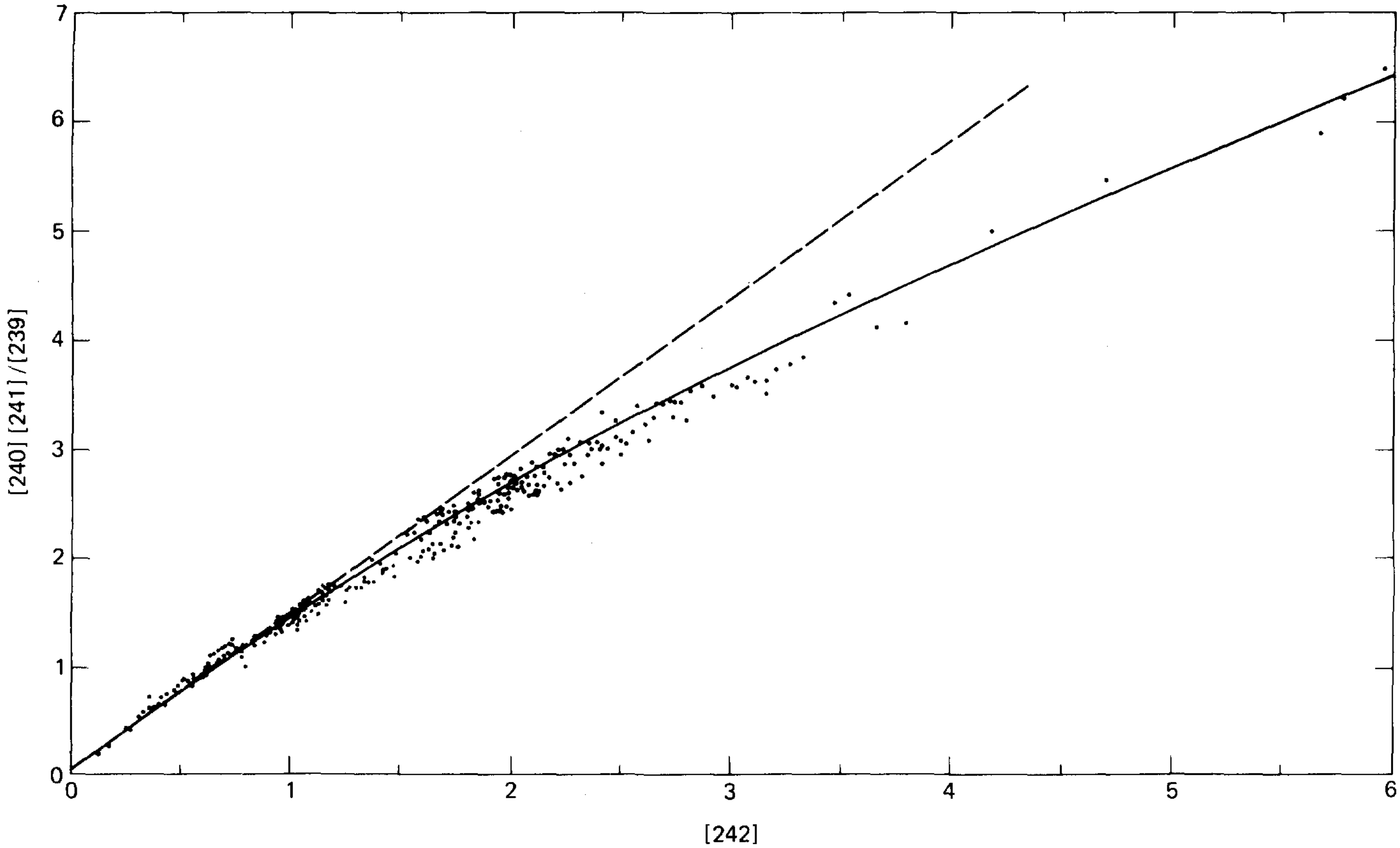


Fig. 1. Correlation of isotopic data using Eq. (5): [242] = C[240][241]/[239], where [242] signifies weight percent of ^{242}Pu. All the data in this study, from three different reactor types, are included in this figure and in Fig. 2.

sections) to be invariant with time, whereas the energy spectrum of the neutron flux is known to change with fuel burnup, and therefore small changes in the cross sections are expected to occur as a function of time. Many other factors also undoubtedly contribute to the discrepancy between the observed data and our idealized correlation.

Empirically, we have found a simple variation of Eq. (5) that gives a very good fit to the observed data. If the ^{239}Pu abundance is squared, i.e. the ordinate value set equal to [240] [241]/[239]^2, a very linear relationship results, as shown in Fig. 2. This relationship is essentially independent of reactor type. Small effects can be observed such as shown in Fig. 3, where data from a PWR reactor (Yankee Rowe) are compared with data from a BWR reactor (Dresden). Table 1 summarizes the correlation results for the various reactors studied. Although it appears that the correlation is more consistent for a given reactor or reactor type, nonetheless the variation in the

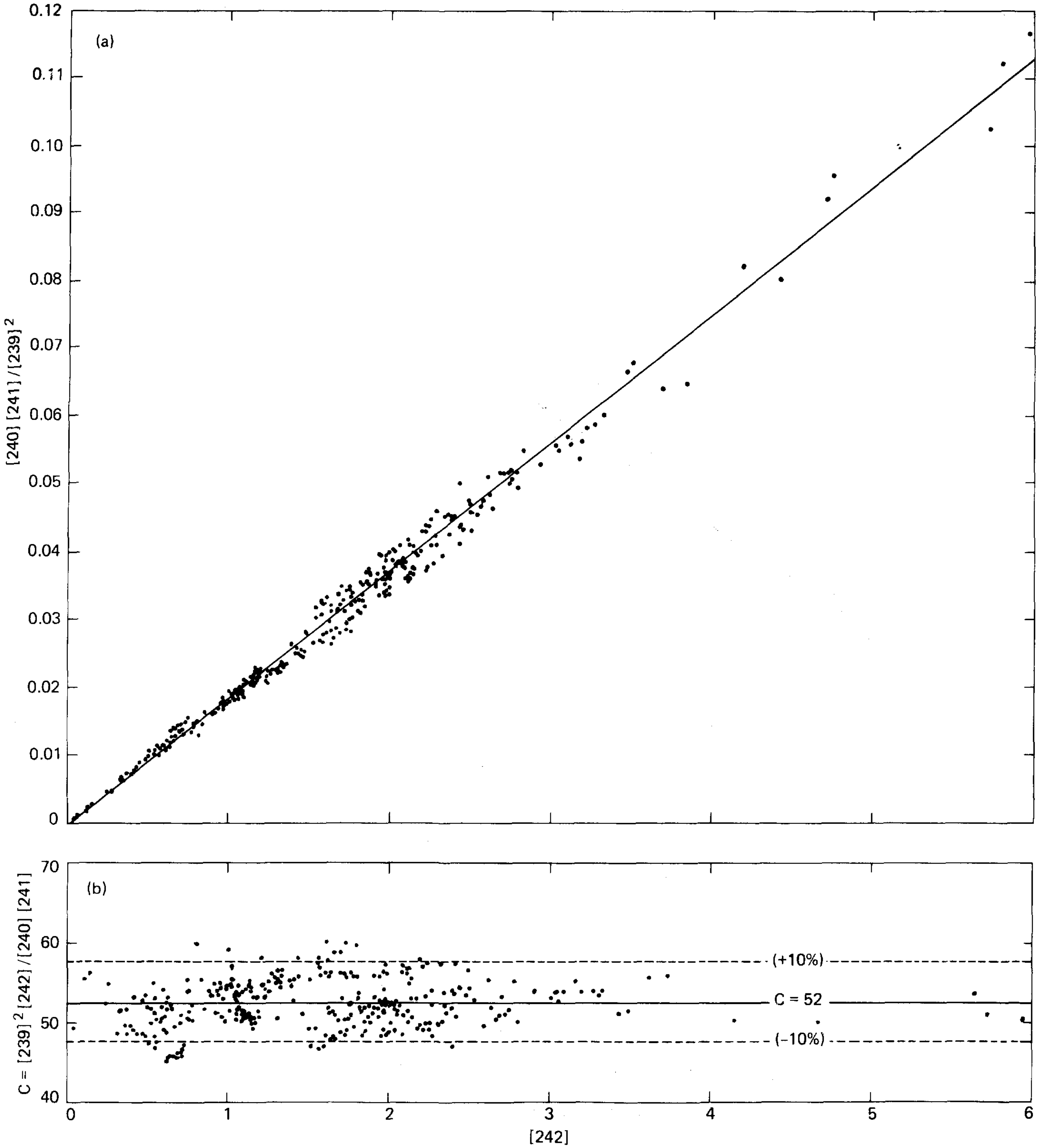


Fig. 2. Adding another [239] term to the denominator of Eq. (5), giving $[242] = C[240][241]/[239]^2$, results in a remarkably linear fit to the data. (a) Correlation of isotopic data using the modified equation. (b) Variation of the correlation coefficient C with ^{242}Pu relative abundance.

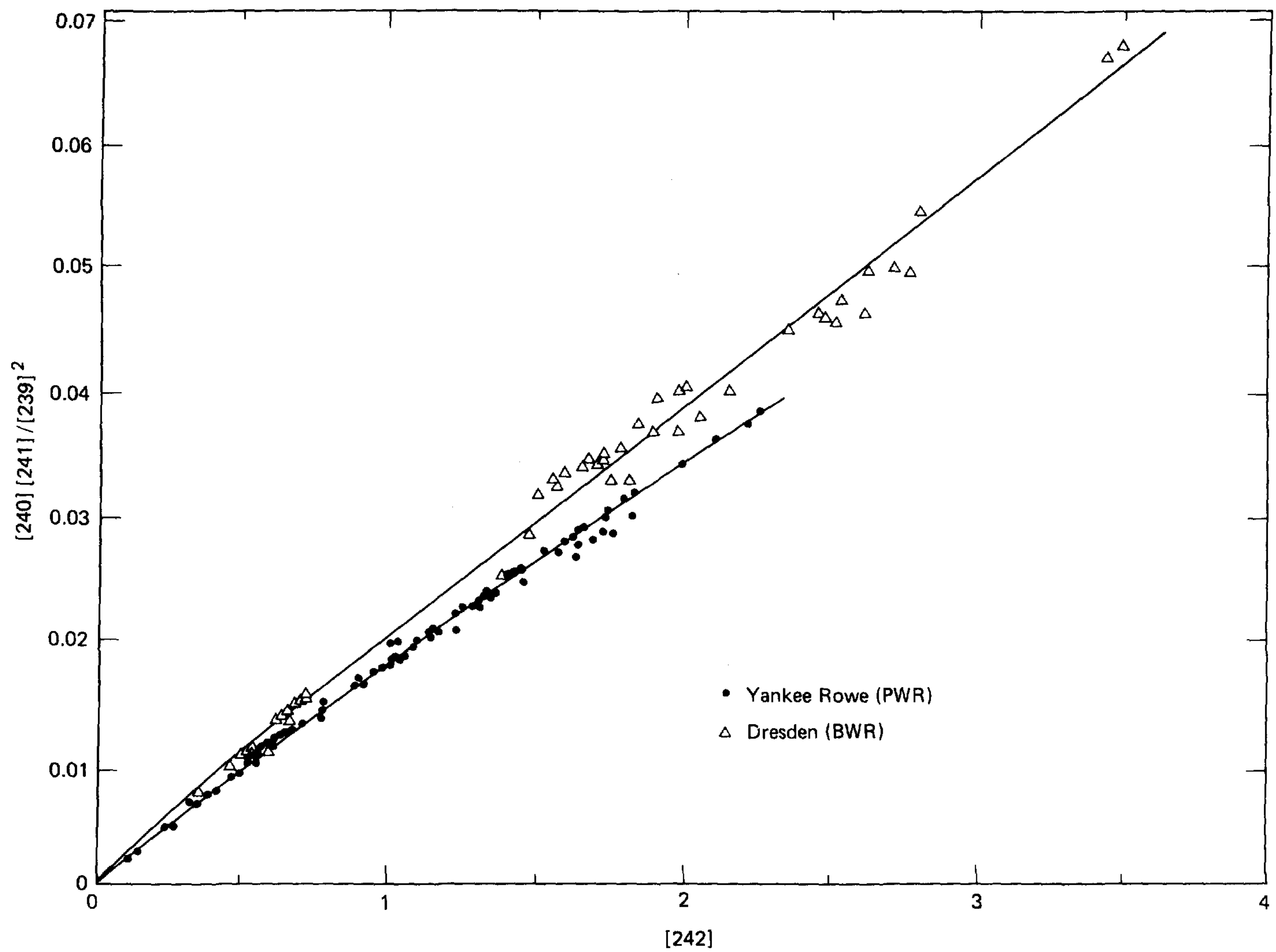


Fig. 3. Plot of Yankee Rowe (PWR) and Dresden (BWR) data shows a small but noticeable difference in slope for the respective correlations.

correlation using all the data does not greatly exceed that for the individual correlations. The best overall slope for the correlation appears to be a value of 52.

Although the correlation just discussed appears adequate for the purposes of predicting the ^{242}Pu content in first cycle fuel, it does require knowledge of the cooling time interval between reactor discharge and chemical separation. This is so because ^{241}Pu with a half-life of 14.4 years decays to ^{241}Am, and therefore decreases its isotopic abundance at the rate of 4.9% per year. To minimize this source of error, the decay time should be estimated to within an accuracy of about $\pm$0.5 year. Decay after chemical separation can be accounted for by determining the ingrowth of ^{241}Am, which is easily measured by gamma-ray spectrometry.

Because of the above-mentioned decay correction, we also investigated a few correlations that did not involve use of the ^{241}Pu abundance. Figure 4(a) shows a plot of the data described by Eq. (6). The resulting correlations were not nearly so good as those using the modified form of Eq. (5). Although the relationship is quite linear for data from a given reactor, there is a strong dependence of the correlation on reactor type and also some distinct differences among reactors of a given type. The slope of the correlation for PWR reactors ranges from 0.35 to 0.60, whereas the BWR data show a slope of 0.85 to 1.25; this slope difference may be a useful means of distinguishing the respective fuels.

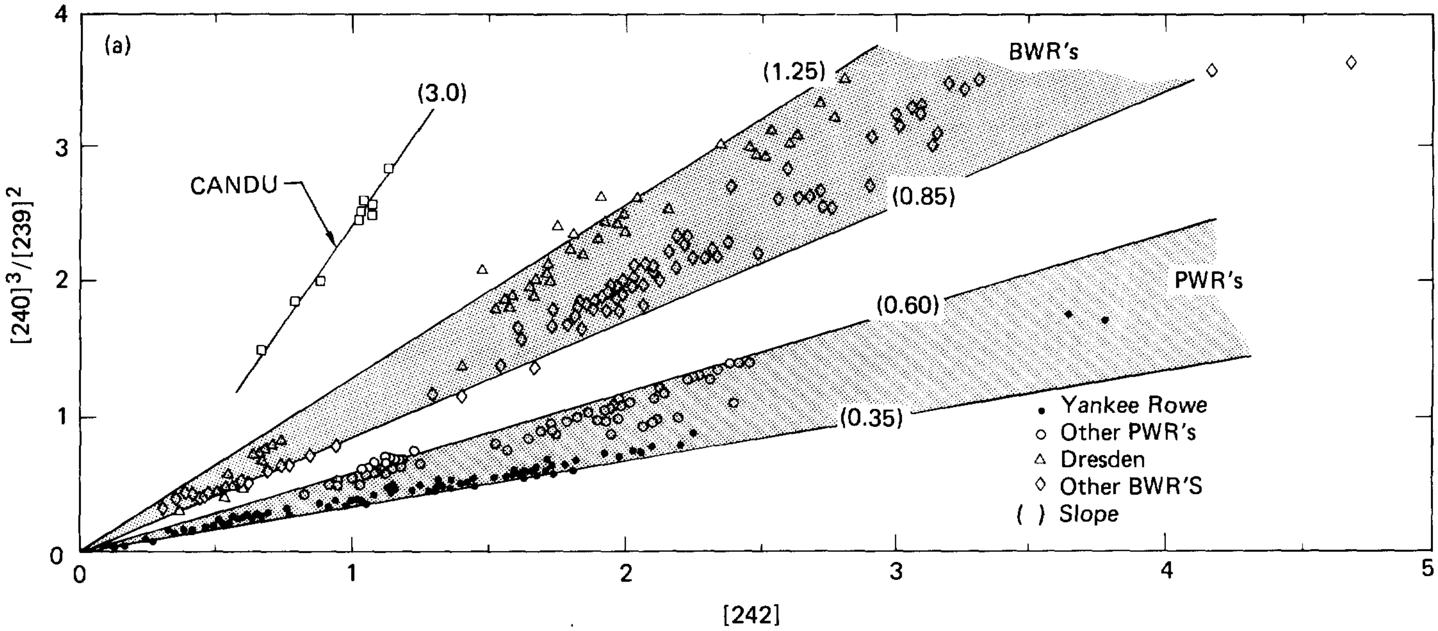
We also plotted the data using the following relationship proposed by Dragnev[9]:

$$[242] = -2.125 + 14.199([240]/[239]) + 23.901([240]/[239])^2. \quad (7)$$

The resulting correlations, shown in Fig. 4(b), resemble those shown in Fig. 4(a). The correlation $[240]^2/[239]$ referenced by Umezawa et al. was also tried with similar results.[6] Of the correlations we studied involving only ^{239}Pu, ^{240}Pu, and ^{242}Pu abundances, the $[240]^3/[239]^2$ vs [242] correlation gave the most linear and consistent relationship, particularly when applied to a fuel coming from a specific reactor.

CONCLUSIONS

A very linear correlation has been found whereby the isotopic abundance of ^{242}Pu can be calculated from the measured abundances of ^{239}Pu, ^{240}Pu, and ^{241}Pu. When isotopic data coming from 12 different reactors representing PWR, BWR, and CANDU designs are used in the correlation of $[240][241]/[239]^2$ vs [242], an overall standard deviation in the correlation constant of about $\pm 6\%$ is obtained. Other correlations excluding the ^{241}Pu content were also investigated but were found to be quite reactor-dependent. The data used were largely from the Battelle Pacific Northwest Laboratory data bank, which has few high burnup values. Further tests should be made of the correlations derived here, using data from spent fuel from as many reactors as possible, and particularly from those releasing fuel having a high degree of burnup.



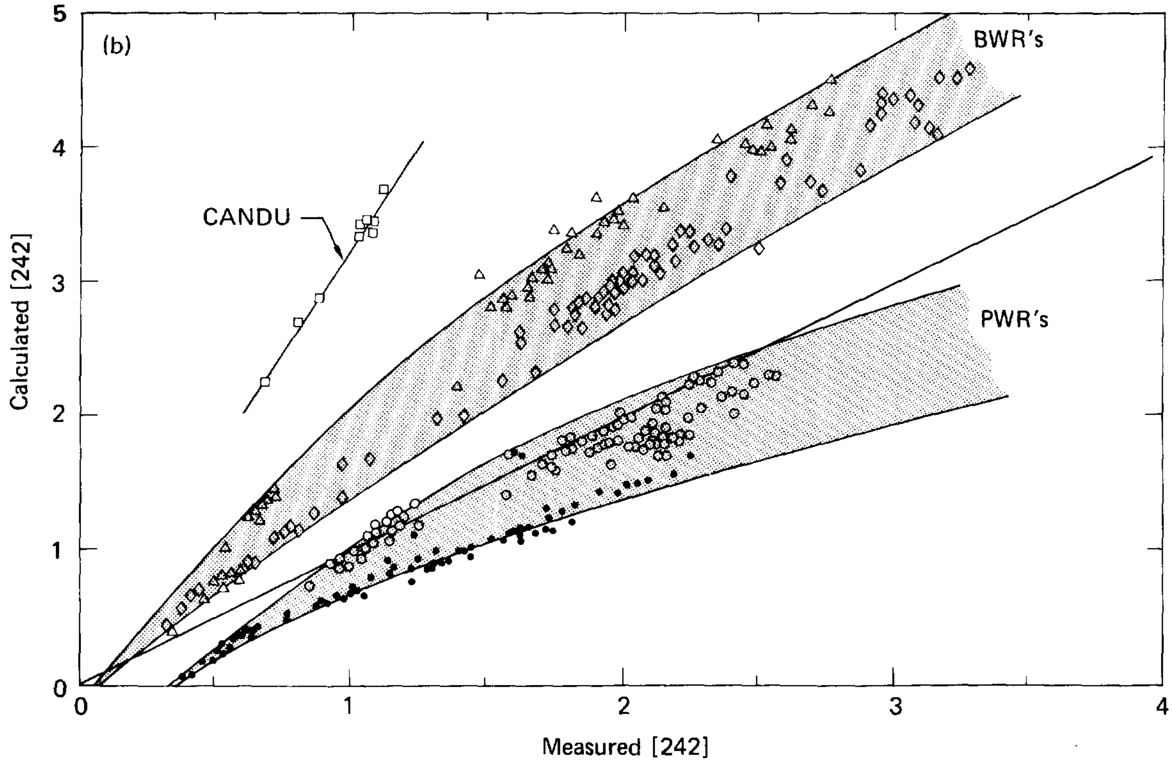


Fig. 4. Correlations not involving the ^{241}Pu abundance (to avoid the ^{241}Pu decay correction). (a) Correlation using Eq. (6): $[242] = C[240]^3/[239]^2$. (b) Correlation using the equation suggested by Dragnev,[9] Eq. (7): $[242] = -2.125 + 14.199([240]/[239]) + 23.901([240]/[239])^2$.

Acknowledgment

I thank Craig Timmerman of the Battelle Pacific Northwest Laboratory for supplying much of the isotopic data used in this study.

REFERENCES

1. R. Gunnink, "Gamma Spectrometric Methods for Measuring Plutonium," Proc. Am. Nucl. Soc. Topical Meeting, Williamsburg, VA, 1978, NBS Special Publication 528, p. 49; see also UCRL-80464 (1978).
2. R. Gunnink, A. L. Prindle, J. B. Niday, A. L. Van Lehn, and Y. Asakura, "TASTEX Gamma Spectrometer System for Measuring Isotopic and Total Plutonium Concentrations in Solutions," 20th INMM Proceedings Issue, Vol. VIII, p. 429 (1979); see also UCRL-82335 (1979).
3. B. F. Rider, J. L. Russell, Jr., D. W. Harris, and J. P. Peterson, Jr., The Determination of Uranium Burnup in MWd/Ton, General Electric Company, Vallecitos Atomic Laboratory, Pleasanton, CA, GEAP-3373 (1960).
4. H. H. Ph. Moeken and H. Bokelund, Verification of the Uranium and Plutonium Measurements on a Batch of Dissolved Reactor Fuel, European Company for Chemical Processing of Irradiated Fuels, Mol, Belgium, ETR-235 (June 1969). Available from NTIS.
5. C. L. Timmerman, Isotopic Safeguards Techniques, ISPO-25/PNL-SA-6761 (1978).
6. H. Umezawa, H. Okashita, and S. Matsurra, "Studies on Correlation Among Heavy Isotopes in Irradiated Nuclear Fuels," Symposium on Isotopic Correlation and Its Application to the Nuclear Fuel Cycle held by ESARDA in Stresa, Italy, May, 1978.
7. C. Beets, "Role of Measurements of Nuclear Materials in Safeguards," presented at Symposium on Practical Applications of Research and Development in the Field of Safeguards, Rome, March 7-8, 1974. Centre d'Etude de L'Energie Nucléaire, Belgium.
8. C. L. Timmerman, Isotopic Safeguards Data Bank (ISTLIB) and Control Program (MISTY), ISPO-34/PNL-2726 (1978).
9. T. N. Dragnev, J. Radioanal. Chem. 36, p. 491 (1977).

A Closed-Loop Control System for a Plutonium Nitrate Storage and Loadout Area

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ABSTRACT

A portion of a physical protection system utilizing closed-loop control of activities in the plutonium nitrate storage and loadout area of a nuclear fuel reprocessing plant was developed to protect against potential insider adversaries. A prototype computerized Closed-Loop Control System was constructed and tested at Sandia Laboratories and an operational system has been installed and is being evaluated at the Barnwell Nuclear Fuel Plant in South Carolina. Results of the evaluation to date indicate that the system is operationally feasible, provides a significant increase in protection and assures more efficient operations.

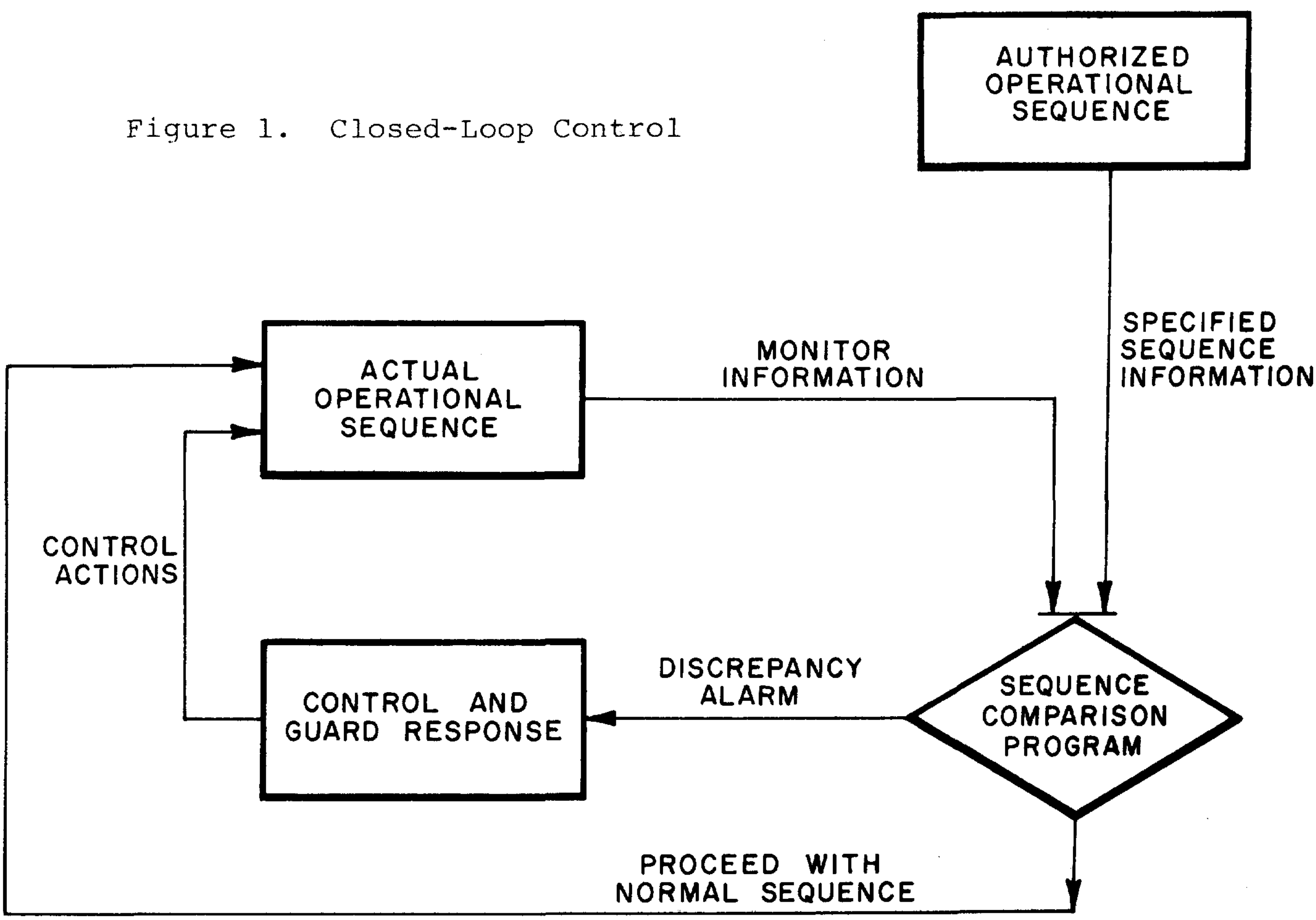
INTRODUCTION

A physical protection system for a nuclear fuel reprocessing facility must be capable of defeating both outsider and insider threats. Protection against outsider threats can be obtained by security forces supported by a combination of barrier, intrusion detection, assessment and entry control elements. These elements may be applied to provide several layers of protection that must be penetrated to reach any target. Detectors associated with each layer can ensure that security forces receive alarms in sufficient time to allow assessment and response.

Protection against insider threats can also be obtained but the design is more dependent upon the specific characteristics of the targets and the target areas. In these areas operating personnel may have access to or be in close proximity to special nuclear material or to vital equipment. This proximity may provide opportunities for persons who have authorized access to the area to attempt theft or sabotage.

A closed-loop control system (CLCS) is one way to provide timely detection and additional delay of insider adversary threats in these more vulnerable areas. A CLCS monitors the orderly sequence of events in an industrial process to detect a significant departure from any prescribed sequence and to allow only authorized persons to perform the sequence. This is accomplished, as shown in Figure 1, by doing the following from a remote protected position, (1) storing in a computer the sequence of key steps in each authorized operational sequence in a target zone, (2) monitoring and enabling key steps that occur during an actual operational sequence, (3) determining whether the actual sequence matches the monitored sequence, and (4) initiating the appropriate controls and responses when a discrepancy occurs to prevent theft or sabotage and to restore the area to normal operations. In the case of maintenance or emergency conditions, the function of the CLCS is to initiate any temporary or partial shutdown procedures and guard actions, consistent with plant safety activities, that are necessary to ensure that adequate protection levels are maintained.

Figure 1. Closed-Loop Control



In order to establish the utility and limitations of a CLCS that is installed in a plant environment, Sandia Laboratories has undertaken a project (reference 1) sponsored by the Department of Energy, Office of Safeguards and Security to develop and demonstrate its use as part of a physical protection system for the plutonium nitrate storage and loadout area of a typical reprocessing plant. This area of the Barnwell Nuclear Fuel Plant (Reference 2), located at Barnwell, South Carolina was the configuration selected for the development effort. The special nuclear materials transfer and sampling operations that occur in this loadout and storage area are similar to other operations in the nuclear fuel cycle. This project consisted of the fabrication and testing of a prototype CLCS at Sandia Laboratories.

This effort was followed by the installation and testing of a near operational CLCS at the Barnwell Nuclear Fuel Plant as part of the safeguards evaluation program that has been carried out at that facility.

LABORATORY MOCK-UP

In order to simulate operations, a mock-up of a portion of the storage and loadout system at Barnwell was constructed at Sandia Laboratories and a prototype CLCS was developed. Figure 2 is a diagram depicting the principal elements of the transfer and sampling operations. These operations involve flow of material from the product line to a specified tank, from one tank to another, from the product line or a tank to the conversion process area, or from a product line to a sample bottle and to an analytical laboratory. Operations are accomplished by opening appropriate valves, starting pumps, or activating the pneumatic transfer tube. The valves and pumps are in glove boxes. The pump and pneumatic tube actuation switches are located on a control panel, external to the glove boxes, in the analytical laboratory.

The transfer and sampling operations were analyzed to identify safeguards concerns that must be addressed if protection against insider theft is to be obtained. These concerns are:

- Unauthorized glove box entry;
- Operation of unauthorized valves;
- Tampering with the valves;
- Tampering with the material lines.

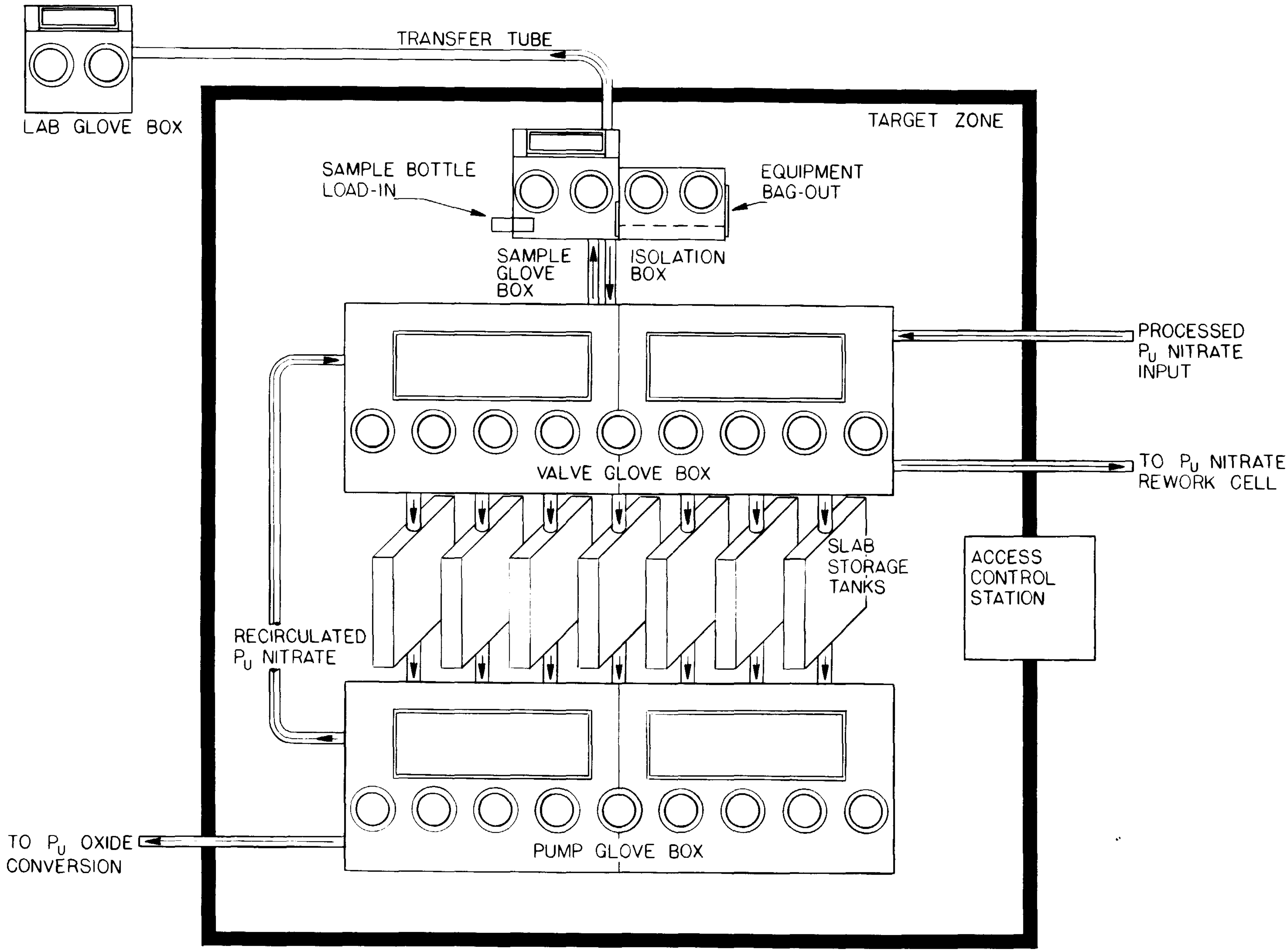


Figure 2. Plutonium Nitrate Storage and Loadout Target Zone

The CLCS elements that were required to protect against these concerns include the detection and barrier devices listed below:

Detectors

- Personnel identification units
- Tamper-indicating locks
- Microswitch and photodiode position monitors
- Light-pen label readers
- Gamma-ray criticality detectors
- Air flow-rate monitors
- Microswitch and pressure tamper monitors
- Magnetic reed switches

Barriers

- Glove box enclosures
- Glove port plugs
- Shield around sample bottle load-in device
- Interlocking bag-out port covers
- Valve stem barrier and valve kit assembly
- Sampling and transfer pipes
- Pneumatic transfer tube sending and receiving units

Figures 3 and 4 give examples of two components that were developed specifically for the CLCS. Figure 3 shows the port plug assembly that has been designed to restrict access to the glove port to only those persons whose identity has been verified and who are authorized to use the glove box during a specified time. The port plug assembly incorporates a solenoid-actuated latch mechanism that is activated by computer to allow the plug to be removed. Port status contacts and interrupt-reed switches are used to monitor port position and provide a tamper indication. Figure 4 shows the valve modification kits used in the Sandia mock-up that provide remote enabling and disabling of the valves in the transfer lines. These valves were designed to be installed in an existing facility without major retrofit or piping modification. A valve stem locking starwheel is controlled by a solenoid which must be actuated before the valve can be turned. A

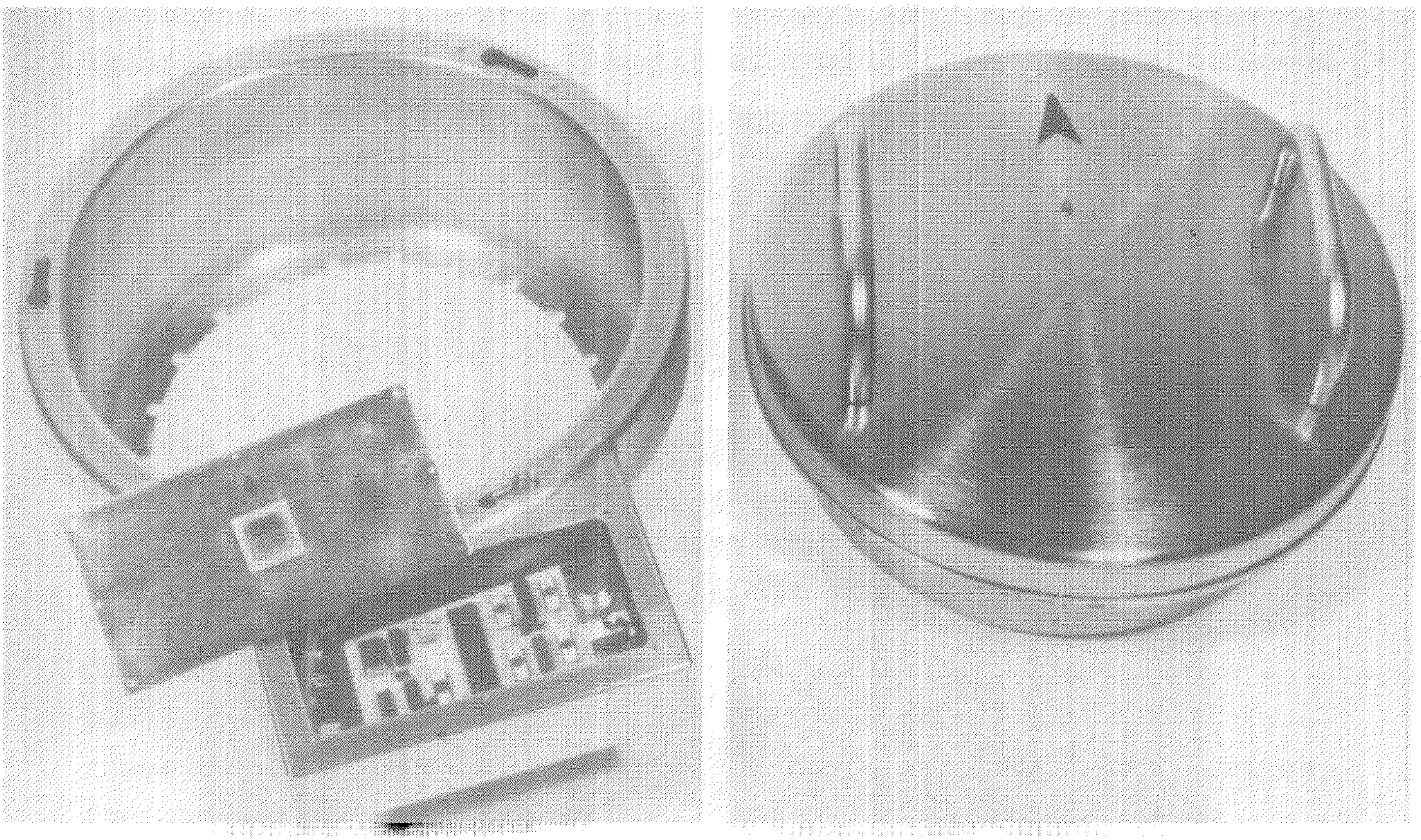
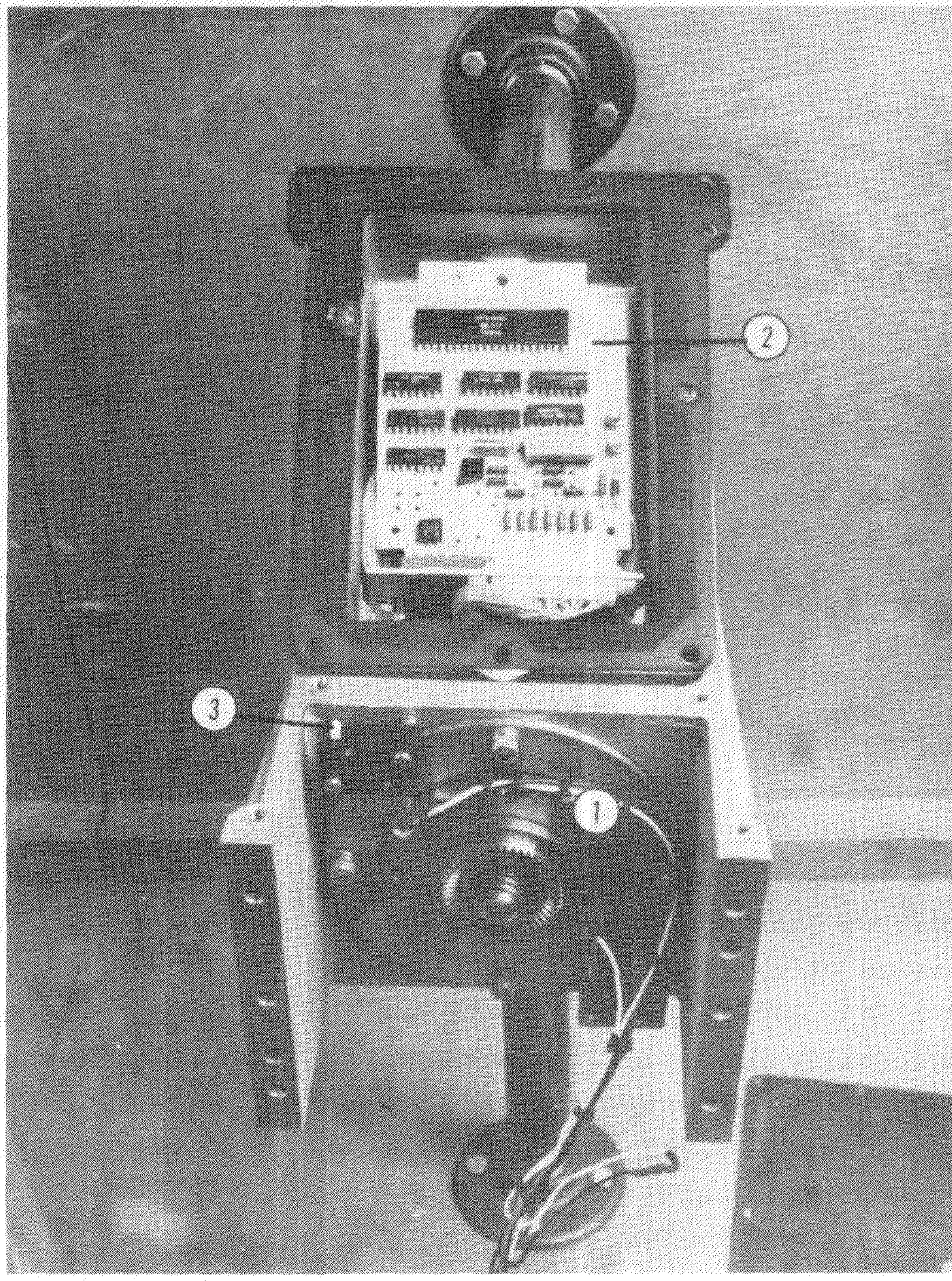


Figure 3. Port Plug Assembly

valve position switch provides a tamper indication which is routed through a tamper indicating unit. This unit provides a communication link that permits polling of the tamper switch and transmission of enable and disable signals.

An extensive series of operational and safeguards engineering evaluation tests were conducted on the prototype CLCS. The operational tests, performed in conjunction with plant operators from Barnwell, indicate that it is feasible to provide operational control of specific activities within the plutonium nitrate storage and loadout area with acceptable operational impact. These controls insure that the operator's identity and authorization are verified and determine that operations take place in the proper sequence and time interval. These tests also showed that the CLCS can provide more efficient and better controlled operations and reduce operator errors.

Based on the test results of the prototype system, Allied-General Nuclear Services decided to incorporate elements of the



1 - Starwheel (valve shaft seat section)
2 - TIU Circuit Board
3 - Tamper Switch

Figure 4. Valve Modification Kit

prototype into their CLCS at the Barnwell facility to provide further insight into the operational feasibility and effectiveness of a CLCS in a more realistic plant environment, (Reference 3).

CLCS INSTALLATION AT BARNWELL

As part of the safeguards evaluation program carried out at Barnwell, elements of a CLCS system have been fabricated and installed in the plutonium nitrate storage and loadout zone. The CLCS is integrated with the Nuclear Materials Control and Physical Security Systems at the plant. Modifications that Barnwell personnel have incorporated in the CLCS include color graphic displays of monitor data as shown in Figure 5, CCTV surveillance, CCTV motion detection, process alarm data for fire, radiation, ventilation, and for tank liquid level and temperature. Figure 6 shows the sampling glove box portion of the Barnwell installation. The CLCS is functionally operational, and has been operating satisfactorily for six months. Tests are underway to further evaluate CLCS compatibility with normal processing, control, safety and security operations. Cold runs of transfer, sampling, and maintainence operations using water have been completed. Nitric acid will be used to simulate flow of plutonium nitrate during the next series of tests in 1980. Data from these tasks will be used to evaluate system reliability, to establish realistic time gates for subtasks, and to determine the operational impact of the CLCS.

Results to date indicate that the system hardware is reliable and has an acceptable impact on operations. Whatever operational impact occurs is offset by the ability of the CLCS to document events and ensure that operation and safety procedures are followed. After the operational tests have been completed, a series of specific safeguards effectiveness tests will be undertaken to formalize more detailed design requirements (Reference 4). It appears that the CLCS offers a potential for significant improvements against insider threats and this concept is being applied to other areas where protection against insider adversaries is required.

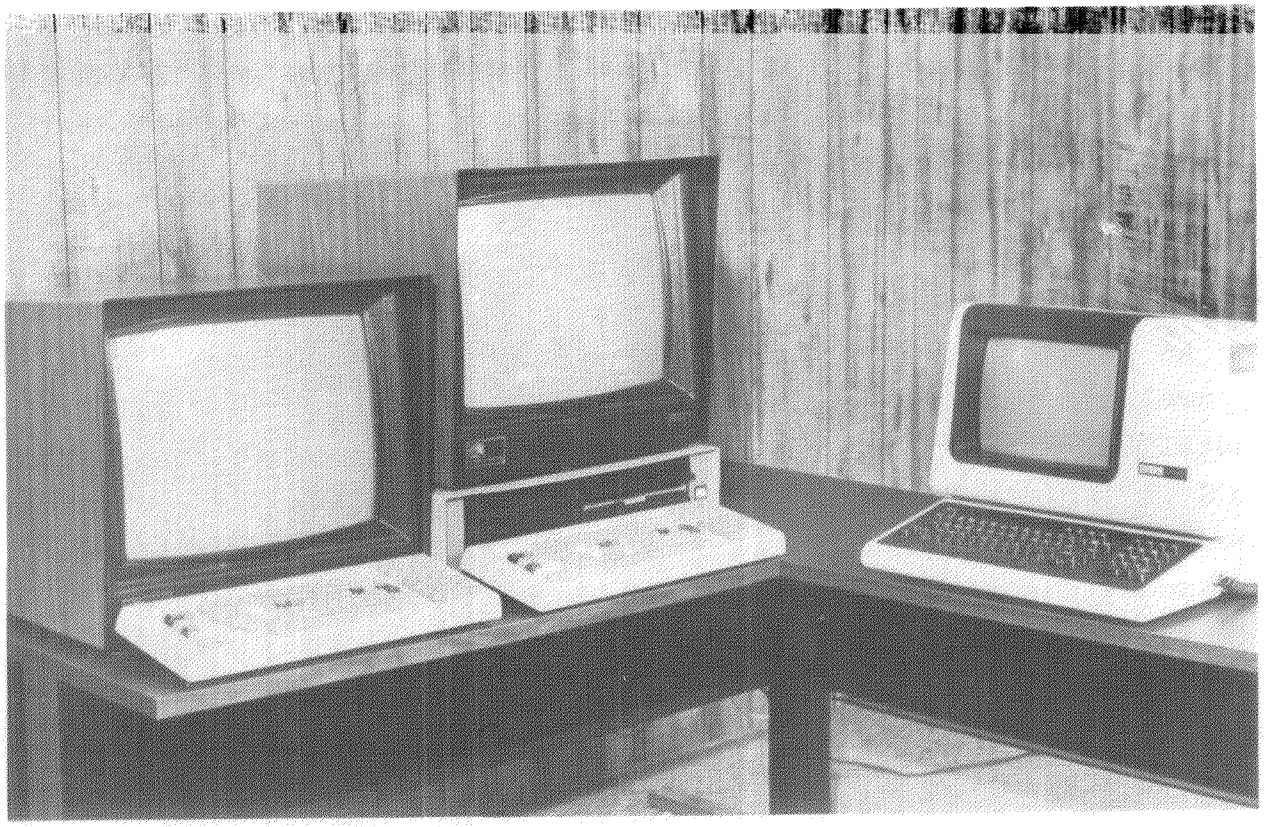


Figure 5. Zone Operations Control Console

Figure 6. Glove Port Assemblies On Sample Glove Boxes

REFERENCES

1. J. E. Deveney, B. R. Fenchel, S. N. Sanderson, Closed Loop Control System Safeguards Project, Review Draft; Sandia Laboratories Report No. SAND79-1562 (Albuquerque, New Mexico, August 1979.

2. L. L. Thomas, Plutonium Nitrate Storage and Loadout Facility; Allied-General Nuclear Services Report No. NMS-6 (Barnwell, South Carolina, August 1979.

3. Barnes, L. D., Crawford, M. L., and King, R. W., "Integration and Coordination of Safety Operations-Safeguards," AGNS-1040-2.3-44 (September 1978).

4. Crawford, M. L., Collert, G. T., and Moultrie, S. A. "Closed Loop Control for Advanced Integrated Safeguards Systems", AGNS-35900-2.3-57 (November 1979).

Some Quantitative Aspects of Measuring Liquid Wastes in Large Collection Basins

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INTRODUCTION

The low level, uranium bearing liquid wastes from the ammonium diuranate (ADU) process used in some low enriched uranium fuel fabrication are typically measured in small critically safe tanks prior to discharge to waste disposal or to large storage basins. To check the cumulative accuracy of the measurements made in the small tanks, an engineering scale experiment was conducted over a several year period to determine the accuracy which could be achieved by measuring the liquid waste in a large shallow storage basin.

The accuracy evaluation was performed using a large flat bottom basin of about a 600,000 gallon capacity as a batch measurement vessel. This report describes some of the quantitative aspects of this type of measurement and reports the limit of error which can be achieved if such vessels are used for accountability purposes.

DESCRIPTION OF THE MEASUREMENT BASIN

For the experimental study, the basin identified as Basin #2 was used to collect and measure the liquid waste. The basin is rectangular with a nominally flat bottom and uniformly sloping sides.

The bottom is approximately 235 feet long and 100 feet wide. The upper operating depth is about four feet. The sides slope from the bottom to the upper rim at an angle to the horizontal plane of about 27 degrees (or a height to horizontal distance ratio of 0.5). A top and side view of the basin are shown in Figure 1.

EXPERIMENTAL AND CALIBRATION

During the experiment, liquid wastes from the ADU process were collected in the basin and the basin allowed to fill over a several month period. When the basin was full, liquid phase samples were taken and depth measurements were made. The basin was then rapidly emptied with a high capacity pump to one of the larger storage basins. The basin bottom was inspected for solids and a solid sampling and volume measurement program was conducted to determine the small fraction of uranium present in the solid phase sediment. Once the solid phase assessment was completed, the collection of liquid waste was resumed and the experiment repeated. This process of filling, measuring, and emptying was repeated a number of times.

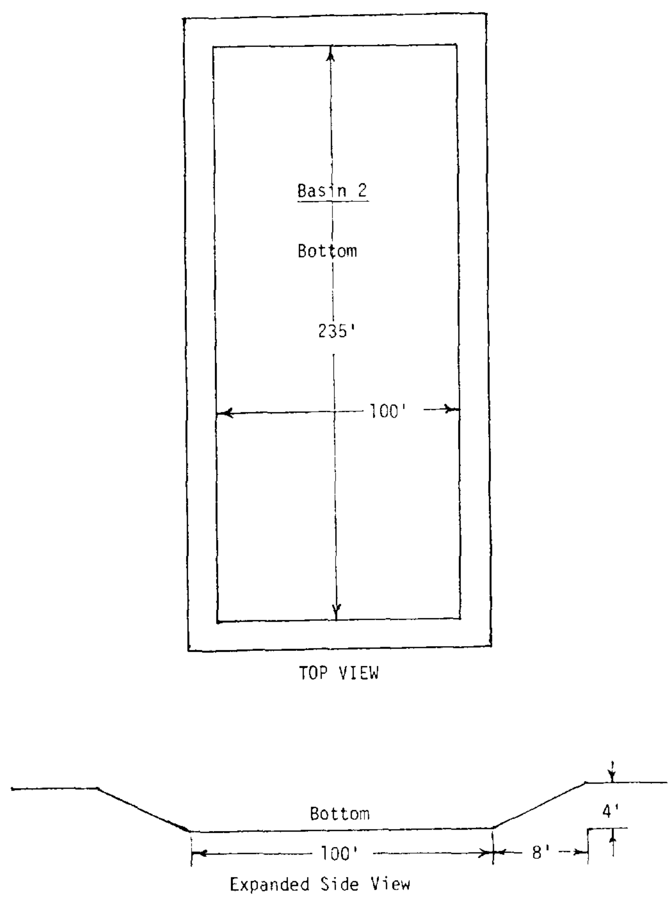

FIGURE 1

Top and Side View of the Basin

Each time the basin was filled, samples of the liquid phase were taken from a boat at nine locations (points of equal area and volume) in the basin. The samples were drawn from just above the bottom to the upper surface so that each set of nine samples represents the overall volume of the liquid phase.

The samples were analyzed for uranium concentration in duplicate using the modified Davies-Gray titration method and/or the fluorimetric method. Three composite samples were prepared from the nine samples for mass spectrometric measurement of the U-235 enrichment.

The basin dimensions were measured (calibrated) using measuring tapes and a surveying elevation marker and transit. The measuring tapes were checked against gage blocks which are traceable to the National Bureau of Standards. The length and width of the bottom and sloping sides were measured at a number of points to take into account variations in uniformity. Some of the dimensional measurements were repeated after a several week interval to check the reproducibility of the measurements.

The liquid level was measured with a calibrated measuring stick (also checked against NBS standards) at approximately 50 evenly spaced points over the entire area of the bottom of the basin. A permanent liquid level marker was calibrated in relation to the basin bottom and sides by repeating the above depth measurements at two different times to relate the liquid level reading of the permanent marker to the average depth.

TABLE 1
BASIN DIMENSIONAL CALIBRATION ERRORS

Dimension		σ, % Relative Volume	
Lagoon Bottom	σ, inches	Transfer Out	Complete Removal
Length	1.95		
Width	1.13 (1)		
Slope-Side Horizontal	1.41 (1)		
Liquid Level Stick		0.34	0.50
Calibration	0.15 (2)		
Random Liquid Level Reading Error	0.072 (3)		

(1) Horizontal distance from end of the flat bottom to junction of liquid with sloping sides. See Figure 1.

(2) Based on two calibrations using about 50 depth measurements at evenly spaced grid positions over the basin bottom.

(3) Random error for a single reading of the liquid level marker with a rounding interval of 0.25 inch.

VOLUME ERROR

The errors associated with measuring the volume of the liquid waste in the basin are shown in Table 1. The volume errors are shown for a complete removal of the liquid phase and also for a partial removal (batch transfer) of the liquid phase.

The very small calibration errors (1-2 inches) for the average length, width, and sides reflect the fact that the basin was constructed to engineering specifications. The standard deviations shown for the dimensional measurement errors were derived from the small differences (1-3 inches) observed between measurements made at different points along the bottom and top of the sloping sides.

A conservative approach (which tends to overestimate the errors) was used for error estimation. The small differences observed between measurements made at different points were assumed to represent repeated measurements of the same quantity rather than true differences which are incorporated in the mean.

The calibration error for the permanent liquid level marker was derived from two calibrations using about 50 evenly spaced depth measurements over the entire bottom of the basin. That calibration is required to relate the average depth over the whole basin to the depth indicated by the permanent marker.

The random error of reading the liquid level marker is based on estimating the liquid level on the marker from the shore to nearest quarter of an inch.

Table 1 also shows the combined dimensional error, that is, the volume measurement error. For a single batch transfer, the volume error is 0.34 percent relative standard deviation and for the total removal of the liquid contents of the full basin the error is 0.50 percent. The volume error for the total removal case is larger than for the batch transfer case since the error in the total removal case includes the error arising from the small variations in the bottom of the basin whereas a batch transfer includes only the volume between two flat liquid surfaces (planes).

LIQUID PHASE SAMPLING AND ANALYTICAL ERROR

Typical random errors for sampling and assaying uranium element concentrations of the basin are shown in Table 2. The data are a composite of four nearly identical experiments in which one sample was taken from each of nine locations (each representing about one ninth of the total volume) and assayed in duplicate. The bottom of the table shows the standard deviations of the mean values for sampling plus analytical and for the separate components. The random error standard deviation for the average element concentration obtained from the nine samples and eighteen assays is about 1.5 percent relative. The random sampling error for an individual sample is about 3 percent relative and the random analytical error for a single assay is about 4.5 percent relative.

TABLE 2

SAMPLING AND ANALYTICAL DATA FOR LIQUID PHASE OF THE BASIN

	Relative Values		
	Uranium		Enrichment
Sample Location[1]	Aliquot 1	Aliquot 2	
E2N2	0.9851	1.0224	
E2N5	0.9030	1.0448	0.9981
E2N7	1.0821	1.0448	
E5N2	0.9552	0.9552	
E5N5	0.9254	1.0112	1.0005
E5N7	0.9254	0.9776	
E9N2	1.0074	0.9776	
E9N5	1.0448	1.0821	1.0015
E9N7	1.0112	1.0448	
Average	1.0000		1.0000

(U Element, Analytical + Sampling) $\sigma_{\bar{X}\ total}$ = 1.44 relative percent

(U Element, Analytical) $\sigma_{\bar{X}a}$ = 1.06 relative percent

(U Element, Sampling) $\sigma_{\bar{X}s}$ = 0.976 relative percent

(1) Sample locations are identified by east and north grid locations which divide the basin into roughly nine equal areas.

LIQUID PHASE MIXING

The general uniformity of the liquid phase in uranium concentration and enrichment is shown in Table 2.

The apparent uniformity of the liquid phase in uranium concentration and enrichment raises engineering questions about how such uniformity is achieved in such a large shallow vessel as the basin. Several natural forces appear to account for the high degree of mixing actually obtained. First, the liquid wastes enter one corner of the basin and fill the basin (∿ 600,000 gallons) over a several month period. The natural force of filling causes liquid distribution forces which themselves promote mixing and diffusion. More importantly, the liquid surface is nearly continuously under some wind force which promotes mixing. The basin is also subject to thermal convection circulation. In a mixing study conducted in one of the large storage basins, sulfuric acid was added to one corner of the basin at an intial lagoon pH of about 8 and in less than 16 hours under mild wind forces (5-10 mph) the entire basin had reached a uniform pH of about 4. Since the basin fills gradually over a several month period during which time there are circulating and diffusion forces continuously at work, it is not surprising that a high degree of uniformity is reached when the full basin is sampled.

It should also be noted that perfect uniformity of the liquid phase is not absolutely necessary for quantitative results, since the average result of the nine samples represents the entire liquid phase of the basin. The error calculation shown in Table 2 includes the between sample variation of the actual data.

SOLID PHASE MEASUREMENTS

To investigate the accuracies which could be obtained if the basin were to be used as a batch transfer accountability vessel, solid phase measurements were made. If the basin were used as an accountability transfer vessel, it would be necessary to measure any solid phase heel at the beginning and end of the accounting period.

The solid phase of the basin was sampled while walking on the empty basin bottom. The silt was swept into piles and measured in containers of known volume. A number of core samples were taken from each pile and composited in a sample container. The composite material was then mixed and sub-sampled for laboratory analysis.

When the solid phase was a fairly uniform thin film (1/4" - 1/2" thick), the volume was determined by measuring off grids and then taking a number of depth measurements to determine the average thickness of each area. Sampling the film was performed by scraping or scooping a large number of small samples from each area and compositing and mixing the composite sample before sub-sampling for laboratory analysis. Sampling and volume measurement errors for the solid phase were relatively large, 10 - 20 percent relative. However, since the solid phase would contain only about one percent of the total uranium measured during an accounting period, the overall contribution of those errors would be relatively small. The analytical measurement errors for the solid phase are the same as those for the liquid phase.

Since all of the uranium discharged to the basin was initially in an ionic form as uranium VI, it is not surprising that the liquid phase would contain the great fraction of the uranium due to the formation of the soluble carbonate complex from the absorption of CO_2 from the air. However, extremely cold weather appears to "freeze out" some of the soluble carbonate complex. Thus if the basin were used for accounting purposes, it is best to have the closing of the accounting period during the warmer months to minimize the amount of uranium in the solid phase heel.

DERIVATION OF VOLUME ERRORS FROM DIMENSIONAL ERROR

The volume of the basin can be represented approximately for purposes of error propagation by the following formula:

$$V = L_1L_2H + L_1HZ + L_2HZ$$

where: L_1 is the average length (235 feet);
L_2 is the average width (100 feet);
H is the average depth (3 feet);
and Z is the average horizontal distance (6 feet) from end of the flat bottom to the junction of the liquid with the sloping sides (when the depth is 3 feet).

In terms of volume contribution, L_1L_2H is the volume of the rectangular solid above the flat bottom, L_1HZ is the volume of the 2 solid trinagles along the longer sides, and L_2H_1Z is the volume of the 2 solid triangles along the shorter sides.

The above formula for volume is used only for error propagation. It is a simplification of the exact integral of the true volume and includes the major sources of error. The above form is used to illustrate the volume errors when L_1, L_2, Z, and H are measured. Similar results are obtained when L_1, L_2, α, and H are measured.

where $\alpha = \frac{Z}{H}$.

The volume errors associated with the dimensional measurement errors may be derived approximately using Taylor's Rule. For a complete removal of the liquid phase, the volume error is derived as follows:

$$V = L_1L_2H + L_1HZ + L_2HZ$$

$$\frac{\partial V}{\partial H} = L_1L_2 + L_1Z + L_2Z$$

$$\frac{\partial V}{\partial L_1} = L_2H + HZ$$

$$\frac{\partial V}{\partial L_2} = L_1H + HZ$$

$$\frac{\partial V}{\partial Z} = L_1H + L_2H$$

and

$$\sigma_V^2 = \left(\frac{\partial V}{\partial H}\right)^2 \sigma_H^2 + \left(\frac{\partial V}{\partial L_1}\right)^2 \sigma_{L_1}^2 + \left(\frac{\partial V}{\partial L_2}\right)^2 \sigma_{L_2}^2 + \left(\frac{\partial V}{\partial Z}\right)^2 \sigma_Z^2$$

The errors associated with a batch transfer (volume between two flat liquid surfaces) may be derived in a similar manner by substitution of ΔH and $\sigma_{\Delta H}^2$ in place of H and $\sigma_H 2$.

The results of the error derivation are shown in Table 3. As shown by the data in the table, conversion of the dimensional measurement error into volume errors gives a volume error of 0.50 percent relative for a complete emptying of the basin and a volume error of 0.34 percent for a batch transfer out of the basin. Both errors are given as relative standard deviations.

Of the total volume error, the main contributor is the error in measuring the liquid depth. The dimensional measurement errors for the length and width of the flat bottom and the sides (Z) make up less than one third of the total variance.

TABLE 3

DERIVATION OF VOLUME ERRORS FROM DIMENSIONAL ERRORS

Complete Removal Liquid Phase			Batch Transfer Out		
Error Term	Variance, ft^3	σ%(1)	Error Term	Variance, ft^3	σ%(1)
$\left(\frac{\partial V}{\partial H}\right)^2 \sigma_H^2$	$(25510)^2 \left(\frac{0.1664}{12}\right)^2 = 125131$ (2)	0.462	$\left(\frac{\partial V}{\partial \Delta H}\right)^2 \sigma_{\Delta H}^2$	$(25510)^2\left(\frac{0.1021}{12}\right)^2 = 46581$	0.283
$\left(\frac{\partial V}{\partial L_1}\right)^2 \sigma_{L_1}^2$	$(318)^2\left(\frac{1.95}{12}\right)^2 = 2670$	0.068	Same as on the left	= 2670	0.068
$\left(\frac{\partial V}{\partial L_2}\right)^2 \sigma_{L_2}^2$	$(723)^2 \left(\frac{1.13}{12}\right)^2 = 4635$	0.089	Same as on the left	= 4635	0.089
$\left(\frac{\partial V}{\partial Z}\right)^2 \sigma_Z^2$	$(1005)^2\left(\frac{1.41}{12}\right)^2 = 13945$	0.154	Same as on the left	=13945	0.154
	TOTALS: 146381	0.500		68101	0.341

(1) Relative standard deviation of volume error associated with an individual dimensional calibration error relative to a total volume of 76530 ft^3 (∿572,400 gallons).

(2) The total variance of 125131 ft^3 has a systematic error component of ∿101680 ft^3 due to calibration of the permanent liquid level marker and a random error component of ∿23450 ft^3 for reading the liquid level on the permanent marker.

TABLE 4

TYPICAL U-235 LIMIT OF ERROR FOR USING THE BASIN AS AN ACCOUNTABILITY VESSEL[1]

		Standard Deviation			
		Uranium		Total U-235	
Stratum	Measurement	Random σ%	Systematic σ%	Random σ%	Systematic σ%
Single Liquid Phase Transfer	Analytical + Sampling	1.44	1.0	1.46	1.00
	Volume	0.28	0.19	0.28	0.19
Total of Three Transfers Out	Combined	0.84	1.01	0.86	1.02
Complete Transfer Out	Analytical + Sampling	1.44	1.0	1.46	1.00
	Volume	0.20	0.46	0.20	0.46
Liquid Phase Total	Combined	0.72	1.02	0.74	1.02
Beginning & Ending Inventory (Solid Phase Heel)	Analytical + Sampling	10	--	10	--
	Volume	10		10	
	Combined	0.1		0.1	

$\% \ \sigma_{U-235} = 1.27\%$ $\qquad$ % L.E. = 2.54%

(1) Limit of error for a six month accounting period.

OVERALL LIMIT OF ERROR

The limit of error for U-235 which would be expected if the basin were used as an accountability vessel is shown in Table 4. The values in the table are based on the assumption that the low level uranium bearing liquid wastes are collected in the basin and measured prior to transfer to storage or to waste disposal. The limit of error illustrated is based on three batch transfers out of the basin, one complete removal of the liquid phase, and two solid phase heel measurements. The values shown in the table are based on the individual error components shown in Tables 1, 2 and 3. It should be noted that the limit of error shown in Table 4 is an average value. The expected range for the U-235 limit of error based on nine similar experiments would be from a minimum of about 2.2 percent to an upper level of about 4 percent. The seemingly small relative error expected for an accounting period is due largely to the fact that during the period there would be 36 liquid phase samples, 72 uranium element analyses and 12 mass spectrometer enrichment measurements of composite samples. This degree of replication results in a 6 to 8 fold reduction in the fairly large random errors (6-10 percent expressed as L.E.'s) associated with a single sample and with a single uranium element assay.

CONCLUSIONS

From the experiments conducted in the large liquid waste basin it is concluded that quantitative accountability results can be obtained for low level liquid wastes in such a large shallow vessel under certain conditions. Those conditions are:

1) A basin built to engineering specifications such that it can be conveniently and accurately calibrated by dimensional measurements,
2) The existence of natural or imposed forces which promote liquid phase mixing, and
3) The ability to periodically empty the basin so that measurements can be made on any solid phase heel and calibrations checked if necessary.

Quantitative results could also be obtained with irregularly shaped large basins and also with circumstances which give less solution mixing. However, it is likely that such situations would involve extensive dimensional measurement and sampling efforts.

The approach of collecting and measuring large volumes of low level liquid waste is more cost-effective than batch sampling and analyzing the same total volume from a number of small tanks. The approach is also competitive cost wise with using continuous sampling and volume integration devices. In some operating modes, the large volume collection and measurement approach (if quantitative), has distinct administrative advantages over endeavoring to measure and record a large number of small batches in close proximity to the process.

ACKNOWLEDGEMENT

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A Field Test of a Transportable Calorimetric Assay System

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ABSTRACT

A transportable system to perform calorimetric assay has been developed for use by U.S. DOE inspectors. This paper describes the system and gives the results of a two-week field test of the unit. The test was made in cooperation with an inspection team from the Albuquerque Operations Office during the course of a scheduled survey.

INTRODUCTION

Verification measurements by safeguards inspectors are an important part of providing assurance that special nuclear materials (SNM) have not been diverted. The utility of calorimetric assay in inspector applications has been demonstrated previously [1,2,3]. It has been used for verifying previous measurements, for identifying measurement biases, and for calibrating other nondestructive assay instruments. In the past these calorimetric assay measurements (power and isotopic composition) have been performed on samples which were selected from the inventory and sent to Mound for measurement. Typically these measurements required six to eight weeks to complete, with much of the time being used for shipment of samples. In addition, many of the materials were of such a nature they could not be easily packaged to meet today's shipping requirements.

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

In order to avoid the problems inherent in shipping SNM and to provide a more timely assay result, a mobile calorimetric assay system has been designed to be easily taken to the inventory site by the inspector. This report describes a prototype instrument and presents the results of a field test at the Los Alamos Scientific Laboratory. This test and evaluation was performed in cooperation with the Albuquerque Operations Office inspection team during a scheduled survey.

INSTRUMENT DESCRIPTION

The calorimeter systems used for the laboratory verification measurements relied on large-volume, temperature-controlled water baths to provide an isothermal environment. These calorimeter systems could not be easily moved from site to site. In the transportable calorimeter design, the water bath is replaced by two heat exchangers, a centrifugal pump, and a small temperature controlled reservoir [4,5]. This design significantly reduces the size and weight of the calorimeter system. Photographs of both systems are shown in Figure 1 to illustrate the differences.

In the transportable design the electronics, water reservoir, and the calorimeter are mounted on a light weight aluminum cart (2 ft wide X 4 ft long). The overall height of the system is 6 ft with a gross weight of 450 lbs. The cart has semi-pneumatic tires and can be readily moved by one person. The electrical requirements for the entire system are a 110 VAC, 30 amp circuit. The sample chamber of the calorimeter used for these tests accommodates sample containers up to 12.7 cm diameter and 20.3 cm high. The wattage range which could be measured is from 0.5 to 10.0W.

The data recording and analysis for the transportable calorimeter have been simplified by using a data acquisition system, DAS, controlled by a Hewlett Packard 9825 calculator. In addition to reading the bridge potential, the DAS monitors the temperature of the water reservoir and the room to assure acceptable operating conditions. Platinum resistance thermometers are used for the temperature monitoring function. The water reservoir is designed to control within $\pm$ 0.001^{o}C. If the reservoir temperature changes by more than 0.004^{o}C, a warning message is printed. Warning messages are also printed if the room temperature varies by more than 1^{o}C. These warning messages are used to document the temperature variations in the field environment. These data are used to evaluate the susceptibility of the instruments to room temperature variations.

The DAS also makes it possible to speed up the assay by using prediction of equilibrium techniques [6,7]. For the samples assayed in this test, the measurement time was reduced from approximately six hours to about three hours using prediction techniques.

The isotopic composition data necessary to complete the calorimetric assay were supplied by nondestructive gamma-ray spectroscopy. An intrinsic germanium detector (1cc) was used to acquire gamma-ray spectra up to 470 keV. The data were stored in a small multichannel analyzer and transmitted by telephone to Mound using a Texas Instruments 765 terminal. The Davidson Model 4106B analyzer with 4096 channels was selected because it is lightweight (5.7 kg) and compact (16.5 X 21.9 X 31.9 cm).

The gamma-ray spectra were analyzed using computer program GRPNL2 to determine the peak areas [8]. Peaks from ^{239}Pu, ^{241}Pu, and ^{241}Am were used to determine the intrinsic self-calibration curve for each sample.

The corrected gamma-ray peak areas were then used to determine the plutonium and americium-241 composition [9].

Next, the specific power and grams of plutonium were calculated using the techniques and nuclear constants from ANSI N15.22 [10]. A results file was generated which contained the specific power, wattage, grams of plutonium, and isotopic composition of each sample. This file was then available for retrieval at the inspection site by means of the Texas Instruments terminal.

SYSTEM SETUP

Approximately four hours are required from the time the system is uncrated until the first measurements can be made. This time is required for the water reservoir to come under temperature control and for the intrinsic detector to cool to liquid nitrogen temperatures. The gamma-ray spectrum of a ^{75}Se source was acquired to assure that the gamma-ray equipment was functioning properly. The base line and a calibration heater measurement were made to test the calorimeter performance. The first sample measurement was begun at the end of the first day and data were acquired overnight.

SYSTEM PERFORMANCE

The overall uncertainty of calorimetric assay has two major components: a) the uncertainty in the power measurement; and b) the uncertainty in the determination of the effective specific power (i.e., watts/g of Pu).

The uncertainty of the power measurement was estimated to be 0.2% + 1mW. This includes errors due to calibration and heat distribution as well as the precision. Since the samples were typically one watt, the calorimeter error was estimated to be 0.3%. These estimates were based on a series of tests at Mound using standard heat sources. The instrument sensitivity and precision were used as indicators of the instrument's continued performance. At LASL these parameters were tested by means of a daily electrical calibration. The sensitivity for the measurements agreed within 0.05% of the values observed while at Mound. The precision in both cases was 0.1%. As a result the original 0.3% estimate was judged valid for the LASL test.

The uncertainty in this calorimetric assay system is dominated by the uncertainty in the determination of the effective specific power (P_{eff}). The computational method, which is described in ANSI N15.22 has been used to calculate P_{eff} from the isotopic ratios determined by gamma-ray spectroscopy. Since the ^{242}Pu concentration cannot be determined by gamma-ray spectroscopy, the book value was adopted and assigned an uncertainty of 25%. The statistical uncertainties of the gamma-ray determinations were used for the uncertainties in the remaining isotopic determinations. Experience with the SALE and Metal Exchange programs[†] at Mound indicates that this method provides a reasonable representation of the uncertainties in the isotopics.

All of the gamma-ray spectra were acquired at the count rates used in the previous Verification Program measurements (2-4 kH). Typically two samples were counted during the normal working hours and one sample was counted

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†The Plutonium Metals Exchange Program serves U.S. Department of Energy weapons laboratories in providing a mechanism for the improvement and standardization of plutonium analysis. The program is managed by Rockwell-Rocky Flats Plant.

The Safeguards Analytical Laboratory Evaluation (SALE) Program serves private and government laboratories in providing a mechanism for the improvement and standardization of safeguards measurements. The program is managed by New Brunswick Laboratory.

overnight.* The uncertainties were combined according to the methods in ANSI N15.22. The overall uncertainty then was 0.98% for the overnight measurements (∿ 11 hours) and 1.64% for the three hour measurements.

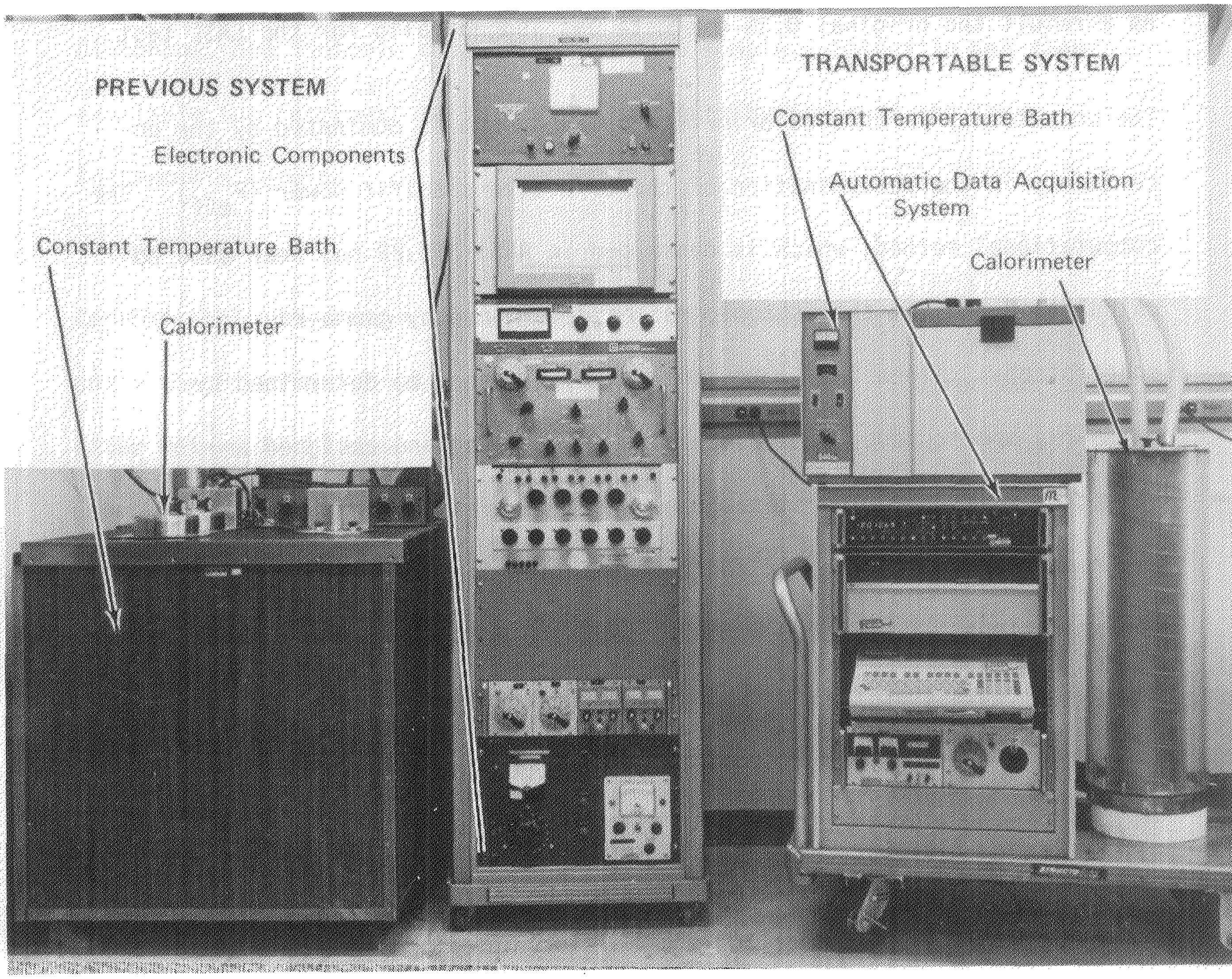

FIGURE 1: Conventional calorimetry system compared with transportable calorimeter. The new design is smaller, lighter, easier to operate and provides a more rapid assay than earlier designs.

*A typical sample had isotopic ratios: $^{238}Pu/^{239}Pu$ = 204 ppm; $^{240}Pu/^{239}Pu$ = 65,201 ppm; $^{241}Pu/^{239}Pu$ = 3851 ppm; $^{242}Pu/^{239}Pu$ = 380 ppm; $^{241}Am/^{239}Pu$ = 572 ppm.

FUTURE WORK

As a result of this test and evaluation, a number of minor modifications are being made to the system hardware and software to make it more suitable for the inspection environment. A second calorimeter is now under construction to assay larger containers up to 15.6 cm in diameter by 33 cm high. This instrument will undergo a similar field test.

Primary emphasis in developing future transportable systems will focus on reducing the size of the calorimeter electronic components, reducing the time required to achieve a 1% assay and simplifying the setup and operating procedures.

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REFERENCES

1. R. O. Inlow and C. S. Smith, "Inventory Verification Methods in DOE Safeguards Inspections," presented at ANS Topical Conference, Kiawah Island, S.C., November 26-30, 1979.

2. R. B. Crouch, "Calorimetric Verification of Plutonium Inventories for Safeguards Surveys," Proceedings of the Symposium on the Calorimetric Assay of Plutonium, MLM-2177, Mound Facility, Miamisburg, Ohio (October 4, 1974), pp. 96-98.

3. R. S. George and R. B. Crouch, "Inspector Measurement Verification Activities," Nucl. Mater. Manage., IV, No. III, Fall 1975, pp. 327-336.

4. M. F. Duff and C. L. Fellers, "Feasibility of a Mound-Designed Transportable Calorimeter," MLM-2603 (1979).

5. C. L. Fellers, W. W. Rodenburg, J. H. Birden, M. F. Duff, and J. R. Wetzel, "Instrumentation Development for the Enhanced Utilization of Calorimetry for Nuclear Material Assay," ANS Topical Conference, Kiawah Island, S.C., November 26-30, 1979.

6. C. L. Fellers and P. W. Seabaugh, "Real-Time Prediction of Calorimeter Equilibrium," NUCL. INST. METH. 163 (1979) 499-505.

7. R. A. Hamilton, "Evaluation of the Mound Calorimeter Equilibrium Prediction Program," Rockwell-Hanford Report, RHO-SA-114 (July 1979).

8. J. G. Fleissner, J. F. Lemming and R. Gunnink to be published.

9. J. G. Fleissner, J. F. Lemming and J. Y. Jarvis, "Study of a Two-Detector Method for Measuring Pu Isotopics," ANS Topical Conference, Kiawah Island, S.C., November 26-30, 1979.

10. American National Standards Institute N15.22, "American National Standard Calibration Techniques for the Calorimetric Assay of Plutonium-Bearing Solids Applied to Nuclear Materials Control," June 5, 1975.

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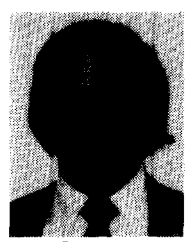
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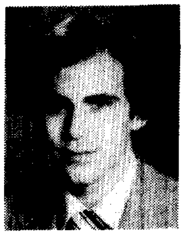
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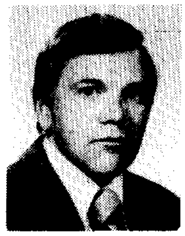
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