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# INMM

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# EDITORIAL

## IAEA Support

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

As is reported elsewhere in this issue, the INMM conducted a very useful workshop on the application of IAEA safeguards to U.S. peaceful nuclear facilities. As we all know, the Non-Proliferation Treaty does not require that IAEA safeguards be applied to nuclear-weapon states party to the treaty. When a number of the advance non-nuclear-weapon states complained that this unequal treatment would give the nuclear-weapon states a commercial advantage, President Johnson volunteered to place U.S. nuclear facilities under IAEA safeguards, so that all would be treated alike. The U.K. followed suit, and the NPT came into effect.

Now that the U.S. Government has imposed the most stringent safeguards anywhere in the world on domestic facilities, declared a *moratorium on reprocessing*, cancelled the CRBR, and applied major constraints on nuclear sales abroad, the U.S. can hardly be said to enjoy many competitive advantages. Why, then, is the U.S. still going ahead with the President's Offer? Surely, the U.S. has no incentive to divert nuclear material from its sick nuclear industry or its nuclear power plants.

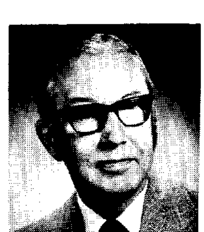
One reason to proceed with IAEA safeguards in the U.S. is that the NPT and the IAEA are likely to be significantly weakened if the U.S. doesn't do so. By accepting IAEA safeguards on our facilities, we in the U.S. demonstrate to the world our continuing faith in the IAEA and reaffirm our support.

The U.S. and the U.S.S.R. have supplied much of the push for adoption of the NPT and for strengthening the IAEA. Neither one of these giants is directly threatened by second or third rate proliferators. The countries which should have the most interest in IAEA safeguards are those who would be more secure if they and their rivals were to remain non-nuclear.

The reason that the IAEA was established, and that it enjoys considerable international support, is that it appears to many nations to contribute to security. It can play only a limited role in deterring proliferation. It cannot prevent it. What it does is to provide independent evidence that a member state is conforming to its pledge to refrain from developing nuclear weapons. It will be more effective if it gains more universal participation **and** if the nuclear weapon powers honor their pledge to reverse vertical proliferation.

The U.S. should not consider acceptance of IAEA safeguards necessary just because our non-nuclear weapon state friends insist that we share the agony with them. What is more important is that we, in the U.S., must learn first-hand what the IAEA is good for, what its present strengths and weaknesses are, and how we can contribute to making it more effective. It is too easy for our representatives to recommend that

**(Continued on Page 75)**



**Dr. Higinbotham**

# Report on Spring Executive Committee Meeting in San Francisco

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

At the Spring meeting of the INMM Executive Committee held in San Francisco March 21 and 22, 1979, a number of timely issues were addressed and deliberated. I want to take this opportunity to give you a brief report on progress made in certain areas as well as some notable new developments that should be of direct interest to the INMM membership.

As you know, in the Institute's program for 1979 we are emphasizing two key areas: Professionalism and Communications; thus, it is particularly gratifying that very significant progress was reported at San Francisco in the area of professionalism—and specifically in the Institute's new certification program. An ad hoc committee under the Chairmanship of **Frank O'Hara** has been established to formulate a new examination regimen for the certification process. O'Hara is assisted by **Fred Forscher,** Chairman of the INMM Standing Committee on Certification. To implement the program, two subcommittees were set up: the INMM Certification Test Formulators, under Forscher, have formulated a pool of over 500 examination questions, and the INMM Certification Test Evaluators, under O'Hara, are reviewing, modifying, and selecting appropriate questions. The formal certification regimen is initiated with an entry level general examination covering the three major areas of nuclear materials accountability, materials control, and physical protection. Upon successful completion of the examination, the candidate is designated a **Qualified Safeguards Intern.** After three years of applicable professional experience and peer recommendation, the candidate will be eligible to take a written and oral examination in one of the three major areas, and receive full accreditation as a **Certified Safeguards Specialist.**

The entry-level general examination is expected to be available for qualified applicants later this year. The major prerequisite for the entry-level examination is a Bachelor's degree in an appropriate discipline (generally some area of the physical sciences) or a minimum of five years experience in the field of nuclear materials management/safeguards (or an equivalent combination of the two).

Parallel to the Institute's stepped-up program in Professionalism and Certification, there is increasing interest in formal academic training in safeguards and materials management on the part of some Universities, notably the University of Idaho, the University of New Mexico, and perhaps others. For example, the University of Idaho has proposed a curriculum in Nuclear Materials Management, and the University of New Mexico has proposed a "safeguards option" within both the undergraduate (BS) and graduate (MS) level curricula of the Department of Chemical and Nuclear Engineering.

In addition to this, there are the ongoing "non-academic" training courses such as John Jaech's INMM-sponsored statistics courses at Battelle Columbus Laboratories, possible future courses in calorimetry, etc., that are intended primarily for safeguards "practitioners" (i.e., full time workers in the field) as opposed to academic courses for university students working toward a specific degree in such areas as nuclear or chemical engineering with an "option" in safeguards or nuclear materials management.

Such diverse, yet obviously related programs and developments in the area of safeguards standards, education and training serve to underscore the importance of coordination between various diverse forms of training (formal and informal, introductory and advanced, academic and "non-academic"), and the Institute's Professional Certification Program.

An independent, objective internationally-constituted professional society such as the INMM is in many ways ideally qualified to provide a focal point for this kind of coordination and service to the nuclear community. It has been pointed out by many that such an effort is closely allied with the Institute's long-standing record of leadership and accomplishment in the major areas of safeguards standards, i.e., consensus, physical and professional performance standards. For example, the ANSI/INMM Draft Standard N-15.28 "American National Standard Criteria for the Certification of Nuclear Materials Managers," and recent attempts at updating such certification criteria, have contributed toward the overall goal of a generally accepted standard or "common denominator," of professional achievement and performance in the safeguards field. Based on extensive expertise and two decades of practical experience, the INMM has both an opportunity and a

Dr. Keepin

professional responsibility to provide continued and expanded leadership in the closely related areas of professional standards/certification, education, and training in safeguards and materials management. Meeting this challenge (e.g., through the combined efforts of the INMM Education, Certification and Standards Committees, and appropriate Technical Working Groups—coordinated, as appropriate, with similar efforts of other professional organizations and Agencies) is the quintessence of the "Professionalism" that has been designated as an area of priority emphasis for the Institute in 1979.

In the second area of current INMM emphasis—Communications—some new developments were also reported at the San Francisco Meeting. The Public Information Committee under Chairman **Herman Miller** is working to arrange press tours of two or three nuclear facilities in the United States during 1979. Miller is also pursuing, with officers of the INMM Japan Chapter, the possibility of sponsoring similar tours at designated fuel cycle facilities in Japan (e.g., at Japan Nuclear Fuels, Yokosuka, and perhaps at PNC, Tokai).

The INMM Safeguards Committee under the Chairmanship of **Syl Suda** is a primary source of input for the Public Information Committee, as is also the INMM News Bureau, composed of Institute members that are responsible for monitoring news releases, articles, editorials, etc. in key areas throughout the U.S. Although some News Bureau responses have been received by the Public Information Committee, to date the progress and output of the Safeguards Committee as reported at the Executive Committee Meeting in San Francisco has been quite disappointing, particularly in view of the importance that has been ascribed to the vital area of public information, and communications generally.*

A concerted effort is being made to address this problem, which is of real concern to me and to all members of the Executive Committee. At San Francisco, significant progress was reported in one activity of the Safeguards Committee, namely the preparation of a "Safeguards Awareness Poster." A proposed poster design was approved, with some modifications, by the INMM Executive Committee, and the new poster (approx. 14" × 18") will be distributed this Spring to some 100 nuclear facilities throughout the U.S.; the basic purpose of this project is to enhance employee and public awareness of the importance of safeguards and security, as well as the rewards and penalties associated with the misuse of special nuclear materials.

As reported earlier (**Nuclear Materials Management,** Vol. VII, No. 3, pp. 3-4) we are currently considering the formation of INMM Technical Working Groups that can more effectively represent the professional interests of Institute members and enable increased membership participation in Institute planning and professional/technical activities. To evaluate the feasibility of this concept, I have asked INMM Vice Chairman **Gary Molen** to head up an Ad Hoc committee to develop a plan of action and scope of activities for the Proposed new Technical groups. The Ad Hoc committee report was presented at San Francisco, and it was decided to first implement the concept in one area of activity—namely physical protection—in order to establish practical workability and operational effectiveness. Other areas of interest which may be represented by INMM Technical Groups in the future include:

- Accountancy and Materials Management.
- Measurement, Calibration, and SNM Control Systems.
- Systems Studies, Statistical Analyses and Evaluations.
- International Safeguards: Inspection, Verification, etc.

In view of its direct relevance to Institute members, the *topic of Technical Working Groups will be an agenda* item for discussion at the INMM Business Meeting in Albuquerque in July.

Needless to say, your comments and input on this, or any Institute matter, are always greatly appreciated.

At San Francisco, Annual Meeting Chairman Molen reported that final plans are being firmed up for the Institute's 20th Annual Meeting in Albuquerque next July. **John Jaech,** Chairman of the Institute's Program Committee, has assembled an outstanding list of distinguished participants, including IAEA Director General **Sigvard Eklund** as keynoter, DOE Deputy Secretary **John O'Leary,** controversial NRC Commissioner **Victor Gilinsky,** GE's **Bert Wolfe,** and a number of other leaders in the nuclear community. Also the new Director of the DOE Office of Safeguards and Security, **George Weisz,** will be the featured speaker at the INMM Buffet Dinner on Tuesday, July 17. The INMM Meeting Arrangements committee (**Joe Stiegler, Roy Crouch, Duane Dunn, Tom Gerdis,** and **John Glancy**) is planning in detail for a well-organized smooth-running annual meeting with a number of colorful features intended to highlight the southwestern culture and atmosphere of "The Land of Enchantment." (Gringo lingo for New Mexico!)

The INMM Awards Committee under the chairmanship of **Sam McDowell** is evaluating nominations in two major award categories: the prestigious INMM Distinguished Service Award and the recently established INMM Student Paper Award. Each of these awards will be formally presented to the selected outstanding candidate at the Albuquerque meeting.

Finally, at San Francisco the INMM Executive Committee reviewed and accepted the Chapter Constitution and By-Laws submitted by the Institute's two new Chapters: the Vienna Chapter headed by **Carlos Buchler** of IAEA and the Pacific Northwest Chapter headed by **Bill DeMerschman** of HEDL. This last formal requirement having thus been satisfied, both the Vienna and Pacific Northwest Chapters now join the Japan Chapter as duly constituted and fully operational Chapters of the Institute. (Cf. individual Chapter reports elsewhere in this issue.) All of us in the Institute extend hearty congratulations and best wishes for every success to all three of our INMM Chapters—which, indicative of the growing international character of our Institute, are strategically located in three different continents of the world.

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***Note added in proof**—the events and publicity surrounding the accident at Three Mile Island nuclear plant in Pennsylvania dramatically underscore the vital challenge of educating and informing the public on the risks and the benefits of nuclear power in the perspective of the same inevitable risk-benefit considerations for all other forms of energy generation.

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# Program Committee Promises Something for Everyone At Annual Meeting

**By John L. Jaech, Chairman**
Technical Program Committee
Exxon Nuclear Co., Inc.
Richland, Washington

What safeguards-related topics are of special interest to you? No matter what your answer may be, you should find that the Albuquerque program will meet your needs.

Are you particularly interested in hearing from the policy makers? You won't want to miss the Opening Plenary Session on Monday morning, July 16. In tune with the Conference theme, "International Safeguards," the Keynote Speaker will be **Sigvard Eklund,** Director General of the IAEA. Joining him will be **Lawrence Scheinman** of Cornell, **Bertram Wolfe** of GE, **John O'Leary** of the DOE, and **Victor Gilinsky** of the NRC. You can be assured that these prominent speakers will stimulate you and others in the audience to react with your comments and questions.

You say you are interested in what's going on in the European community? **Charles Beets,** Chairman of the invited papers session on "Safeguards in ESARDA (European Safeguards Research and Development Association)" has lined up an impressive group of speakers on such topics as implementing safeguards in the European community, the role of ESARDA in international safeguards, activities of ESARDA working groups, the ESARDA approach to facility-oriented safeguards problems, and the increasing importance of containment and surveillance in international safeguards.

On the U.S. domestic scene, if you feel that the INMM program has had little to offer you as a utility representative in recent meetings, we've got something special for you this year. **Bob Kramer,** chairing the session on "Safeguards Concerns of Utilities" has pulled together a representative group of speakers from various utilities. Although as of this writing specific topics have not been identified in all cases, I can promise you some exciting papers. As one example to whet your appetite, we will have a security manager from one of the utilities speaking on his experiences in handling demonstrations at reactor sites.

Does your interest lie in the area of measurements technology? Or perhaps you are interested in the estimation and control of measurement errors? We have two invited papers sessions on these topics for you also, one chaired by **George Huff** and the other by **Darryl Smith.** Both sessions are already set, and the papers in these sessions will be well worth your while.

In the winter issue, we promised you a session on "Safeguards and Alternative Fuel Cycles"—a plenary session on Tuesday afternoon chaired by **Bill DeMerschman.** Because of problems in lining up appropriate papers on this topic in time for the July meeting, the session has been broadened to "Safeguards—An Overview of Domestic and International Programs." You won't want to miss this session; the list of speakers that Bill has lined up is an impressive one.

I've not mentioned other choice program tidbits—the many fine contributed papers to be expected. If past years' experience is any indication of the quality of such contributed papers, the Contributed Papers Chairman, **Dick Chanda,** will have a tough job as he and his committee of **Tom Collopy, John Glancy, Jay Durst,** (and possibly others not identified as of this writing)

**Jospeh E. Stiegler (left) of Sandia Laboratories and John L. Jaech of Exxon Nuclear have important jobs in planning and coordinating of the 1979 INMM Annual Meeting set for July 16-19 at the Albuquerque Hilton Hotel in Albuquerque, New Mexico. Mr. Stiegler is in charge of meeting arrangements. Mr. Jaech is in charge of the technical program for the meeting.**

**Collopy**

**Jaech**

**O'Leary**

**Wolfe**

**INMM ladies share a light moment at the Chairman's special reception for overseas guests during the 1978 Annual Meeting in Cincinnati. Left to right—Janet Lee (Mrs. Jim), Barbara Cardwell (Mrs. Roy), Jean DeVito (Mrs. Vince), and Lucretia Hurt (Mrs. Nate).**

screen the papers. Nor have I mentioned the Second Annual student award paper, being selected by **Sam McDowell** and his committee. Finally, at the buffet dinner party, we've got a mystery guest speaker lined up—more on this later.

That's an overview of the program as it stands now. Come and hear the papers on the topics closest to your heart, at the same time, broaden your horizons by listening to other safeguards related papers on topics with which you may not be so familiar.

There may be reasons why you will not attend the Albuquerque meetings; your Program Committee hopes that **your** reason for not attending is not because the program has little appeal to you.

See you in Albuquerque!

# Japan Chapter to Conduct Special One-Day Conference This Coming September

The Japan Chapter of the Institute of Nuclear Materials Management held its second Executive Committee meeting on Friday, March 9, at the Nuclear Material Control Center with seven members present.

The committee decided to conduct its chapter annual business meeting in June. That meeting will mainly emphasize future organizational matters.

The chapter plans to conduct a special one-day conference in September. The conference will consist of several invited papers followed by general discussion so that the total picture of nuclear materials management will be clearly brought out. The meeting will be open to the public and will hopefully serve as an occasion to recruit new members.

Prof. **Ryohei Kiyose** of the Nuclear Engineering Faculty at the University of Tokyo has been designated Chairman of the September meeting. Prof. Kiyose is Vice Chairman of the Japan Chapter.

**Yoshio Kawashima,** Chapter Chairman and Executive Director of the Nuclear Material Control Center, was designated to serve on the INMM Editorial Advisory Committee. This desicsion followed receipt of a recent letter from the Editor of **Nuclear Materials Management, Thomas A. Gerdis,** to Mr. Kawashima inviting Mr. Kawashima to serve on the committee.

It was noted Dr. **Takeshi Osabe** of Japan Nuclear Fuel Co., Ltd., participated in the December 7-8 INMM Special Workshop on IAEA Safeguards in the U.S. The workshop was held at the Washington Hilton Hotel in Washington, D.C. Dr. Osabe's paper recounting "Experience with IAEA Safeguards at a Japanese LEU Fuel Fabrication Facility," appears in this issue beginning on page ??.

**Dr. Osabe**

# N-15 Goals Include Professional Acumen

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

One need not be intimately involved in the problems of today's U.S. nuclear energy future to realize that 1979 may be a pivotal year. Significant policy actions are planned at the congressional level and public opinion is both undecided and volatile. As a result, future long-term directions may be greatly influenced by well conceived short-term actions.

The recent years of debate have worn thin simple analogies concerning energy questions. However, one seems to ring particularly true: "The Train Is Leaving The Station." As evidenced by recent Wall Street Journal articles, entitled "Assessing the Atom" (February 8 and 12, 1979), the proverbial energy train already has a full head of steam, and the nuclear industry is fighting like hell to keep from getting pushed off at the station. Within our field of expertise, the most timely question remaining is how can the Institute and the N15 Standards Committee best use its limited resources to help stave off this increasing tide of nuclear pessimism.

Before addressing this question, some comments from recent experience may be helpful. In California, we learned an important lesson early during the successful 1975 Proposition 15 anti-nuclear fight. It was that public information and scientific abstractions do not easily mix. In conflict with our scholastic training and engineering experience, logical technical arguments cannot be expected to be accepted on their own merits in the public arena, particularly in the short term. Today's media is repleat with examples to support this pragmatic, albeit inconsistent, chronicle of the current social scene. For example, often without sufficient sicentific basis, anti-nuclear proponents have routinely and successfully resorted to highly emotional public outcries and irrational claims which, irrespective of their basis in fact, have left a lasting mark on the public mind.

How can such attacks be effectively countered? First, by assessing our technical strengths and weaknesses. For example, two technical issues currently loom large on the 1979 nuclear political horizon and threaten to forestall affirmative nuclear decisions:

1) Licensing Delays

2) Waste Disposal Uncertainties

Until industry and government actions are taken to authoritatively demonstrate that these issues have technical solutions and are not flaws in the nuclear armor, the reconciliation of more important social issues relating to nuclear alternatives will not be possible.

Secondly, and more importantly, by developing a new sense of **Professional Acumen.** This would result in taking the interaction between social, economic and technical issue to the public in a new and more soluble framework.

The seeds of such professional acumen were germinated in California and other states during the 1975/1976 elections, and turned the public tide. They resulted in moving the industry from its historical silent or indifferent role into a more aggressive public information and involvement posture. This movement brought forth a whole new approach to public education based on simple social common denominators. The result was greatly enhanced public understanding and acceptance of key nuclear energy issues. However, a key predecessor to this success was acceptance within the industry, perhaps for the first time, that the tools of war are different in the socio-political arena and that these tools are both new to our high technology business and ones with which we are not yet fully adept.

How then can similar concepts be applied to our 1979 nuclear predicament and goals for the 1980's? First, by recognizing again that today's problems are primarily social, not technical, and therefore have political solutions. Secondly, by assuring that our technical house is in order. Third, by using these bases on both the technical and political fronts to put to rest beyond the shadow of a doubt the sometimes fabricated anti-nuclear arguments.

The decade of the 1970's can best be characterized as a period of reaction for the nuclear industry—not action. For the first time, we have come to realize, as does

D.M. Bishop

**TABLE 1.**
**CURRENT N15 ACTIVITIES**

| SUBCOMMITTEE | TITLE | CHAIRMAN | AFFILIATION | PHONE |
|---|---|---|---|---|
| — | N15 Chairman | Dennis Bishop | General Electric | (408) 925-6614 |
| — | N15 Secretary | Robert Kramer | No. Indiana Public Service Co. | (219) 787-8531 |
| INMM-1 | Accountability and Control Systems | Howard Menke | Westinghouse | (412) 373-4511 |
| INMM-3 | Statistics | Frank Wimpey | Science Applications | (703) 821-4429 |
| INMM-5 | Measurement Controls | Yvonne Ferris | Rockwell International | (303) 497-7000 |
| INMM-6 | Inventory Techniques | Frank Roberts | Battelle—PNL | (509) 946-2685 |
| INMM-7 | Audit, Records and Reporting Techniques | Bob Sorensen | Battelle—PNL | (509) 942-4437 |
| INMM-8 | Calibration | Lou Doher | Rockwell—RFD | (303) 497-2575 |
| INMM-9 | Nondestructive Assay | Darryl Smith | LASL | (505) 667-7777 |
| INMM-10 | Physical Security | Tom Sellers | Sandia Labs | (505) 264-4472 |
| INMM-11 | Certification | Fred Forscher | Consultant | (412) 521-0515 |
| INMM-12 | International Safeguards (Proposed) | To be assigned | — | — |
| INMM-13 | Transportation (Proposed) | To be assigned | — | — |

every young salesman, that all the world does not want our wares simply because we offer them. Like it or not, during the next few years we will be asked to put-up or shut-up. It is a crucial test, and our eventual success can only be assured by using the available time and resources effectively.

This period of retrenchment offers significant challenge and opportunity for professional growth to provide a firm basis for future years. This basis is a primary goal of the N15 Standards Committee—to complete the definition of professional methods in the nuclear materials control area through consensus standardization. It has been a long standing goal of the Institute, and one that requires significant member involvement.

The current N15 Standards Committee scope and organization is shown in Table 1. Based on this organization, N15 has defined a series of aggressive goals for 1979. They include:

1) Issuing six new INMM Standards for ANSI balloting
2) Reviewing and revising nearly a dozen previously issued standards
3) Implementing previously outlined major scope expansion changes
4) Establishing international avenues of communication

However, none of these goals will be attained without continued membership support and participation on individual N15 subcommittee writing groups. If you are currently a writing group member, please do all you can to meet technical and schedule commitments set by your group. If you are new to the INMM or not on an N15 writing group, please feel free to contact any of the subcommittee chairmen in your area of interest and volunteer to help. Based on the increasing numbers and level of expertise possessed by the Institute membership, we could easily be doing twice as much as we have in the past.

Please do not hesitate to give your full support to the Institute efforts during these critical times. It is time to reach down for all the **Professional Acumen** we can muster and keep pace with the increasingly well organized anti-nuclear movement by laying our solutions and action plans for current nuclear obstructionist tactics. ANSI-INMM Standards form an important part of this solution. In this way, the INMM, the N15 Standards Committee and all its members can help the nuclear industry withstand today's scrutiny and build for tomorrow.

A final note. On the international front, the N15 Standards Committee presented a paper entitled, "USA-INMM Safeguards Consensus Standardization Program Status Review" at the April 1978 European Safeguards Research and Development Association (ESARDA) Symposium on Safeguards and Nuclear Materials Management. Results of this activity will be reported in subsequent issues of the Journal.

**Dennis Wilson (left) and Dennis Bishop, both of GE-San Jose, posed for this photo taken by Lou Doher of Rocky Flats. Mr. Doher took this photo on January 22 after lunch following discussions of ANSI INMM N15 Standards Activity.**

Chapter Lists 40 Members

# INMM's Vienna Chapter Elects Four Officers

The idea of a Vienna Chapter of the INMM was first publicly mooted among INMM members and their friends and colleagues at a "Heurigen" evening during the IAEA Symposium on "International Safeguards Technology" held in October 1978. (A "heurige" is a typical Viennese establishment where the local wine is imbibed, accompanied usually by copious amounts of Austrian food from the buffet, with Viennese musicians who stroll from table to table). The idea was well received by those present, which included officers of the INMM who were attending the Symposium. As a result, a petition for the formation of a Chapter was submitted to the Executive Committee by 29 members; this received the blessing of the Committee on 9 November 1978 as the third Chapter of the Institute, following those of Japan and Pacific-Northwest. Meanwhile, much "behind the scenes" work was going on, in the preparation of a list of existing INMM members in Vienna, the canvassing of potential new members and persuasive approaches to possible candidates for the positions of the officers of the new Chapter. Particular gratitude is due to **Yvonne Ferris** for her hard work in this regard, and to the Nominating Committee chaired by **Ray Parsick** and staffed by **Dan Smith** and **John Mahy**. As a result of these activities, on the 12 January 1979 the first meeting of the Chapter was called to order by **Tom Shea,** one of the leading petitioners for its formation, in a magnificent old Viennese dining room reserved for us at the famous "Goesser Bierklinik." Then, over a good lunch, the members proceeded to elect their officers.

It is to the greatest possible credit of those who worked for the formation of this Chapter that a membership list could be circulated which was 40 strong, representing 13 nationalities; 28 members were present at the inaugural meeting and participated in the election.

The officers elected are:

Chairman: **Carlos L.A. Buechler**

Vice-chairman: **Donald R. Terrey**

Treasurer: **Marco Ferraris**

Secretary: **Iain Hutchinson**

**Carlos Buechler** has been on the staff of the IAEA Department of Safeguards for 20 years and an INMM member for 15 years; he is currently Head of the Section for Standardization and Administrative Support. **Don Terrey** was doing safeguards work with the UKAEA for 9 years before joining the IAEA Department of Safeguards 3½ years ago; he is at present in the Division of Development and Technical Support, Technical Service Section. **Marco Ferraris** worked on nuclear material measurement techniques for CNEN for 10 years before joining the IAEA laboratory at Seibersdorf in 1970, transferring to the Department of Safeguards in 1972. He is currently Head of the North America Regional Operations Section. **Iain Hutchinson** was a nuclear materials accountant and planner with the UKAEA for 10 years before joining the Department of Safeguards in 1969. He is now with the System Studies Section of the Division of Development and Technical Support and has special responsibility for training.

The formation of this Chapter has great significance for all practitioners of nuclear materials management and safeguards, since Vienna, through the presence of the IAEA, really is a crossroads of the nuclear world in general and of our own special field of endeavour in particular. However, we must at this point emphasize that what we have established is a **Vienna** Chapter—not an IAEA Chapter or a European Chapter. Thus, we do not wish it to be thought that we have pre-empted the formation of other Chapters in Europe or that our membership is restricted to those serving with the IAEA. Indeed, all members of the INMM who come to Vienna, either as visitors or to stay for long or short periods will be welcomed in our Chapter. All who are active in the field of nuclear materials management will be encouraged to join us (and we will be setting up a Membership Committee for this purpose.)

Our immediate aim at this time is to prepare a constitution and by-laws for the Chapter, and, of course, we will be forming a Program Committee to put together the first thoughts about our program. Little can be said about this at present except that we hope to arrange our meetings to correlate as far as possible with those of the IAEA in order to maximize the possibilities of attendance for members and their guests who are not normally resident in Vienna.

In a city such as Vienna our members are likely to experience an exceptionally rich cultural life, with unrivalled opportunities to participate in the musical, artistic and social activities which have made Vienna famous—the operas, the concerts, the balls and many others. We look forward with confidence to our future and to filling what we hope may be a unique place in the activities of the Institute.

**Participating in the March 13-15 INMM introductory statistics course at Battelle Columbus Laboratories taught by John L. Jaech were (standing, from left)—Harley Toy, Lavella Adkins, Raymond Jackson, Richard Johnson and A.F. Endler; (seated, from left)—Daniel Hill, John L'Heureux, John Jaech and Carl Ostenak.**

# Education Committee Seeks To Provide More Courses

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

Our schedule of spring and fall statistics courses is proceeding as planned. We shall continue this schedule as the needs and demands dictate.

Since the beginning of the year, the Education Committee has been actively pursuing a survey and inventory of available nuclear materials safeguards and management courses. Our findings to date have been less than encouraging. Our cursory examination has revealed what we suspected all along—very few course offerings or training programs. With the exception of DOE's "Safeguards Technology Training Program" at the Los Alamos Scientific Laboratory, there is essentially no formal training available. I guess this reinforces and substantiates what Chairman **Bob Keepin** has been stating all along—a true need exists for additional training and course studies.

Our logical response to this situation is that the Institute must face up to this obligation of providing the essential training needs of our members and the nuclear community as a whole. In other words, "it is time to get on with the job." The Institute does, in fact, have the "where-withall" to establish and conduct effective training programs. Without doubt we have the expertise within our membership to provide the required faculty. It is now time to pull together our resources—membership, finances, and organizational capabilities to proceed with our own comprehensive training program—a training program that will address the several disciplines in

**INMM-Sponsored Safeguards**
**Training Courses in Fall, 1979**
**Battelle Columbus Laboratories**

| | |
|---|---|
| "Introductory Statistics with Applications to Special Nuclear Material Control." | October 2-4, 1979<br>20 Attendees |
| "Selected Topics in Statistical Methods for Special Nuclear Material Control." | October 29-November 2, 1979<br>20 Attendees |

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

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

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

| | |
|---|---|
| "Gamma-Ray Spectroscopy for Nuclear Material Accountability" | May 14-18, 1979<br>25 Attendees |
| "Fundamentals of Nondestructive Assay of Fissionable Material Using Portable Instrumentation" | October 1-5, 1979<br>30 Attendees |
| "In-Plant Nondestructive Assay Instrumentation" | December 3-7, 1979<br>20 Attendees |

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

the total area of nuclear material safeguards and management. I speak here of the three basic components of materials safeguards and management; accounting, material control, and physical protection, and the several sub-systems under each of these components.

Later this month, the Education Committee will be attending the spring Executive Committee meeting in San Francisco. At that time, we will present our thinking and preliminary plans for initiating a comprehensive training program as noted above. We will outline our educational objectives, proposed faculty, curriculum, and physical facility requirements. This course of action is within the scope of the Education Committee. I guess it all "boils down" to the realization that we must provide our own training programs, utilizing our in-depth resources. Our own program will augment DOE's training activities.

At the annual meeting we will present a status report on our efforts and outline our immediate plans.

**Mr. Toy**

**Short Courses, Conferences, Workshops**

• Nuclear Criticality Safety Specialists' Update, May 21-25, 1979, Department of Chemical and Nuclear Engineering, University of New Mexico, Albuquerque. 505-277-5431.

• American Nuclear Society Annual Meeting, June 3-8, 1979, Atlanta, Georgia. Contact: Lynn E. Weaver, Georgia Institute of Technology, Atlanta 30322.

• Topical Meeting. Measurement Technology for Safeguards and Materials Control, November 26-29, 1979, Kiawah Island, South Carolina. Contact: T.R. Canada, Los Alamos Scientific Laboratory. Co-sponsored by INMM, National Bureau of Standards, and American Nuclear Society.

# Seeks to Attract More Industry Members

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

The Institute must be doing something right these days. Despite the unhappy state of the nuclear industry, our new memberships total more so far this year than they did at the same time the two preceding years. We have 81 new members at this writing. In 1978 at this time the figure was 67, down a little from the 69 in 1977.

We've added a few more domestic members this year than foreign, just the opposite of last year when a greater portion of the increase came from foreign applicants. Our utility employee memberships are up this year, too.

For several years the Membership Committee has devoted considerable effort towards means of increasing the interest and participation of utility representatives in INMM. Just about everything the Institute does, and every program it schedules, touches matters of interest to utility employees. The December 7-8 INMM Special Workshop on IAEA Safeguards, for example, attracted a good number of utility representatives.

For this reason, we were glad to learn from a recent letter to the Chairman, from **John Barry** of Gulf States Utilities Company that INMM members from the utility field share our concern about the small proportion of utility representatives in our membership (2.7%). In addition to pointing out this fact, Mr. Barry also offers a possible remedy, proposing that INMM form an ad hoc working group to correspond on nuclear materials management issues. This suggestion is under consideration by Chairman **Bob Keepin**; however, the Membership Committee also has put in a bid for Mr. Barry's services, realizing that his well-founded suggestions and sincere desire to help the Institute can be of great value to Membership Committee activities.

Mr. Barry is a fine example of the kind of member we have talked about in previous columns when we said that INMM isn't looking for just "members"—it is looking for qualified, interested individuals who will better themselves by actively participating in the work of the Institute. We are pleased to welcome Mr. Barry as the newest member of the Membership Committee.

Various other members of the Institute also have devoted much personal time and effort towards obtaining more utility employees as members. **Armand Soucy,** during his tenure as Chairman of INMM brought a number of utility representatives into the Institute and **John Ladesich** took a number of membership invitation packages to utility meetings in which he particiapted.

The Program Committee is slating more time for matters of utility interest and has scheduled a special invited paper session for the next Annual Meeting under the chairmanship of **Bob Kramer** to cover invited papers from utilities.

Our invitational letter to non-member attendees at the 1978 Annual Meeting in Cincinnati resulted in a number of new applications, and with the help of **John Jaech, Harley Toy** and **Bill DeMerschman,** we continue to send special invitations to join INMM to registrants in all meetings and classes sponsored by the Institute.

## New Members

The following 25 individuals have been accepted for INMM Membership as of February 28, 1979. To each, the INMM Executive Committee extends its welcome and congratulations.

New members not mentioned in this issue will be listed in the Summer 1979 (Volume VIII, No. 2) issue to be sent out August 1, 1979.

**G. Anthony Adams,** Staff Assistant, Westinghouse Electric ARD Cheswick, Cheswick Avenue, Cheswick, PA 15024.

**Mose Baston,** Project Leader, Monsanto Corporation, Mound Avenue, Miamisburg, OH 45342.

**Marco M. Ferraris,** Head, North America Section, International Atomic Energy Agency, P.O. Box, A-1011 Vienna, Austria.

**Richard Joseph Gigliotti,** Manager, Security, United Nuclear Corporation, Wood River Junction, RI 20894.

**Wayne B. Harbarger,** Goodyear Atomic Corp., P.O. Box 628, Piketon, OH 45661.

**Lee**

**Barry**

# Acting Director Named At LASL

Los Alamos, NM, February 16—Dr. **Robert N. Thorn,** associate director for weapons at the Los Alamos Scientific Laboratory, was named Acting Director of the Laboratory by the Regents of the University of California, effective March 1, 1979.

The announcement was made today by Dr. **David S. Saxon,** president of the University of California which operates the Laboratory for the Department of Energy.

Dr. Thorn's temporary appointment is brought about by the resignation of Dr. **Harold M. Agnew** who announced his intention to resign as Director, effective March 1.

Dr. Thorn said that he does not know how long his tenure as Acting Director will be, and that he does not plan to make any major changes in Laboratory structure during that tenure. He commented that he would deal with unforeseen developments as they may occur, and said he hoped all Laboratory employees would help uphold morale, and work—as they have under Dr. Agnew—to satisfy the Laboratory's program needs.

A committee has been appointed to advise Dr. Saxon and DOE on the selection of a new permanent Director for LASL

Dr. Thorn received the Ph.D. in physics from Harvard University in 1953, and joined the staff of LASL shortly thereafter. He served as a staff member in the Theoretical Division from 1953 to 1962; group leader in the same division from 1962 to 1967; alternate and associate division leader in the division from 1967 to 1970; and head of the Theoretical Design Division from 1971 to 1976.

In May, 1976, he was named associate director for weapons.

Dr. Thorn received the **E.O. Lawrence** Memorial Award for achievement in nuclear physics in 1967. He has served as a member of the U.S. Air Force Space Systems Scientific Advisory Group, the USAF Scientific Advisory Board Nuclear Panel, the Defense Atomic Support Agency Scientific Advisory Group on Effects, and the Defense Intelligence Agency Scientific Advisory Committee.

He is currently a member of Phi Beta Kappa, Sigma Xi, the American Physical Society, and the American Association for the Advancement of Science.

---

Dr. **Todd L. Hardt,** Research Engineer, Babcock & Wilcox Company, P.O. Box 1260, Lynchburg, VA 24505.

**M. Guy Jeanpierre,** DSMN, Centre d'Etudes Nucleaires, B.P. 6, 92260 Fontenay-aux-Roses France.

**Howard B. Kreider, Jr.,** Supervisor, Special Materials Control, Monsanto Research Corporation, Mound Facility, Mound Avenue, Miamisburg, OH 45342.

**Ahmed Keddar,** First Officer, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

**Maria Candida Leal,** Scientific Officer, Gabinette de Proteccao e Seguranca Nuclear, Av. Republica, 45-60. 1000 Lisboa, Portugal.

Dr. **Gregory J. LeBaron,** Process Engineer, Rockwell Hanford Operations, 202A/Tr.10, 200E, Richland, WA 99352.

Dr. **Robert C. McBroom,** Nuclear Safety and Statistics Specialist, General Atomic Company, P.O. Box 81608, San Diego, CA 92138.

**Janice V. McGee,** Station Officer Manager (Nuclear), Duquesne Light Company, Shippingport Atomic Power Station, P.O. Box 57, Shippingport, PA 15077.

**Thomas J. Midura,** Principal Associate, HRA, Inc., 49 Mall Road, Suite 207, Burlington, MA 01803.

**Emilio M. Lopez-Menchero Ordonez,** Attache, Industry and Energy, Embassy of Spain to Austria, Prinz Eugenstrasse, 18/2/1, 1040 Vienna, Austria.

**Dwight H. Pfaehler,** Senior Management Systems Consultant, Computer Sciences Corporations, 400 North Capitol Street, N.W., Washington, DC 20001.

**Bernardino Coelho Pontes,** Safeguards Inspector, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

**Reginald D. Ryan,** Deputy Director, Australian Safeguards Office, 45 Beach Street, Coogee NSW 2036, Australia.

Dr. **James P. Shipley,** Alternate Group Leader, Safeguards Systems, Los Alamos Scientific Laboratory, Los Alamos, NM 87545.

**Willie Ray Simonds,** Nuclear Engineer, Tennessee Valley Authority, 603 Edney Building, Chattanooga, TN 37401.

Dr. **Hastings A. Smith, Jr.,** Staff Member, Los Alamos Scientific Laboratory, MS 540, Los Alamos, NM 87545.

**Etienne A. Van Der Stricht,** Inspector (Euratom), Commission of the European Communities, Av. Alcide de Gasperi, Luxembourg-Kirchberg.

## Address Changes

The following changes of address have been received by the INMM Publications Office (Phone: 913-532-5837) at Kansas State University, 20 Seaton Hall, Manhattan, Kansas USA 66506, as of February 28, 1979.

**Michael F. Kelly,** United Nuclear Corp., 67 Sandy Desert Road, Uncasville, CT 06382.

**Allen A. Madson,** Bechtel National, Inc., P.O. Box 3965, San Francisco, CA 94119.

**David H. Nichols,** 550 Westridge, Idaho Falls, ID 83401.

**Cecil S. Sonnier,** Project ISPO Coordinator, International Atomic Energy Agency, P.O. Box 645, A-1011 Vienna, Austria.

**Joseph E. Stiegler,** Sandia Laboratories, Org. 1750, Albuquerque, NM 87185.

# INMM Forms First Domestic Chapter In Pacific Northwest

By A.W. DeMerschman, Chairman Pro Tem
Westinghouse Hanford Company
Richland, Washington

The inaugural meeting of the Pacific Northwest Chapter of the Institute of Nuclear Materials Management was held on Tuesday, March 27, 1979 at the Holiday Inn in Richland, Washington.

As we look back on the events which led to the formation of the first domestic chapter and which were culminated at the inaugural dinner meeting, it is fair to say that another significant milestone in the history of the INMM has been established.

At the September, 1978 INMM Executive Committee meeting in West Palm Beach, authorization was granted on a petition to establish the Chapter. The Constitution and Bylaws were accepted by the Executive Committee in the San Francisco meeting in March and the Pacific Northwest Chapter was a viable and functioning organization.

Ninety-three members, potential members and guests attended a dinner meeting to signify the existence of the Chapter. Chairman **Bob Keepin** was a distinguished guest and speaker at the meeting. Bob reviewed past events of significance in the history of the Institute as well as previewed what can be expected in the future for the Institute and its members. One of the highlights of the evening was Bob's presentation of the "Inaugural Plaque" and Chapter Banner to Chairman Pro Tem **Bill DeMerschman.**

The immediate plans for the organization are in the hands of the petitioners. Those who participated in this effort and their company affiliation are as follows:

**E. Alford**
Washington Public Power Supply

**A.W. DeMerschman**
Westinghouse Hanford Company

**D.W. Engel**
Westinghouse Hanford Company

**H.L. Henry**
Pacific Northwest Laboratory

**R.J. Sorenson**
Pacific Northwest Laboratory

**J.W. Jordon**
Rockwell Hanford Operations

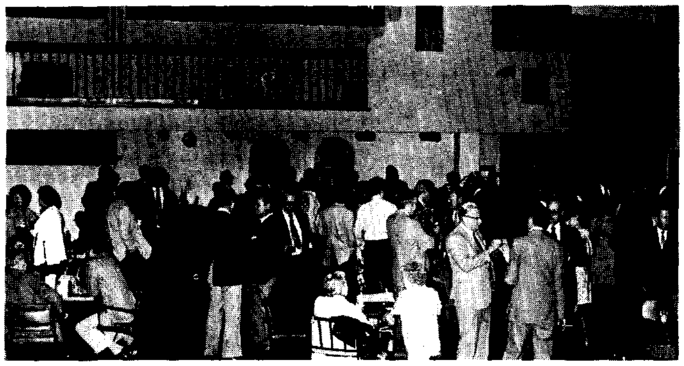
**J.L. Jaech**
EXXON Nuclear Company

**R. Nilson**
EXXON Nuclear Company

**A.C. Walker**
DOE/Richland Operations Office

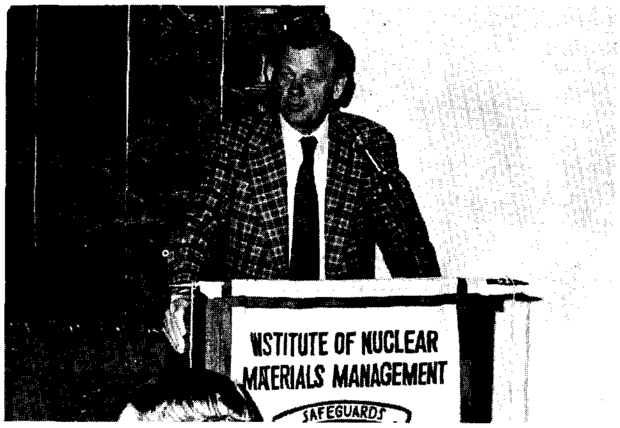
Mr. DeMerschman

The membership is looking forward to the election of its first slate of officers who will assume responsibility in August of this year. We believe the Chapter will provide a mechanism whereby a larger number of members can actively participate in the affairs and growth of the Institute of Nuclear Materials Management. It is also hoped that individuals in other areas where there is a concentration of Institute members will follow the Pacific Northwest's lead in establishing other Regional Chapters.



Social hour at the Holiday Inn.

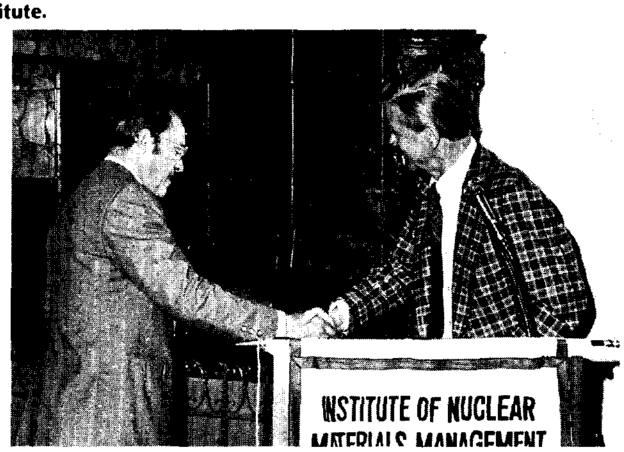
Curt Colvin, Rockwell, and Jack Bloom, retired from DOE-RL.



Chairman Bob Keepin delivered the welcoming address to the new Pacific Northwest Chapter of the Institute.


Caroline Nilson, HEDL; Jack Bloom; and Lew Hansen, DOE-RL.


V.D. Donihee and wife. Mr. Donihee is a charter member of the Institute.



Presentation of the Charter to the Pacific Northwest Chapter.


From left are Tony Kraft and Milton Campbell of Exxon Nuclear and Curt Colvin of Rockwell.


Bob Sorenson of Battelle with John Jaech of Exxon and Bill DeMerschman of HEDL. Mr. Jaech and Mr. DeMerschman were petitioners for the new chapter.


Clint Doriss of United Nuclear and Hank Henry of Battelle. Mr. Henry was a petitioner for the new Chapter.


Dennis Haskins and Rocky of HEDL Security.

# INMM Chairman Receives Feedback On Washington Workshop

By Tom Gerdis, Editor
Nuclear Materials Management
Kansas State University
Manhattan, Kansas

As noted in the previous issue of the Journal (cf. Vol. VII, No. 4, pp 47ff) INMM Chairman **Bob Keepin** has invited Feedback from the nuclear community on last December's INMM Workshop on the Impact of IAEA Safeguards in the United States. Shortly after the Washington Workshop Keepin sent a follow up letter and brief report on the Workshop to a group of key leaders in national and international safeguards. A copy of the Keepin letter/report to **Joseph Hendrie** of NRC was reprinted in the previous issue of the Journal. Reproduced on the following pages are some typical responses—from NRC Chairman Joseph Hendrie, U.S. Senator **John Glenn**, IAEA Director General **Sigvard Eklund**, and DOE Deputy Secretary **John O'Leary.**

Based on the various inputs and feedback from the Washington Workshop received to date (all quite favorable) there seems to be something of a consensus building for more INMM Workshops of this kind in the future.


**Eklund**


**Hendrie**


**O'Leary**

Department of Energy
Washington, D.C. 20585

February 5, 1979

Dr. G. Robert Keepin
Nuclear Safeguards Program
Director
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87545

Dear Dr. Keepin:

Thank you for your letter of December 26, 1978, summarizing the views of the participants in the recent Workshop on the Impact of IAEA Safeguards sponsored by the Institute of Nuclear Materials Management.

I am glad to hear of the overall positive attitude of the industrial participants toward the need for the US to rapidly move to the effective implementation of IAEA safeguards on US licensee facilities.

I look forward to appearing before the Annual Meeting of the Institute in July.

Sincerely,

John F. O'Leary
Deputy Secretary

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OFFICE OF THE CHAIRMAN

January 9, 1979

Mr. G. Robert Keepin, Director
Nuclear Safeguards Program
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87545

Dear Bob:

Thanks for the report on the INMM workshop. Our staff members also report that the meeting was both interesting and useful.

We are pleased to participate with the INMM in exchanges of this type, since we believe that they are helpful in enabling both the Government and industry to meet our mutual commitments in a more efficient and effective manner. We look forward to continued close interaction with the INMM in the future.

Best wishes for the New Year.

Sincerely,

Joe

Joseph M. Hendrie
Chairman



United States Senate
COMMITTEE ON
GOVERNMENTAL AFFAIRS
SUBCOMMITTEE ON ENERGY, NUCLEAR
PROLIFERATION AND FEDERAL SERVICES
WASHINGTON, D.C. 20510

January 9, 1979

Dr. G. Robert Keepin
Chairman
Institute of Nuclear
Materials Management
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87545

Dear Dr. Keepin:

Thank you for your letter of December 26, concerning the recent workshop held by the Institute of Nuclear Material Management on the subject of International Safeguards.

I have been advised by my staff that the meeting was most useful in providing information concerning the U.S. - IAEA Agreement and the often complex problems associated with the future implementation of this document.

I intend to be actively involved in the Senate's consideration of the Agreement and welcome the important contribution you and the Institute have made in helping to clarify the issues involved.

Best regards.

Sincerely,

John Glenn

John Glenn

JG/lsj

INTERNATIONAL ATOMIC ENERGY AGENCY
AGENCE INTERNATIONALE DE L'ENERGIE ATOMIQUE
МЕЖДУНАРОДНОЕ АГЕНТСТВО ПО АТОМНОЙ ЭНЕРГИИ
ORGANISMO INTERNACIONAL DE ENERGIA ATOMICA

KARNTNER RING 11, P O BOX 590, A-1011 VIENNA, AUSTRIA

TELEPHONE 52 45 11 52 45 25
TELEX 1-2645
CABLE INATOM VIENNA

IN REPLY PLEASE REFER TO
PRIERE DE RAPPELER LA REFERENCE
I/651-US-9

1979-01-30

Dear Bob,

Many thanks for your letter of 26 December and for the report on the INMM Workshop on the Impact of IAEA Safeguards.

I have received encouraging comments from our participants in the meeting, and it is clear, as you say, that this type of discussion is most useful in developing direct contacts between the Agency and industry in safeguards matters, in clarifying the purpose, scope and methods of work of our safeguards operation and in eliminating misunderstandings. The Workshop played a useful role, therefore, in preparing the ground for the implementation of our safeguards agreement with the US.

The misgivings expressed by some of the participants reflect similar views held earlier by other countries in which we were applying safeguards. It was important, therefore, to have plant operators from such countries present at the meeting so as to dissipate any misunderstandings.

As Ambassador Smith implied in his remarks, it is important from the point of view of the acceptability of the IAEA safeguards in certain other countries that US industry should also demonstrate its readiness to accept these safeguards.

One point which, I believe, the nuclear industry in all industrial countries should constantly keep in view, is that an effective international safeguards regime is an absolute condition for the future viability of international trade in nuclear materials, plant and equipment. Any major setback in the non-proliferation regime would be a setback for nuclear industry everywhere, at least in the Western industrial world.

I hope that the Institute will be able to arrange more Workshops of this kind. The only suggestion that we have on the organizational aspects is that it might be better to have somewhat fewer participants in the next meeting.

Some of the above comments are relevant to the more general question as to what the Institute might do in support of international safeguards and non-proliferation goals. Any efforts that the Institute can make to help demonstrate or promote the "safeguardability" of the so-called sensitive fuel cycle operations such as reprocessing and enrichment would also be very timely.

I shall be in touch with you later about the Albuquerque meeting.

With best wishes,

Yours sincerely,

Sigvard

Sigvard Eklund

Dr. G. Robert Keepin
Chairman
Institute of Nuclear Materials Management
Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87545
USA

**Review of Nuclear Safeguards Analysis; Nondestructive and Analytical Chemical Techniques,** E. Arnold Hakkila, Ed., American Chemical Society Symposium Series 79, Washington, 1978.

By Anthony Fainberg
Brookhaven National Laboratory
Upton, New York

This volume is an analysis based on a symposium on nuclear safeguards at the 175th meeting of the American Chemical Society in March, 1978. The symposium was sponsored by the Division of Nuclear Chemistry and Technology. This summary of techniques for destructive (analytical) and non-destructive assay of nuclear material is particularly welcome at a time when the various methodologies in the field are developing and multiplying fairly rapidly. Also, given the recent increased interest in non-proliferation on the part of the U.S. Government, it becomes even more vital for policy makers to know just what the limitations of measurement techniques for accountancy and control of special nuclear material are.

Twelve papers are presented which deal with various aspects of safeguards analysis including thermal calorimetry, gamma-ray spectroscopy, isotopic correlations, absorption edge densitometry, decision theory, and systems analysis, to give just a partial list. I am somewhat puzzled by the omission of any article dealing with passive or active neutron assay techniques. The development of such methods is vital for non-destructive analyses of entire fuel assemblies, since the (relatively low-energy) gamma rays which happen to come from internal rods are rapidly attenuated by the intervening material. Aside from this lacuna, however, a quite comprehensive picture of current capabilities is presented.

The first paper is a useful summary of the history and evolution of safeguards measurement techniques and applications since the inception of the field in the mid-1940s. The relative advantages of analytical or NDA methods are given, depending on the form and location of the SNM in question. Here, incidentally, neutron methods are listed, along with others, and the discussion, though brief, is complete.

The next two papers deal with standard reference materials. Most work in this area in the U.S. is done at New Brunswick Laboratory (Argonne, IL) or at the National Bureau of Standards and these two institutions are represented in the papers. This topic is somewhat dry, but is essential to high precision assays. Of prime concern is the traceability of all measurements to the National Measurement System, whence the NBS assures agreement with international standards.

Dr. Fainberg

The NBS issues standard reference materials to provide a direct link to the NMS. These may be chemical or isotopic standards. There are "less equal" standards supplied by NBL, among other sources, which are much easier to provide because they are not as pure. They are, however, more available and sometimes sufficiently good to function as references. The latter are called secondary references, as opposed to the primary references provided by the NBS. A current problem is the restricted variety of secondary references, which may force a facility to prepare internal standards. In this case, traceability can be difficult to establish.

There is also need to remeasure plutonium isotopic ratios for standards using separated plutonium (and not uranium) isotopes for the mass discrimination data. Further, some more accurate measures of plutonium and americium half-lives are needed to calibrate better thermal calorimetry measurements to plutonium mass. Work is underway in this area.

NDA measurements provide particular standards problems since data are dependent not only on purity but on size, geometry, non-SNM matrix material, etc. Since it is difficult to satisfy all configuration requirements, the path taken here will likely be for internal standards to be developed at each facility which will then be sampled for traceability purposes.

Finally, the possibility of alternative fuel cycles, such as the thorium breeder cycle, may necessitate development of a series of thorium standards, as has been done for uranium. Preliminary efforts have begun in this area.

There are two papers on mathematical methods as applied to safeguards analysis. An interesting paper on decision analysis as applied to material accounting and diversion detection is given. A two-state Kalman filter is applied to a MUF calculation in a sequential decision framework to provide a more reliable indicator of a diversion. The methodology developed is applied to the material accounting system of the Barnwell Reprocessing Facility, in order to exemplify the procedure. Also presented is a paper on the fitting of calibration curves, taking into consideration measurement errors on the independent as well as the dependent variable. This was applied to an NDA measurement (X-ray fluorescence technique) where the independent variable is the mass of a reference standard. This is clearly one way to deal with standards problems of NDA measurements, mentioned above.

There are two papers dealing with techniques for assaying spent fuel at reprocessing plants. The first discusses an automated X-ray fluorescence system, an automated isotope dilution analysis laboratory (AIDA), and isotope correlation techniques. The latter two methods use mass spectrometers for ratio measurements. Isotope correlation's predictions of burnup ranged in accuracy from 3 to 8%. All methods make heavy use of on-line computers to cross-check data and catch measurement anomalies. The system is impressive, but for most techniques, no errors were cited.

The second paper in this section is on isotopic techniques only, and provides a good summary of motivations and goals of these methods, outlining the current situation in a few pages. A large data base of spent fuel characteristics now exists and is being played with to find useful ratios of isotopic concentrations which are linear with respect to burnup and relatively insensitive to other variables.

There are four other hardware-type papers which each describe different analysis techniques. One is a detailed and fascinating description of absorption edge densitometry. Here, the sudden jump in gamma (or X)-ray absorption at an emission or electron capture line of Pu or U is used to get a handle on the concentration of the SNM. Accuracies are as good as 0.5% for concentrations in excess of 10 g/l. Less precision is obtainable in less expensive or portable set-ups.

There is a report on on-line process alpha-monitors, evaluating performance on plutonium-bearing nitric acid solutions. For some reason, this paper uses the inch as a linear measure and the metric system elsewhere. The detector was found to be linear in plutonium concentrations over four orders of magnitude. Concentrations were as low as $10^{-4}$ g/l. At the lowest concentrations there was a problem with some "plating out" of Pu onto the surface of the detector and corrections needed to be applied to the data. Sensitivity to beta activity was tested by spiking with $^{90}$Sr. A discriminator was used to cut the smaller pulse heights arising from beta rays, and the sensitivity was over 50 counts/sec/uCi/ml. The response to rapid changes in concentration was practically immediate. Accuracies are approximately 4% RSD over most of the range.

In the next paper, a Ge(Li) well detector is described for use in off-line U and Pu analyses. For a $10^3$ second counting period, nanogram quantities of $^{239}$Pu or $^{235}$U can be detected, which I find quite impressive. The 185.7 keV peak is used for $^{235}$U and low energy ULB$_1$ X-ray lines as well as the 51.6 keV peak can be used for $^{239}$Pu. Other peaks are also useful such as the 163.4 keV peak in $^{235}$U for material with substantial $^{222}$Ra present (producing a 186.1 keV line, too close to 185.7 keV for comfort). Resolutions in this region are somewhat less than 1 keV FWHM.

Finally, a sophisticated thermal calorimeter system is discussed, which can measure samples containing 1-2 g of Pu to better than 1%. The classical technique which just measures the heat given off by radioactive decay still is highly competitive with nuclear detectors, at least for some measurement purposes.

The last article in the compendium returns us from hardware to the domain of systems analysis. The accountability measurement system of the Idaho Chemical Processing Plant is described. Fuel with enrichments of 20-93% $^{235}$U can be handled by this facility. Accountability samples include concentrations from 10 g/l (waste streams) to pure $UO_3$. Interfering activity from fission products varies greatly from input to the plant (high activity) to output (very low activity). Remote analytical facilities must, of course, be used for the very hot samples. Analysis techniques run from mass spectrometry to complex chemical analysis, and ultra-violet fluorescence. Precision is checked by comparing quality control data with data from duplicate samples. The two methods of obtaining a precision measure happily agree—relative standard deviations are less than 1/2%. The principal source of uncertainty in calculating the limits of error on the BPID is, interestingly, the error on the weight of the input material. The results are sometimes facility-specific, and thus of limited general application, but the overall view gained from the report has enough universal information to be of general interest.

Summarizing impressions from the whole collection, the volume is useful, either (for cognoscenti), as a quick survey of the state-of-the-art, or (for the pedestrians) with a bit of effort, as a start in understanding the field of safeguard analysis techniques. The only caveat I have, as mentioned above, is the lack of full discussion of neutron assay methods.

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Review of **Light Water—How the Nuclear Dream Dissolved,** Irwin C. Bupp and Jean-Claude Derian, Basic Books, New York (1978).

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

Reading this book is very disturbing. One has the same feeling that develops when looking through a pane of bottle-glass. The world on the other side appears familiar, but individual parts are distorted in size and shape and have the wrong relation to each other.

Bupp and Derian have drawn on an intimate knowledge of the development of nuclear power in the United States and Europe. They have also profited from the excellent histories of atomic energy written by **Richard Hewlett** and others, and have talked extensively with Hewlett in assembling the material for this book. There can be no better source for most of the history—Hewlett was the competent and scholarly historian for the Atomic Energy Commission, who can usually tell it the way it was.

The events described in the book are factual, and where I know what happened I find myself agreeing that indeed it was that way. Yet, overall the book's discussion frequently comes out wrong in my estimation. The question is of course—how can this be?

The answer is probably that the history reconstructed by Bupp and Derian is still taking place, and the transformation from actual events to written chronology and interpretation will have to evolve further. After all, writing history involves selecting among many events the ones of lasting impact on the eventual outcome, emphasizing some of these and completely passsing over many events that are deemed irrelevant. When the out-

**Dr. Kouts**

come is still unknown, the selection and emphasis can be disputed.

This is part of the basis for my reaction, but not all. In fact, though the book will be found highly informative to those who wish to understand the history of nuclear power, it is nonetheless defective.

The writing frequently seems ambivalent. This may sometimes reflect a difference in background and attitude of the two authors, one of whom reports from his long association with the U.S. Atomic Energy Commission, and the other of whom spent a long period with the French Commissariat a l'Energie Atomique (CEA). Some may be the result of trying to make clear the arguments of the anti-nuclear community. In the course of presenting these arguments in detail, an impression is sometimes given that certain ones contain more substance than is actually the case. This has a tendency to undercut the opening statement by the authors that they are "for" nuclear power, and even to give sections of the book an opposite flavor.

Several specific points in the book need addressing. One is the reasons given by the authors for the growth to world preeminence of light water reactors. The reason for this development in the United States can be traced most directly to the experience industry had previously accumulated with light water systems in fossil-fueled power plants. The book does not recognize this. The technology was in hand for pumps, valves, vessels, piping, etc. to operate with hot water and steam. Utility engineers and executives found light water systems acceptable, where they had reservations about the three largely untried competitors—gas, liquid sodium and organics. As for heavy water, there was strong doubt among industrialists about the ability to make a heavy water system tight enough to avoid excessive loss of the heavy water. Parenthetically, it may be noted that the Canadian designs do appear to have achieved the necessary leak-tightness, though some recent adverse experience with the larger CANDU plants has raised the question anew.

At any rate, the principal factor leading to acceptance of light water as a coolant for both naval propulsion and electrical power generation in the United States was surely the apparent natural evolution from previous conventional technology. This factor operated in the rest of the world, too, and may have been equally important in leading to the nearly global acceptance of light water reactors. This is not to deny the reason discussed by Bupp and Derian, who stress the effect of U.S. prestige in the nuclear area following the success of the Manhattan Project.

The growing cost of light water nuclear power plants and the electricity they produce is given a great deal of attention. In round numbers, the first commercial light water reactors were built for about $100 per installed electrical kilowatt of capacity, and the price is now approaching $1,000 per kilowatt. This massive increase in cost has occurred despite economies of scale that should have accompanied the approximately fivefold increase in capacity. The authors attribute the escalation of cost to misjudgement of the difficulty of the job. In their history, light water reactors were much more complex technically than had first been estimated, and only now is the true cost of their construction becoming well known.

There is some truth to this view. But the reality is much more complicated still. It is not easy to find any large technical undertaking whose magnitude has not been underestimated at the outset. We are by now quite accustomed to cost escalations and overruns of complex undertakings. Nuclear power plants of all kinds (not just light water plants) fit in with other similar-sized projects.

However, it is also true that a number of other factors have been at work to increase the cost of building light water power plants. Some of these are recognized by the authors: inflation, longer construction times with increased periods for paying interest, higher interest rates. By my estimate, these themselves account for over an order of magnitude increase in plant cost.

Other factors that are only partly taken into account or are altogether ignored by the authors are: the heavy dependence of cost of complex engineering projects on the primary cost of energy (OPEC oil), the deadening effect of the mountain of paper churned out to meet quality assurance requirements, and the greater complexity that results from larger size. In fact, the increase in plant size to reduce capital cost per kilowatt is now believed by many to be counter-productive.

Bupp and Derian discuss at some length the history of gas-cooled reactors in the U.K. and France, in showing how light water reactors eventually won out (in France, at any rate). The events ran pretty well as they describe them, but again the complexity of events was greater than they say. Though the authors have a low opinion of the costing of light water reactors, they really should extend the disapproval to their competitor reactors as well. It has apparently been true that in cost comparisons in the two countries, when economic assumptions and ground rules have been the same, the light water reactors have come in at less cost. The economic ground rules have been important, because such means of subsidy as low interest rates or interest-free financing have profound effects on costs.

In addition, it is not mentioned in the book that at about the same time Electricite de France announced its intent to build light water reactors in the future, all French gas-graphite reactors were down because of steam generator leaks. There was general pessimism about the ability to solve the problems simply or soon. The final blow to the prospect of additional Magnox reactors in the U.K. was the determination of weakening of structural bolts from radiation assisted corrosion in the high temperature gas stream, that led to a lasting derating of these plants. The forces pressing for light water reactors in the U.K.'s future electrical additions have gained strength from the high costs and schedule difficulties of the first AGR's, and the prohibitive cost estimates for the Steam-Generating Heavy Water Reactor.

On the other hand, there is the more recent success story of CANDU reactors. The sales of these Canadian power plants in the international market have occurred for other than economic reasons. The customers of natural-uranium-fueled reactors wish to be free of the need to deal with the United States for slightly enriched fuel, because the United States is seen as an unreliable supplier.

One further and embarrassing point must be discussed. This is the unfortunate relationship between foreign reactor sales and the attitude of individuals and groups toward the United States. This has been men-

## Underwood, Jordan and Yulish Merge Public Relations Firms

NEW YORK CITY—The merger of Underwood, Jordan Associates and Charles Yulish Associates into Underwood Jordan Yulish Associates, Inc., management consultants, public relations and advertising, was announced today.

Underwood Jordan Yulish Associates becomes the leading international management consulting and public relations agency in the energy field. The organization offers comprehensive communications services to organizations with interests in conservation, coal, electric power, petroleum, natural gas, nuclear energy, solar power, wind, geothermal, fusion and other advanced energy technologies. The new firm offers communications services related to licensing and regulation, environmental impact, site acceptance, community relations, public information and education programs.

Underwood Jordan Yulish also has many clients with interests outside the energy and environment field, including chemicals, consumer goods, associations, finance, economics and others. Services to these clients include marketing; financial, management and corporate counseling; advertising; media relations; and public issue management. Underwood Jordan Yulish Associates will expand their "Communications Audit" program to provide clients with a comprehensive analysis and cost/benefit profile of their communications organization, programs, and requirements.

Headquartered in the Underwood, Jordan central offices at 230 Park Avenue, New York, the firm utilizes existing offices in Washington (1115 National Press Building) and London (24 Tudor Street). A new Underwood Jordan Yulish Associates office has been established in Canada (185 Bay Street, Toronto) in conjunction with Inside Canada Public Relations Limited.

**Don Underwood** continues as chairman and **Thomas R. Jordan** as president; **Charles Yulish** (an INMM member) becomes president/international. Underwood Jordan was established in 1967 and Charles Yulish Associates in 1966.

Combined billings for 1979 are projected at $2,000,000, with 40 employees. The merged firm serves clients in every state in the Union; as well as in Canada, Mexico, Great Britain, Europe and Japan.

Underwood Jordan Yulish is the founder of The Pinnacle Group, a consortium of public relations firms covering major marketing areas in the United States, with members in Atlanta, Houston, Denver, Chicago, San Francisco and Australia as well as New York and Washington. The agency also is the United States anchor for Inside Canada Public Relations, Lt. with members in each Canadian province.

Through its London office, Underwood Jordan Yulish and McLeish, the agency also is the associate in the United States for Inside Europe Public Realtions, Ltd., with firms in Finland, Norway, Sweden, France, Ireland, Spain and West Germany.

Chester Burger Associates assisted in effecting the merger.



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tioned above as one of the principal subjects treated in the book: American reactor sales went where American influence was strong. Unfortunately, there was another side of the coin, too. The United States and its actions have also antagonized many people. The story is frequently not to our credit. There has been a high correlation between those abroad who are opposed to light water reactors and those who are opposed for one reason or other to the United States. In fact, the same correlation appears when one considers opposition inside the United States.

I believe that this book is too pessimistic about the prospects for nuclear power in general, and light water reactors in particular. At the end of the book we are seen as being in stalemate, with no further advance possible, and some chance that the existing nuclear industry will be shut down.

How could this be? Fifteen percent of our electricity nationally is now derived from nuclear power plants. Already large sections of the country obtain over half of their electricity from nuclear fission. We cannot do without nuclear power and continue to exist as a nation, no matter how many modern Rousseaus fancy that we can. And if we were on the verge of extinction as a nation because of the impossibility of meeting energy needs, opposition to nuclear power would become a trivial subject.

# Certification Test To Be Open to All Qualified Applicants

**By Frederick Forscher, Chairman**
INMM Certification Committee
Energy Management Consultant
Pittsburgh, Pennsylvania

With the increasing importance of Safeguards and Non-Proliferation, the INMM is in the public spotlight as the only professional organization, worldwide, dedicated to these important issues. The requirements for professional recognition—and this is true for almost every professional organization—includes a written test to evaluate the candidate's knowledge and understanding of the subject matter.

What constitutes the pertinent subject matter of our profession was the first order of business when the ad hoc committee of Certification Test Formulators met at Rocky Flats, 19 January 1979. The Table below represents—to my knowledge—the first compilation of pertinent subject headings. The committee then proceeded to quickly scan and classify submitted test questions. We have now, in an organized and typed form over 360 questions, and expect another 150 before the next meeting.

As indicated in this column last time, we visualize a two-step process. The first step would lead to a Qualified Safeguards Intern. After three years of applicable professional experience, the candidate would be eligible to apply for Certified Safeguards Specialist in any one of three specialties: Material Accounting, Material Control, and Physical Protection/Security. The actual test procedure, cost, and administration has not yet been decided. For guidance only, the current thinking assumes a test-question pool of about 200 questions in each of the main specialties. The qualified intern test could consist of 20-30 random questions from each of the specialties of which some designated percentage should be answered correctly. The certified specialists are expected to pass this requirement and make an even better grade on a larger selection of questions from all three categories but concentrating on the candidate's specialty.

It should be noted that the test will be open to all qualified applicants, irrespective of nationality, creed, color, sex or age; even non-INMM members. In the future, we expect to find requirements for employment of safeguards specialists, not only in industry and academia, but also in governments—domestic, foreign and in international organizations.

Dr. Forscher

# Richard A. Cordon, Charter Member

SOUTH YARMOUTH, Mass.—A founder of the Institute of Nuclear Materials Management, **Richard A. Cordon,** passed away December 30, 1978, at age 75. Mr. Cordon had been an active INMM member for several years.

A former member of the INMM Executive Committee, Mr. Cordon was an Executive Assistant at Yankee Atomic Electric where he was in charge of the nuclear materials management function.

"Richard Cordon was one of the most respected and cherished members of the Institute. He was well liked by all those who knew him," said A.R. Soucy, former INMM Chairman and currently Assistant Treasurer of Yankee Atomic.

According to Mr. Soucy, Richard Cordon was among the first members of INMM to be involved with IAEA (International Atomic Energy Agency) safeguards. He presented technical papers in safeguards in Vienna.

A native of Rhode Island and a graduate of the University of Rhode Island, Kingston, Mr. Cordon is survived by his wife, Tamar, who resides on Cape Cod at South Yarmouth.

**Mr. Cordon**

**TABLE I**
**AN OUTLINE OF PERTINENT SUBJECT MATTER**

| **A.**<br>**Material Accounting** | **B.**<br>**Material Control** | **C.**<br>**Physical Protection/ Security, at fixed sites and in transportation** |
|---|---|---|
| 1. **Measurements**<br>Bulk (mass, volume)<br>Chemical<br>NDA<br>Treatment of data<br>and uncertainty | 1. **Process Control**<br>Process streams and flow<br>Process measurement<br>Indicators<br>Packaging<br>Sampling<br>Preparation for shipment | 1. **Deterrence**<br>Laws and regulations<br>Signs<br>Personnel clearances<br>Procedures, operating<br>Physical characteristics<br>Seals |
| 2. **Records**<br>Internal MBA records<br>Facility records<br>Transfer documents<br>Book inventory | 2. **MBA System**<br>Item identification<br>(serialization)<br>Physical inventory<br>Custodian/responsibility | 2. **Detection/Assessment**<br>Access/Egress Control<br>Sensors and alarms<br>Surveillance<br>Operating procedures |
| 3. **Reports**<br>International requirements<br>National requirements<br>Facility management | 3. **Quality Control**<br>Reference materials<br>(physical standards)<br>Standards<br>Traceability<br>Sampling | 3. **Communication**<br>Modes<br>Communications Security<br>Redundancy<br>Network |
| 4. **Data Analysis**<br>Statistics<br>Errors, bias treatment<br>Inventory difference<br>Limit of Error<br>Shipper/receiver dif. | 4. **Laboratory Qualification**<br>Sample exchange<br>Referee/verification | 4. **Delay**<br>Physical barriers,<br>passive and active<br>Remote response<br>mechanism |
| 5. **Data Processing Technique**<br>Licensee<br>State System<br>IAEA | 5. **System Auditing**<br>Sampling | 5. **Response**<br>Reaction time<br>Guard force<br>Backup forces |
| 6. **Audits**<br>System audits<br>Sampling | | 6. **Audits**<br><br>7. **Transport** |

*Compiled by the Institute of Nuclear Materials Management,
Certification Test Formulators
19 January 1979

SPECIAL REPORT

# INMM Chairman Visits Tokai Reprocessing Plant in Japan

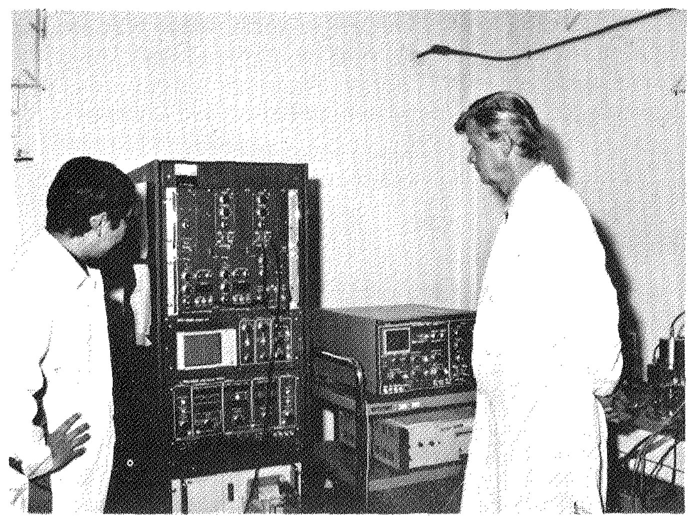
**By Herman Miller, Chairman**
INMM Public Information Committee
National Nuclear Corporation
Redwood City, California

In the course of his recent trip to Japan, INMM Chairman **Bob Keepin** visited a number of facilities at the Tokai Mura complex, located approximately 140 kilometers northeast of Tokyo on the shores of the Pacific Ocean. The giant Tokai Mura Complex includes R&D facilities of the Japan Atomic Energy Research Institute (JAERI) as well as the Power Reactor and Nuclear Fuel Development Corporation (PNC) which was established in 1967 to develop technology relating to advanced power reactors and all stages of the nuclear fuel cycle. Fuel cycle activities include prospecting and refining of uranium ores, development of centrifuge technology for uranium enrichment, development and fabrication of plutonium fuels, reprocessing of spent fuel and the treatment/disposal of radioactive waste.

Of particular interest was the visit to the Tokai Reprocessing plant including briefings and discussions with various Japanese technical experts concerning the US-Japan-IAEA cooperative effort known as the TASTEX program. TASTEX—the acronym for Tokai Advanced Safeguards Technology Exercise—is an extensive program of test and in-plant evaluation of advanced safeguards technology in connection with the Tokai reprocessing facility. The program includes some 12 specific tasks ranging from development, test, and evaluation of instrumentation for measuring the various chemical and physical forms of SNM found in a reprocessing facility to feasibility studies related to possible back-fitting of an advanced materials accountancy system into the Tokai facility.

The Tokai reprocessing plant has a capacity of 700 kg/day; it is divided into three material balance areas: MA-1: spent fuel storage, chop and leach, MBA-2: chemical treatment (i.e., all bulk processing, leading to Pu nitrate product and $UO_3$ product), and MBA-3: product storage.

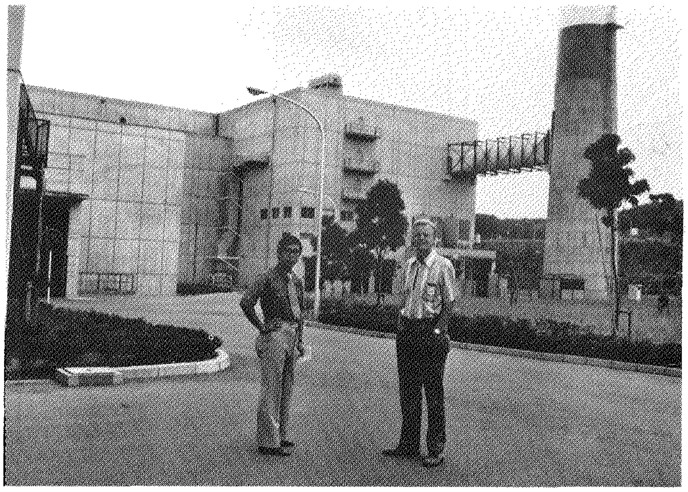
Mr. Miller



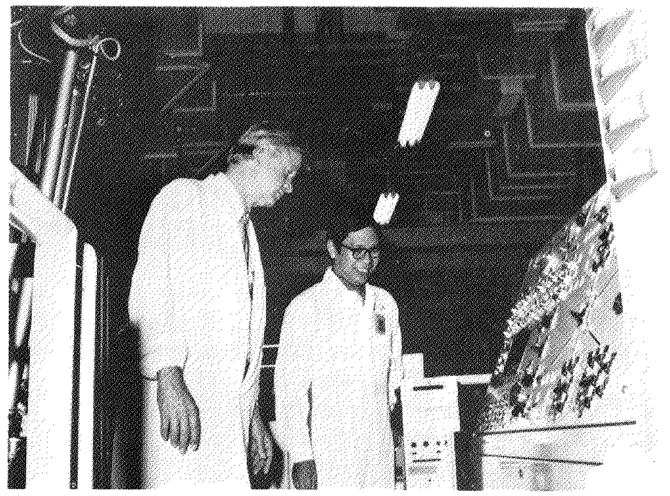
Demonstrating operation of a gamma-spectrometer in the analytical laboratory.

Chairman Keepin held discussions with Mr. **Kentaro Nakajima,** plant manager of the Tokai Reprocessing plant, and a member of the Executive Committee of the Japan Chapter of the INMM, and with other key members of Mr. Nakajima's staff. He was given an extensive tour of plant facilities by Mr. **Naohiro Suyama,** Plant Design Engineer, who is also a member of the INMM Japan Chapter. The tour of the plant included visits to the spent fuel receiving area, the mechanical treatment (chop and leach) and input accountability areas, the central control room and the analytical laboratory. The accompanying pictorial record of Dr. Keepin's visit was very kindly provided by Mr. Nakajima, Mr. Suyama, and the Tokai staff.

Advanced measurement technology and advanced material accountancy/control systems are receiving increased attention in Japan and several other countries, both from the standpoint of their potential future role in effective national safeguards systems and as components of an overall international safeguards system under effective independent inspection and verification by the IAEA.

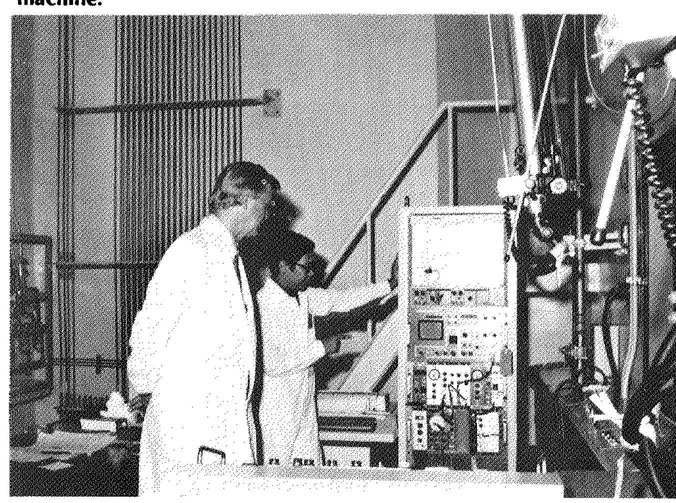


INMM Chairman Keepin and PNC's Suyama at the front of Tokai reprocessing plant.



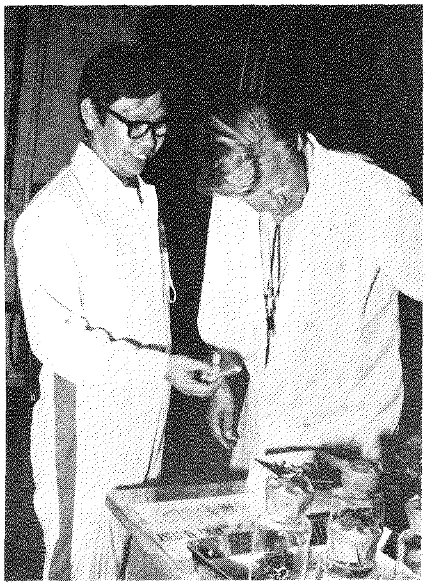
Examining the main control panel of spent-fuel-element chopping machine.

INMM Chairman Keepin and PNC's Suyama at the side of the spent fuel storage pool in the Tokai Reprocessing Plant. Plant capacity is approximately 0.7 metric tons of uranium per day (approximately 210 metric tons per year) and uses the PUREX process with chop and leach at head end.

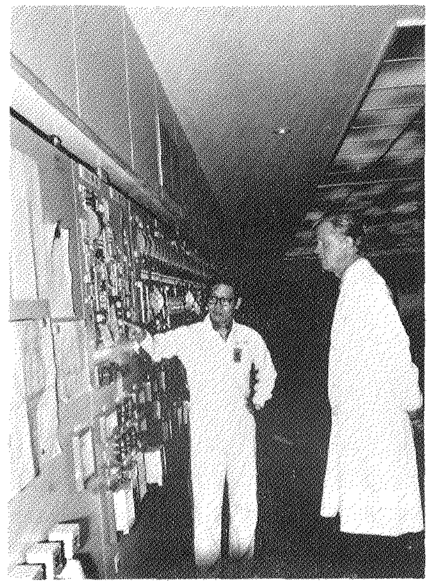


Suyama demonstrates automated control of the leached hull monitoring system.

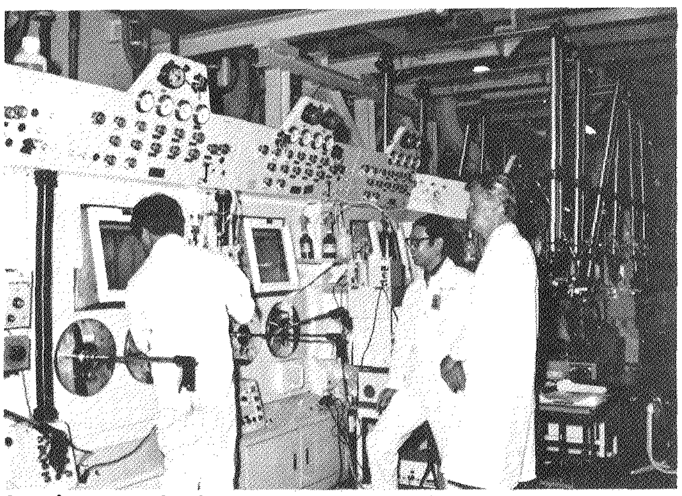
Central control room of Tokai Spent Fuel Reprocessing Plant.



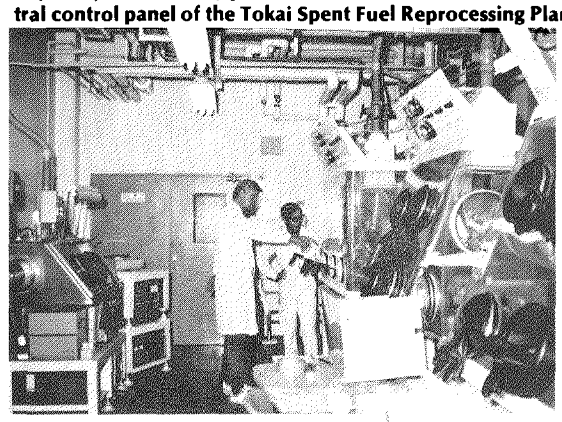
Keepin inspects leached hull of a dummy fuel assembly.



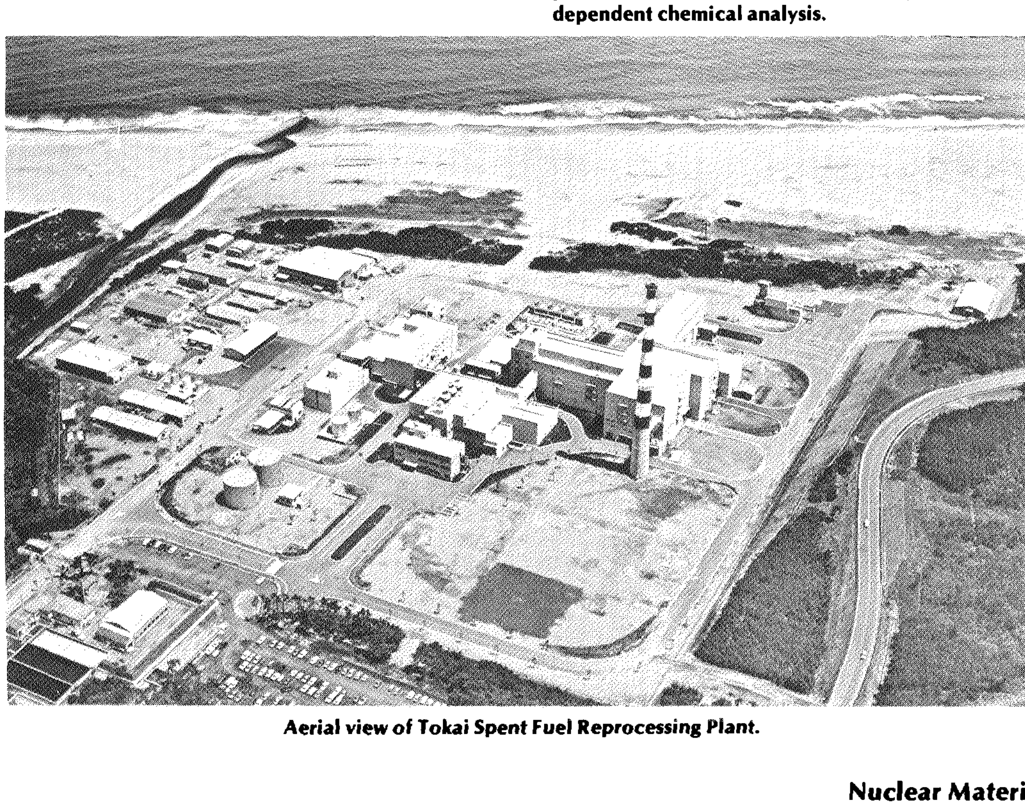
Suyama points out key process control indicators at the front of the central control panel of the Tokai Spent Fuel Reprocessing Plant.



Sample preparation by remote operation in hot cells of the analytical laboratory at Tokai.

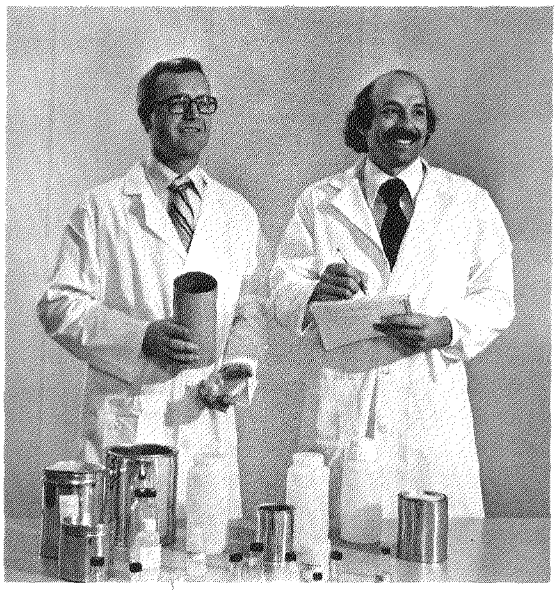


Examining glove boxes to be used for evaluating NDA techniques in the analytical laboratory at Tokai. As part of the U.S.-Japan-IAEA TASTEX program, the glove box being indicated here will house an absorption edge densitometer system for nondestructive assay of plutonium nitrate product solution, and detailed comparison of NDA results with independent chemical analysis.



Aerial view of Tokai Spent Fuel Reprocessing Plant.

# NRC Selects IRT to Study Feasibility Of Standardizing Containers for SNM



**Nuclear materials are stored in a variety of common containers including metal paint cans, plastic bottles and food containers. To date, IRT scientists have surveyed over 200 containers ranging from 1/2-ounce pill bottles to 55-gallon steel drums! Principal Investigator and author Tom Atwell (right) is shown reviewing one of the containers with co-investigator Ken Alvar (left)**

**By Thomas L. Atwell**

Any agency or facility licensed to possess more than one effective kilogram of SNM (special nuclear material, e.g., $^{235}U$, $^{239}Pu$) is required by the U.S. Nuclear Regulatory Commission (NRC) to maintain a system of control and accountability for that material. The success of a licensee in meeting this requirement depends, to a large extent, on his ability to accurately measure the SNM, which in turn, is affected by the type of container in which the SNM is confined when the measurement is performed. A further complication is the fact that different licensees use different types of containers, which inhibits collective efforts among licensees and the NRC to improve and refine the measurement process, because the different container configurations make it difficult to compare test results.

It is believed that standardization of SNM containers could lead to measurement uniformity, easier and more rapid sharing of measurement technology and finally, more accurate and precise control and accounting for SNM. In April of last year IRT received a contract from NRC to establish criteria for selection of containers for SNM and to explore the feasibility of using standardized SNM containers for NDA (nondestructive assay) measurement, storage and transfer throughout the nuclear industry.

In performance of the contract IRT scientists have already visited over 20 sites within the United States where significant quantities of SNM are stored and processed. The purpose of the visits was to determine, first-hand, the number and physical characteristics of the various containers now in use, as well as the process, safety and accountability requirements that dictated the choice of those containers.* At the same time, information was obtained on the possible economic effects of container changes and how the characteristics of present containers affect NDA accuracy.

IRT investigators are also conducting tests to further evaluate how container characteristics such as dimensions, wall thickness, dimensional uniformity and material type affect NDA accuracy. Nondestructive assay techniques being employed for these tests include gamma spectroscopy, neutron coincidence counting, neutron activation analysis, calorimetry, and gamma- and X-ray transmission measurements.

Based on careful analysis of the data obtained during on-site visits and subsequent tests, IRT investigators will develop the criteria required for standardizing the size, wall thickness, and composition of SNM containers currently in use by NRC licensed facilities. In addition, they will analyze the economic and technical impacts on the users and assess their ability to comply with the proposed criteria.

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*"Current Usage of Containers For SNM Storage, Transfer and Measurement," Interim Report, NUREG/CR-0591, Feb. 1979.

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Thomas L. Atwell is a Principal Scientist with the Nuclear Systems Division. Besides his role as Principal Investigator on the Container Study Program, he has three areas of general responsibility: (1) specifying and implementing hardware and software components for nondestructive assay and inspection systems which require real-time, minicomputer analysis and control, (2) providing direct nuclear research and development support to projects involving nondestructive assay (NDA) of nuclear materials or nondestructive inspection of nonnuclear materials by nuclear means, and (3) Program Manager for Nuclear Materials Measurements.

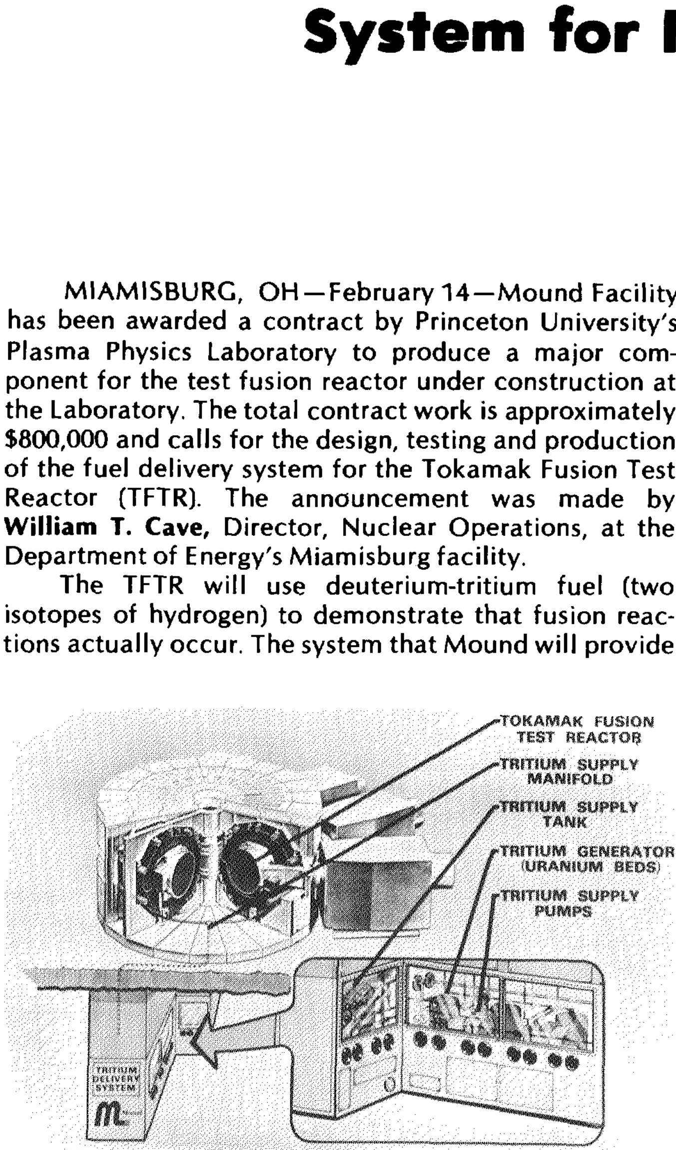
Prior to joining IRT in 1977, Tom was a staff member of the Nuclear Safeguards Group, Los Alamos Scientific Laboratory where he developed advanced techniques and instrumentation for nondestructive assay (NDA) of uranium and plutonium in a wide variety of forms, matrices and concentrations. He had primary responsibility for putting together and installing computerized prototype NDA systems at the following sites: Richland Operations, Savannah River Plant, General Atomic Co., Oak Ridge, and Los Alamos Scientific Laboratories. The system he engineered for LASL's Uranium Reprocessing Plant represented a significant advance in the integration of discrete in-plant NDA instruments into a real-time nuclear materials accountancy system.

Tom received his B.S., Mechanical Engineering from Marquette University and M.S. and Ph.D. in Nuclear Engineering from the University of Wisconsin. His Ph.D. thesis was "The Development of a Lead Slowing-Down Time Spectrometer for Fissile Assay and Fast Reactor Research."

# Mound to Deliver Fuel System for Fusion Reactor

MIAMISBURG, OH—February 14—Mound Facility has been awarded a contract by Princeton University's Plasma Physics Laboratory to produce a major component for the test fusion reactor under construction at the Laboratory. The total contract work is approximately $800,000 and calls for the design, testing and production of the fuel delivery system for the Tokamak Fusion Test Reactor (TFTR). The announcement was made by **William T. Cave,** Director, Nuclear Operations, at the Department of Energy's Miamisburg facility.

The TFTR will use deuterium-tritium fuel (two isotopes of hydrogen) to demonstrate that fusion reactions actually occur. The system that Mound will provide




**Tritium Storage and Delivery System**— Shown at twice the scale of the Tokamak Fusion Test Reactor above it, the Mound Tritium Storage and Delivery System (TSDS) is a pair of glove boxes containing equipment that will provide high purity (99%-plus) radioactive hydrogen (tritium) fuel to the plasma chamber. The TSDS is a critical part of the test reactor for several reasons. First, it is imperative that the radioactive tritium be contained within the system. Second, as a radioactive element it can affect the integrity of materials used in the system. Third, extremely high purity of the fuel is essential to the success of the fusion reaction. Fourth, the system must perform reliably because if the time and expense that are required to repair radioactive equipment. Mound was chosen to design, construct and test the TSDS because of its history of safe handling of tritium.

will deliver tritium fuel to the reaction. In the TFTR scientists expect to demonstrate the first fusion experiment to simultaneously attain the required temperature (100 million degrees) and plasma density (1,000,000,000,000,000 atoms/cc) for a long enough time (about one second) to prove the feasibility of fusion power.

Until now, fusion experiments were performed with hydrogen or deuterium gas rather than with the deuterium-tritium fuel that will be used in nuclear reactors. Tritium is a radioactive gas, which Mound has been handling for many years as the main recovery site of the material for the Department of Energy's Albuquerque complex.

During that time, Monsanto scientists have amassed years of experience in designing and constructing safe systems for storing, processing and containing tritium in an environmentally safe manner.

Mound will act as a consultant to Ebasco/Grumman, the architectural-engineering firm that is responsible for the overall design of the TFTR. Together Mound and Ebasco/Grumman will design the TRIDICUBE Storage and Delivery Systems (TSDS). Mound will construct the system and run full-scale tests, using tritium, before delivering it to Princeton. In addition, Mound will train several technicians from Princeton to safely operate the TSDS and other tritium systems used with the TFTR.

The quality standards for the system will be extremely high, since the reactor must have very pure tritium gas (99%) in order to function properly. In addition, almost all the operations must be performed within a closed glovebox system controlled from a remote location. Furthermore, tritium, a radioactive element, will require a containment system that is state-of-the-art.

Mound work on the TSDS began September 1978, and will continue until about September 1980. The Monsanto project team includes Dr. **Warren Smith** who is the Project Manager, Dr. **William Wilkes** who is the Technical Project Leader, and **Reed Watkins,** the Engineering Project Leader.

# Analytical Chemistry and Nuclear Safeguards in Reprocessing Of Thorium-Based Fuels

By E.A. Hakkila
Safeguards Systems Design Group Q-4
Los Alamos Scientific Laboratory
Los Alamos, NM 87545

## I. INTRODUCTION

Nuclear safeguards has become increasingly important for the public acceptance of nuclear energy. Effective safeguards are as necessary in the uranium-thorium fuel cycle as they are in the uranium-plutonium fuel cycle. All materials measurement strategies will rely heavily on analytical chemistry both for primary accountability measurements and for calibration of NDA instruments.

The reprocessing of thorium-uranium fuels will require highly precise and accurate analytical measure ments of both uranium and plutonium. This requirement imposes additional burdens on the materials measurement over and above those characteristic of plutonium recycle facilites.

Originally, reactor designs for the uranium-thorium fuel cycle relied on initial core loadings of high-enriched $^{235}$U. Subsequent recycle cores were to contain high-enriched $^{233}$U produced from thorium during operation of the initial core, or mixtures of $^{235}$U and $^{233}$U. Nonproliferation considerations have invoked the concept of denaturing these materials by diluting them with non-fissile $^{238}$U to less than 20% $^{235}$U or less than 12% $^{233}$U. The secondary consequences of this dilution are a loss in economic and neutronic efficiency and the production of significant quantities of weapons-usable plutonium, which is not normally produced in high-enriched thorium-uranium reactor systems.

## II. THORIUM FUEL CYCLES

Some of the thorium-based reactor concepts will be discussed briefly to point out features that may be important in selecting analytical methods for accountability purposes in Thorex- or Purex-type reprocessing plants.

### A. Light-water Reactor.

The thorium LWR fuel cycle is initiated by replacing some of the $^{238}$U with thorium to breed $^{233}$U.[1,2] The amount of thorium that can be added is dictated by the nonproliferation requirement that fuel enrichment be less than 20% $^{235}$U or less than 12% $^{233}$U. Thus, both $^{238}$U and thorium are present as fertile material, and plutonium as well as $^{233}$U will be formed. The plutonium content of the discharged fuel will be 20-35% of the amount formed in conventional LWRs. Fertile and fissile materials are mixed as oxides, hence $^{233}$U and $^{235}$U are coprocessed as a single stream. In an alternative seed-blanket concept uranium and thorium are placed in separate fuel rods, and could be reprocessed separately.

Thorium oxide fuels are difficult to dissolve with $HNO_3$, and some HF must be added to facilitate fuel dissolution. Fuel cladding may be stainless steel or Zircaloy, with the latter providing some advantage in neutron efficiency. During fuel dissolution some Zircaloy may dissolve with the fuel and inhibit further fuel dissolution by complexing the fluoride.

### B. Light-Water Breeder Reactor.

The LWBR is a thermal breeder, similar in concept to the LWR, but with a reactor core designed to optimize the neutron yield to enable breeding to occur. The breeder fuel is a mixed thorium-uranium oxide. The uranium enrichment can range from less than 20% to 93%, depending on nonproliferation criteria.[3]

An important difference between fast and thermal breeder fuels results from the lower neutron penetration into the fuel element for thermal breeders. Thus, for thermal breeders a significantly larger fraction of both fission and breeding occurs in the outer portions of the fuel rod, and the potential for cladding interactions with the bred uranium (or plutonium) is greater. The resulting concentration gradients may affect measurements of residual fissile material in the leached hulls. Reprocessing of LWBR fuels is similar to LWR fuels.

### C. Fast Breeder Reactor.

Fast breeder fuels consisting of mixed oxides of thorium and uranium, and of their metal alloys, have been studied.[4,5] Cladding could be stainless steel or Zircaloy. Reprocessing of oxide fuels would be similar to LWR fuels but probably with reduced throughputs or lower concentrations if higher burnups are used. Metal fuels may require modifications in dissolution procedures.

**D. High-Temperature Gas-Cooled Reactor.**

The HTGR fuels consist of fissile uranium oxide or carbide and fertile thorium oxide or carbide microspheres embedded in a graphite matrix.[6] In the General Atomic concept[7] the fertile particles contain a duplex (Biso) porous graphite-pyrolytic graphite coating. The fissile particles contain a triple (Triso) coating of porous graphite-SiC-pyrolytic graphite. After graphite burning, fissile and fertile particles can be separated by air classification. Fuel dissolution and reprocessing are similar to LWR fuel, but fissile and fertile fuels can be reprocessed separately.

**E. Heavy-Water Reactor.**

Thorium can be used in heavy-water reactors with enriched uranium as fissile fuel.[8] Reprocessing would be required to recover bred $^{233}U$.

## III. SPENT FUEL CHARACTERISTICS

The characteristics of spent fuels depend to a large degree on the initial enrichment of the fuel. The approximate heavy metal content of spent high- and low-enriched fuel is summarized in Table I. Note that the total fissile plutonium content of the high-enriched fuels is orders of magnitude less than that in the low enriched fuels.

**Table I**
**Heavy Metal Content of Discharged High- and Low-Enriched Fuels**

| Element | Kg/MTHM High Enriched[9] | Low Enriched[10,11] |
|---|---|---|
| Th | 929 | 789 |
| U | 51 | 207 |
| Pu | 0.03 | 4 |

The approximate uranium and plutonium isotopic compositions of spent high- and low-enriched thorium-based fuels are summarized in Table II.

**Table II**
**Isotopic Composition of Discharged High- and Low-Enriched Fuels**

| Isotope | Isotopic Composition High Enriched[9] | Low Enriched[10,11] |
|---|---|---|
| U-232 | 0.02 | 0.01 |
| 233 | 29 | 5.4 |
| 234 | 7 | 0.4 |
| 235 | 41 | 7.7 |
| 236 | 21 | 2.5 |
| 238 | 2 | 84 |
| Pu-238 | 83 | 3 |
| 239 | 13 | 61 |
| 240 | 3 | 17 |
| 241 | 1 | 15 |
| 242 | 1 | 4 |

## IV. PROCESS STREAM ANALYSES

### A. Accountability Tank.

**1. Isotope-Dilution Mass Spectrometry.** Mass spectrometry probably will be the method of choice for high-precision measurements of uranium, plutonium, and thorium in dissolver solutions.

Plutonium can be measured using $^{242}Pu$ or $^{244}Pu$ as the isotopic spike, and thorium can be measured using $^{230}Th$ as the spike. For uranium measurement in initial fuel loadings containing $^{235}U$ as the fissile fuel, $^{233}U$ can be used as the spike, but for fuels loaded with $^{233}U$, a $^{235}U$ spike will be required.

The precision and accuracy claimed for isotope-dilution mass spectrometry of dissolver solutions can range from 0.1 to 1% or even greater, and is a function of several parameters including sampling, analytical techniques used, instrumentation, and the care exercised by the analyst. Further work is required with actual dissolver samples to establish precision and accuracy limits. The effect of the spike on recycled fuel containing significant amounts of both $^{233}U$ and $^{235}U$ (see Table II) should be evaluated.

A microsampling method for dissolver samples is being developed by ORNL.[12] The method relies on adsorbing sub-microgram amounts of sample onto an ion exchange resin bead. The radioactivity of the sample is sufficiently low so that samples can be commercially transported to IAEA or other laboratories for independent verification.

**2. X-Ray Fluorescence Spectrometry.** X-ray fluorescence spectrometry is not as well developed for dissolver solution analysis as isotope-dilution mass spectrometry. It is element, rather than isotope, specific. Therefore a mass spectrometric analysis on batches will be required to obtain an isotopic analysis for subsequent atomic weight corrections.

Both energy-dispersive and wavelength-dispersive methods have been investigated. The energy-dispersive method[13] has been applied to Savannah River Plant (SRP) dissolver solutions for measurements of uranium and plutonium. For uranium/plutonium ratios of 400:1 and uranium concentrations of 50 g/L, accuracies of 3% have been obtained for plutonium measurements. The plutonium concentration is lower than would be encountered in normal LWR fuel reprocessing but is more representative of thorium fuels.

Wavelength-dispersive methods have been applied to both LWR-type[14,15] and thorium-uranium fuels.[16] Samples with activities to 1000 Ci/L were evaporated onto filter papers. Serious line interference from fission products was not observed. An accuracy of 1% was claimed.

A direct at-line or in-line x-ray fluorescence method for dissolver or other process solutions has been proposed.[17] The method will rely on a high-power x-ray tube and a high-dispersion crystal to eliminate background and overlapping x-ray interferences. The instrument should be available for evaluation in the 1980 time frame.

### B. Product Solution.

**1. Chemical methods.**

**a. Thorium.** Gravimetry and complexometric titration probably will continue to be the methods of choice for thorium measurements. A number of precipitation reagents can be used, including hydroxide, fluoride, oxalate, peroxide, or several organic precipitants. The precipitates are ignited at 950°C to form the oxide. For pure thorium solutions a precision of better than 0.1% can be obtained.

Complexometric titration with (ethylenedinitrilo)-tetraacetic acid (EDTA) is more rapid than gravimetry and with suitable masking agents and pH control the method is somewhat more tolerant of impurities. However, the location of the end point is sensitive to the end-point indicator, and titration with electrogenerated EDTA from a Hg(II) EDTA complex provides the best precision.[18] Addition of excess EDTA and back titration with Cu(II) provides better precision and accuracy than direct titration with EDTA.[19] Relative standard deviations of 0.1% or better can be obtained for high-purity standards, but precision in the range 0.1-1% can be expected for routine samples.

**b. Uranium.** Uranium can be determined gravimetrically in product samples with a precision of better than 0.1%. However, because of its speed and accuracy, the Davies-Gray method will continue to be the method of choice.[20] The method has been automated.[21]

**c. Plutonium.** Electrometric methods will be the preferred techniques for rapid measurement of plutonium in product samples. Either the $Pu^{3+}$-$Pu^{4+}$ or $Pu^{6+}$-$Pu^{4+}$ couple can be used, but the latter is preferred in the presence of iron or uranium. Precision and accuracy of better than 0.5% are attainable routinely on purified solutions, and smaller than 0.1% for high purity reference materials. Methods should be evaluated using plutonium of isotopic composition representative of reprocessed plutonium. The controlled-potential coulometric method has been automated.[22]

**2. In-Line Methods.** Absorption-edge densitometry[23] is an element-specific analytical method that can be applied in-line or at-line to the measurement of thorium, uranium, and plutonium in flowing streams. With proper choice of cell path length and K- or $L_{III}$-absorption edges, plutonium, uranium, or thorium concentrations between 5 and 500 g/L can be measured with a relative standard deviation of better than 1%. Using $L_{III}$ edges, uranium[24] and plutonium[25] concentrations between 5 and 40 g/L were measured with RSDs (1 sigma) in the range between 0.34 and 1%. Using K-edge techniques, plutonium in the concentration range between 150 and 500 g/L was measured with RSDs (1 sigma) in the range 0.2-0.5%.[26] Solutions containing 230 g/L of thorium and 30 g/L of uranium were measured using a $^{169}Yb$ source with relative standard deviations in the range 0.5-2.5%.[27]

With a continuum x-ray source, uranium and thorium or uranium and plutonium solutions can be analyzed simultaneously with RSDs ranging from approximately 5% to better than 1% (1 sigma), depending on concentration ranges and ratios.[28] The method is applicable to radioactive samples, and thus could be used as an in-line measurement technique in reprocessing streams.

Use of a curved-crystal spectrometer as an energy filter may enable measurements to be made of thorium and uranium in the high gamma-radiation fields associated with $^{232}U$ and $^{228}Th$ daughters.[29]

**C. Waste Streams.**

**1. Thorium.** Thorium in waste streams probably will be measured in the laboratory using spectrophotometric methods. Of the numerous dye reagents that have been shown to be sensitive for measuring low concentrations of thorium, probably the most important is Thoron. With suitable masking agents and pH control, thorium can be measured in a several-fold excess of uranium or rare earths. The method has been adapted to determining thorium in both the aqueous and organic phases in Thorex solvent extraction.[30]

**2. Uranium.** In-line polarography has been investigated extensively for measuring uranium in waste as well as in product streams.[31] The method has been applied at the SRP for measuring uranium concentrations of $10^{-4}$ to $10^{-5}$ **M** in flowing streams.[32] In Japan, in-line polarography has been used to measure uranium in aqueous[33] and TBP[34] recycle streams. Polarography is planned for determination of uranium in process waste streams at the HTGR reprocessing plant at Julich.[35]

Both $^{233}U$ and $^{235}U$ can be measured in process scrap using the LASL-designed shufflers.[36] The technique also could be used to measure in-process holdup in areas such as pipes and tanks.

**3. Plutonium.** The most sensitive in-line method for determining plutonium is alpha spectrometry. Cerium-activated Vycor glass detectors can provide alpha/beta discrimination factors of $10^4$ by optimizing the thickness of the active layer, the cell thickness, and the detector electronics. The detector provides linear response over the range $10^{-4}$ to 1 g/L of plutonium.[37] Because the detector measures primarily $^{238}Pu$, the isotopic composition must be known.

**D. Leached Hulls.**

Gamma-ray and neutron methods have been proposed for measuring fissile content of leached hulls. The gamma-ray method relies on correlating the measurement of the 2.16-MeV gamma ray from $^{144}Pr$ to fissile concentration through a $^{144}Ce/Pu$ (or U) measurement in the accountability tank.[38] The method is not applicable to analysis of aged fuel elements because of the decay of 284-day $^{144}Ce$. In addition the method may not be applicable to thorium fuels due to interference from the 2.6-MeV gamma ray of $^{208}Tl$, a daughter of $^{228}Th$ and $^{232}U$.

Neutron measurements can be performed using active or passive methods. Using passive neutron methods both spontaneous fission and (alpha, n) neutrons can be measured. The (alpha, n) neutron yield is sensitive to the light-element content of the hulls, particularly fluoride. The method can be made specific for spontaneous-fission neutrons using coincidence counting techniques, but with some loss in sensitivity. The passive neutron techniques are sensitive to curium content of the fuel, and the $^{242}Cm$ and $^{244}Cm$ concentration relative to plutonium must be known. A prototype passive neutron system for measurement of plutonium in leached hulls is being developed and evaluated at Hanford.[39]

An active neutron method based on the LASL-designed barrel shuffler has been proposed to measure fissile materials in hulls.[40] This system also can be operated in the passive mode.

Further work on development of neutron methods for leached-hull assay is required.

**E. Wastes.**

Low-level wastes may be measured using either gamma-ray or neutron methods.

For wastes where $^{232}U$ or $^{228}Th$ daughters have had time to reach equilibrium, the $^{208}Tl$ gamma ray can be used for measurement of fissile content. This technique has been applied to measuring $^{233}U$ in process scraps.[41]

For analysis of solid low-level plutonium waste packaged in 55-gal drums the 414-keV gamma ray from $^{239}Pu$ can be used to detect as little as l g plutonium in a 5-min scan.[42] Measurement accuracy depends on administrative control in sorting waste to ensure reproducible matrices. The method may not be applicable in the presence of high concentrations of $^{233}U$ due to gamma rays from $^{232}U$ daughters.

Passive neutron methods can be used to detect both uranium and plutonium, but are most sensitive for plutonium. The sensitivity for the even-numbered plutonium isotopes is a factor of $10^5$ to $10^6$ more than for uranium. Curium or californium can interfere with the plutonium measurement.

Active neutron methods generally use a $^{252}Cf$ source and coincidence counting of induced fission neutrons.

## V. SUMMARY AND CONCLUSIONS

The analytical chemical needs in a plant designed to reprocess uranium-thorium fuels will require highly precise and accurate measurements of uranium as well as plutonium. The $^{233}U$ (and $^{235}U$ for first-generation reactor fuel) must be measured with the same care given to plutonium.

Isotope-dilution mass spectrometry will continue to be a key accountability measurement for both uranium and plutonium in dissolver solutions, not only because of its potential for high precision and accuracy but because isotopic analysis can be correlated with reactor data. Thorium also can be measured using a $^{230}Th$ spike. X-ray fluorescence can provide more rapid analyses for all three elements in dissolver solution, and may be required for near-real-time accounting schemes. Electrometric methods for uranium and plutonium will be important methods for product solutions. In-line alpha monitors for plutonium and in-line polarography for uranium may be developed for waste-stream measurements but should be supplemented by spectrophotometric and fluorimetric methods.

Thorium, though not an SNM, must be measured for accountability checks and to meet NRC and IAEA requirements. Gravimetry and EDTA titrations probably will be the methods of choice. A thorium primary standard must be developed to establish the accuracy of proposed thorium analytical methods. For thorium product measurements, analyses must be adapted to hot-cell operation. The process of radioactive decay cannot be ignored in the analytical scheme, nor can the influence of thorium content on the analyses of the fissile materials.

The automation of instrumentation for remote operation will be necessary for many routine analyses because of the high radiation levels associated even with purified uranium and thorium product streams. Much work has already been done in this direction, including the automated spectrophotometer for uranium and plutonium analyses, potentiometric determination of uranium, the controlled-potential coulometric determination of uranium and plutonium, mass-spectrometric determination of uranium and plutonium, and x-ray fluorescence analysis of all three elements. Remote-sampling techniques and small-sample methods will be important to minimize personnel exposure. In-line methods will be required not only for near-real-time accounting but to minimize personnel exposure.

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# Wackenhut Corporation Purchases NUSAC, Inc.

Coral Gables, Florida, December 28.—The Wackenhut Corporation has purchased for an undisclosed sum the assets of NUSAC, Inc., a technical service and consulting organization serving the nuclear industry, President **George R. Wackenhut** announced today.

Mr. Wachenhut, head of one of the world's largest international security and investigative organizations, headquartered in Coral Gables, said, a newly formed wholly-owned subsidiary, NUSAC, Incorporated, will be a Florida corporation.

Headquarters for NUSAC will remain in McLean, Virginia. It will continue to be a self-operating, autonomous company.

"NUSAC is and will remain an independent firm," Mr. Wackenhut stated. "Its independence, policies and dedication to quality will be preserved."

Dr. **Ralph F. Lumb,** a recognized authority on nuclear materials management, will continue to serve as President of NUSAC. Other NUSAC executive management will remain. Dr. Lumb served as the first Chairman of the Institute for Nuclear Materials Management. He also chaired the AEC ad hoc Committee on Safeguarding Special Nuclear Materials.

Dr. Lumb stated that the complementary nature of the services of The Wackenhut Corporation and NUSAC will enable both firms to provide broader and more effective services to clients.

"Further," he added, "the relationship will be synergistic in that it should result in more business for each company than either would be able to generate alone. Of course, the extensive Wackenhut worldwide marketing organization will be of considerable benefit to NUSAC in the projected expansion of its growing business."

NUSAC, founded in 1968, services the needs of the nuclear industry in a number of highly specialized areas, including nuclear fuels quality assurance, out-of-core fuels management, industrial security for plant and material protection, nuclear material control and accounting, radiological protection, representation at UF6 enrichment facilities and surveillance of spent fuel reprocessing.

The Wackenhut Corporation, under contract to the European Economic Commission, last year completed security surveys for nuclear power plants in Holland, Italy and Belgium. The company also has provided security services for a number of nuclear power generating plants in the United States.

With nearly 100 offices in the United States, The Wackenhut Corporation operations extend to Canada, Europe, United Kingdom, the Middle East, Indonesia, Latin America and the Caribbean.

**Dr. Lumb**

# The Design of a Limits of Error Of Inventory Difference (LEID) Computation Program

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Abstract

This paper describes the design and development of an automated LEID, limits of error of inventory difference, computation process. The experience and procedure used in this project may be of help in solving related problems. In the Introduction, the definition of ID, inventory difference, and LEID and the reasons for computing them are introduced. The fabrication plant operations and the ID and LEID computation related activities are briefly described, for background knowledge. The analysis of LEID computations, which involves the assumption of an additive model of all the possible error sources, is described, including the application of the error propagation method of computing the variance of each error source, and the use of the analysis of variance technique to estimate random error and systematic error variances. Finally, the organization of the computations process and its input/output files are explained.

## Introduction

At the General Electric low enriched nuclear fuel fabrication plant in Wilmington, North Carolina, the Nuclear Material Management group is responsible for nuclear material accounting. [1] Physical inventories are performed annually (previously at 6-month invervals) and a material balance is performed. The inventory difference (ID), which is the algebraic difference between an ending booked inventory and an ending physical inventory, is calculated. The ID is usually generated by unavoidable measurement errors, such as random errors and systematic errors; therefore, one would expect there always will be an ID (either positive or negative). However, how big an ID is reasonable? The question is answered by applying the statistics concept called limit of error of ID (LEID). The statistician in the material management group is responsible for the calculation of LEID. If the ID is greater than the LEID, it implies that there are mistakes in registering book inventory or physical inventory or that material has been lost. If the LEID is greater than a pre-calculated value (e.g., 0.5% of additions to or removals from the process - whichever is greater), it also implies measurement or sampling mistakes in the nuclear material control system. Confirmed material balance discrepancies regarding ID and LEID are reported and reasons for the discrepancies identified, when possible. Of course, the ID and LEID calculations are designed to detect nuclear material losses which may be due to material (1) exiting from the facility without having been measured, (2) remaining within the facility unknown to anyone and therefore unaccountable, and (3) removed for reasons of intentional diversion.

## Plant Operations Related to LEID Calculation

A brief description of the material flow that affects the LEID calculation follows. It is intended to provide only an overview.

### Shipper/Receiver Comparison

The major material inputs to the fabrication plant are $UF_6$ cylinders and UNH products. Occasionally, discrepant material such as fuel rods and powder are returned to the plant. All material receipts are entered into the booked inventory (Nuclear Material Accountability and Reporting System, NUMARS) and the perpetual inventory (Manufacturing Information Control System, MICS), at measured receiver's values, which include gross weight, tare weight, U factor, enrichment, and container number.*

These measured material quantities are then released for processing and identified by a MICS ID card denoting the discrete container number, material type, U factor**; and nominal enrichment. All receiver's values are reported to the Nuclear Regulatory Commission (NRC) within the required reporting period. Every significant and confirmed shipper-receiver difference is documented in a report prepared by the material management group, and becomes part of the receiving documents.

### Fuel Fabrication Process

Upon receipt and measurement verification of the low enriched uranium in the form of $UF_6$, the conversion process is ready to begin. Conversion of $UF_6$ to $UO_2$ utilizes either the Ammonium Diuranate process or the GE patented GECO process. The $UO_2$ is formed into pellets which are sintered, ground to proper diameter, and loaded into tubes. Loaded tubes are fitted with end cap closures, welded and assembled into bundles. The uranium purification system reprocesses certain materials which do not meet the required in-process specifications for $UO_2$ product, as well as high grade by-products. The treatment of process liquid, discharged air stream, and solid waste are also integrated parts of the plant operation.

## Important Activities Related to LEID Calculation

### Measurement and Quality Assurance

In order to control the quality of the intermediate and final products, measurement points are assigned strategically within the plant. Measurements include bulk values (weight or volume), analytical values (U factor, enrichment), and other values which are required for the calculation of U contents. The Quality Assurance group is responsible for maintaining the measuring standards and developing the calibration schedules and sampling plans. Statistical computer programs are used on a routine basis to quantify

*Data input to MICS is on a container basis. Input to NUMARS is usually summarized by enrichment and material type - not by container.

**The MICS data card does not specifically denote U factor. By knowing the material type one can usually determine the U factor from predefined tables.

measurement system performance and determine total measurement uncertainties.

The weights of discrete containers are input to MICS directly by the workers. The samples collected at various measurement points are analyzed by the Chemet Laboratory and the analytical results, such as U factor and enrichment, are accumulated.* Based on the sampled results, a computer program called UFACTOR is run once a month; the outputs are used by the statistician of the material management group to update the U factor records in MICS. There is also a computer program which performs a similar calculation for enrichment.

The material management group also assigns a technician to obtain samples, as well as standards data on scales, in order to estimate the biases and variances of scales and the random variance of the sampled data.

### Perpetual Inventory and MICS

In order to keep track of inventory in real time, MICS accepts data from strategically located remote terminals at the actual time when nuclear material is transferred. Usually, a remote computer terminal is located in a queueing area, a process operation area, or a storage area. Input is made to MICS via one of the terminals whenever a discrete container is received, filled, shipped, emptied, or has a weight change. In addition, whenever a container is moved from one identified location to another, a transaction is inputted to MICS to reflect the change of location, e.g., in or out of storage.

### Activities Before Inventory Date

Of all the items within the plant, there might be some for which the U factor and enrichment have not been measured during the year. Usually, it is because these items are not routinely measured, e.g., have been in storage. An activity called pre-inventory U-factor measurement is scheduled about one week before inventory date to update measurements on such items.

Another activity called Equipment Holdup Value Estimation is performed in conjunction with the inventory verification (this activity usually starts before inventory date). When the production process has not been changed, the holdup values can be estimated by using the historical and present data for processing equipment that are not cleaned out (usually these equipment are run dry), e.g., calciners, reactors, mills, etc. When the production process is changed, a complete cleanup of the equipment is necessary and a sample taken to determine the U content.

### Activities On and After Inventory Date

Starting on the inventory date the inventory verification team verifies the physical inventory by using the MICS Inventory Accountability Report, which is a list of all the containers supposed to be in the plant.

After the inventory verification, the team can take the difference between the in-process untamper safe physical ending inventory and the in-process untamper safe booked ending inventory as the Inventory Difference (ID).

*The accumulation method is only used for certain material types. Scrap is measured and updated on MICS on a can-by-can basis.

## LEID Calculation

### Introduction

The limit of inventory difference, LEID, is defined as

$$\mathrm{LEID} = t_{.05}(\nu) \cdot \sqrt{V(\mathrm{ID})}$$

where $t_{.05}(\nu)$ is the value of a student t random variable with $\nu$ degrees of freedom such that

$$P_r(|t| > t_{.05}) = 1 - \int_{-t_{.05}}^{t_{.05}} f(t)dt = 0.05;$$

$$\text{for } \nu \geq 30,\ t_{.05} = 2.0$$

V(ID) is the variance of inventory difference.

The approach used to find the variance of ID involves expressing ID as a linear combination of Beginning Inventories, Additions, Removals, and Ending Inventories. Explicitly,

$$\mathrm{ID} = \mathrm{BI} + \mathrm{A} - \mathrm{R} - \mathrm{EI}$$

The variance is found for each of these components, and the variance of ID is then found by appropriately combining the component variances.

The random error variance of ID, $V_r(\mathrm{ID})$, can be expressed as the sum of variance of each component, if the components are statistically independent, i.e.,

$$V_r(\mathrm{ID}) = V_r(\mathrm{BI}) + V_r(\mathrm{A}) + V_r(\mathrm{R}) + V_r(\mathrm{EI}).$$

However, in order to compute the systematic error variance of ID, $V_s(\mathrm{ID})$, the algebraic sum would be performed first.

Since there are many items in BI, all related items will be grouped together and the variance can be written as

$$V(\mathrm{BI}) = V(\mathrm{BI}_1) + V(\mathrm{BI}_2) + \dots .$$

The same kind of process will be repeated for A,R, and EI. Once this has been done, the next step is to find the variance of each item in the group.

From the above discussion, it is clear that to calculate LEID one needs all the independent items and their bulk values (weight or volume) in beginning inventory, ending inventory, removals from the process, and additions to the process for a given inventory balance period (six months or one year).

In addition, one needs:

(1) the relative variances (i.e., variance/net weight) of all material types,

(2) U factors and enrichments,

(3) sampling frequency, and

(4) a statistical model.

In order to remove all the correlated items, before any computations of the variance of ID are performed, data for any items that are identical in both a plus and minus component of the ID equation must be deleted. The plus components are Additions or Beginning Inventories and the minus components are Removals or Ending Inventories.

Since the major interests are focused on the ID of U and its isotope U235, one needs to know the net weight of U content material, its U factor and enrichment. All three quantities have random errors and systematic errors associated with them. The random errors of U factor and enrichment include the random analytic error and the random sampling error. Therefore, there are eight different variance categories - two random error variances for U factors, two random error variances for enrichments, one random error variance for bulk measurements, one systematic variance for U factors, enrichments, and bulk measurements, respectively. Since all eight sources of error variance are far from equal, one should use an error propagation method, or sometimes called moment generating method to compute the contribution of error due to each source. [2] [3]

## The Statistical Model

In a factory environment, such as Wilmington Manufacturing Department, millions of items are processed each year; therefore, items with a common U factor are batched together for computational purposes. For example, a fuel rod, made up of many pellets, is scanned to determine its U factor and is considered as a batch. The $UO_2$ powder produced over one month period may be assigned a U factor by the quality assurance group, and therefore, is considered a batch.

In the following, we shall set up an additive model and derive the error components for a given batch of material with the average U factor $\bar{U}_f$. Assume that the net weight of the U content material for the whole batch is W, and the uranium weight of the material is Y.

Then

$$Y = W \cdot \bar{U}_f$$

$$W = W_T + W_S + W_\gamma$$

$$\bar{U}_f = \sum_{i=1}^{A} \left( \sum_{j=1}^{B} U_{ij} \right) /AB$$

where

$W_T$ is the true Net Weight

$W_S$ is the systematic error of Net Weight with variance $\sigma_{W_S}$

$W_\gamma$ is the random error of Net Weight with variance $\sigma_{W_\gamma}$

A is the number of analyses per sample

B is the number of samples per batch

$U_{ij}$ is the measured U factor for the $i^{th}$ analysis of the $j^{th}$ sample.

Now assume the measured U factor is the sum of several error components. Explicitly,

$$U_{ij} = U_T + \gamma_{a_{ij}} + \gamma_{S_j} + U_S$$

where $U_T$ is the true U factor.

$\gamma_{a_{ij}}$ is the random analytic error of the $i^{th}$ analysis of the $j^{th}$ sample, with variance $\sigma^2_{\gamma_{a_{ij}}}$

$\gamma_{S_j}$ is the random sampling error of the $j^{th}$ sample, with variance $\sigma^2_{\gamma_{S_j}}$

$U_s$ is the systematic error of the measurement method with variance $\sigma^2_{U_S}$

Therefore, we can express the average U factor as:

$$\bar{U}_f = U_T + \frac{\sum_{i=1}^{A}\sum_{j=1}^{B} \gamma_{a_{ij}}}{AB} + \frac{\sum_{j=1}^{B} \gamma_{S_j}}{B} + U_S.$$

We can rewrite

$$Y = (W_T + W_S + W_\gamma)\,(U_T + \frac{\sum_{i=1}^{A}\sum_{j=1}^{B} \gamma_{a_{ij}}}{AB} + \frac{\sum_{j=1}^{B} \gamma_{S_j}}{B} + U_S)$$

Since Y is a function of $W_S$, $W_\gamma$, $\gamma_{a_{ij}}$, $\gamma_{s_j}$, and $U_S$, the variance of Y, $\sigma_y^2$, can be expressed as

$$\sigma_Y^2 = (\frac{\partial Y}{\partial W_S}) \cdot \sigma_{W_S}^2 + (\frac{\partial Y}{\partial W_\gamma})\, \sigma_{W_\gamma}^2 + (\frac{\partial Y}{\partial \gamma_{a_{ij}}})^2\, \sigma^2_{\gamma_{a_{ij}}}$$

$$+ (\frac{\partial Y}{\partial \gamma_{S_j}})^2\, \sigma^2_{\gamma_{S_j}} + (\frac{\partial Y}{\partial U_S})^2\, \sigma^2_{U_S}\,.$$

Since we assume that the variables are uncorrelated, the second order cross terms are zero.

In our model, since

$$\frac{\partial Y}{\partial W_S} = \bar{U}_f,\ \frac{\partial Y}{\partial W_\gamma} = \bar{U}_f\ \frac{\partial Y}{\partial U_S} = W$$

$$\frac{\partial Y}{\partial \gamma_{S_j}} = \frac{W}{B},\ \frac{\partial Y}{\partial \gamma_{a_{ij}}} = \frac{W}{AB}.$$

the error variance of Y can be stated as:

$$\sigma_Y^2 = \bar{U}_f^2\, \sigma_{W_S}^2 + \bar{U}_f^2\, \sigma_{W_\gamma}^2 + \frac{W^2}{A^2B^2}\, \sigma^2_{\gamma_{a_{ij}}}$$

$$+ \frac{W^2}{B^2}\, \sigma^2_{\gamma_{S_j}} + W^2 \cdot \sigma^2_{U_S}\ .$$

Therefore, the relative error variance of Y,

$$\delta_Y^2 = \delta_{W_S}^2 + \delta_{W_Y}^2 + \frac{1}{A^2B^2} \cdot \delta_{Y_{a_{ij}}}^2 + \frac{1}{B^2}\,\delta_{Y_{S_J}}^2 + \delta_{U_S}^2 \quad , \text{----} \ (A)$$

where

$$\delta_Y^2 = \frac{\sigma_Y^2}{Y^2}$$

$$\delta_{W_S}^2 = \frac{\sigma_{W_S}^2}{W^2},\ \delta_{W_Y}^2 = \frac{\sigma_{W_Y}^2}{W^2},\ \delta_{U_S}^2 = \frac{\sigma_{U_S}^2}{\overline{U}_f^2}$$

$$\delta_{Y_{a_{ij}}}^2 = \frac{\sigma_{Y_{a_{ij}}}^2}{\overline{U}_f^2},\ \delta_{Y_{S_j}}^2 = \frac{\sigma_{Y_{s_j}}^2}{\overline{U}_f^2}$$

Now, it is clear that the relative error variance of a batch of material with uranium weight Y can be expressed as the sum of five relative error variances as in Equation (A). Since the factory performs scrap recovery and material blending, it is also necessary to compute the variance of U235 inventory difference. The formula for computing the sources of relative errors can be derived similarly. In fact, there are three more sources of error: the random analytic error of enrichment, the random sampling error of enrichment, and the systematic error of enrichment.

In the past, Wilmington Manufacturing Department batched materials by their material types and each type required a number of samples and analyses for estimating the type variances. In the new grouping method, batches of like material with similar variance behavior form a stratum, where the same type of analytical measurement method, or sampling technique, is used. In order to test the homogeneity of the variance, a Bartlett test is applied to each stratum. The use of the stratum approach can reduce the number of samples and analyses needed to estimate the variance of a measurement method or a type of scale. As a consequence, the load on the analyses laboratory has been reduced by 35%.

In Wilmington Manufacturing Department all the batch data is identified by its sub-strata code. However, the strata are formed differently. For example, one stratum may be formed by the analytical method used in determining the random analytical variance; another stratum may be formed by the sampling method used in determining the random sampling variance. Yet, both strata may contain the same sub-strata batch data. Therefore, it is necessary to establish a relation between sub-strata code and the strata names so that a computer program can accumulate the error induced by the specific measurement method identified by the stratum name.

So far, we have assumed that the relative variances are known for each stratum. In the following, we shall describe the methods for computing relative variances.

Estimating the Variances

To estimate the random error variation of a U factor or enrichment stratum (either due to analytical method or sampling method), a one-way analysis of variance (ANOVA) or two-way nested ANOVA can be used.

To estimate the random error variation of the net weight, the random error variance of gross weight and tare weight are determined by using the standard ANOVA. The gross weight stratum are grouped together by the type of scales used. However, the tares used within a gross stratum very likely consist of several types of tares. Since the number of each type of tares used and the error variance of each tare type are known, the average tare error variance, the gross error variance, and rounding error variance of the scale can be combined to determine the random error variance of the net weight. More precisely, the random error variance of net weight is

V (net weight) = V (gross weight) + V (tare weight),

where

V (tare weight)

$$= \frac{n_1 V\ (\text{tare weight } 1) + n_2 V\ (\text{tare weight } 2) + \ldots}{n_1 + n_2 + \ldots}$$

V (gross weight) = the ANOVA computed variance or the rounding error variance of the scale, whichever is larger.

V (tare weight i) = the same computation procedure as the gross weight is followed for all i's.

To estimate the systematic error variance of the net weight, the systematic error variances of gross weight and tare weight are combined. The systematic error variance of gross weight and tare weight consist of three terms: (1) the variance of the bias associated with the standard, (2) the rounding error variance, and (3) the variance of the standard.

The systematic error variance for the net weight depends on the degree of correlation between the errors for the gross and tare weights. This correlation will be assumed to be zero, if the gross and tare weights are determined on different scales. The systematic error variance of the net weight is then the sum of the systematic error variance of gross weight ($S_G^2$) and the systematic error variance of tare weight ($S_T^2$). If the gross and tare weights are made on the same scale and $S_G^2 \neq S_T^2$, the systematic error variance of the net weight, $S_N^2$, is

$$S_N^2 = S_G^2 + S_T^2 - 2\sqrt{S_G^2 \cdot S_T^2}$$

Note that the condition $S_G^2 \neq S_T^2$ gives a more conservative value of $S_N^2$.

If the rounding error variance of the scale is the major term, then

$$S_N^2 = S_G^2 + S_T^2$$

If the variance of the bias associated with the standard is the major term, then a less conservative formula is used:

$S_N^2$ = the variance of the bias associated with the gross standard

+ the variance of the bias associated with the tare standard

To estimate the systematic error variation of a U factor or enrichment stratum, one can collect repeated measurements of a known standard and apply an ANOVA to compute the variance of the mean value as the major part of the systematic error variance. That is,

systematic error variance of a measurement method

$= \mathrm{Var}(\bar{X}) + S_o^2$

where

$X_i$'s are the measured values of a known standard with variance $S_o^2$

and $\bar{X}$ is the average of $X_i$'s.

However, in the manufacturing environment, several known standards are often used. Therefore, the above procedure has to be modified. By assuming that the systematic error variation is independent of the standards used, one can find the delta difference between the measured value and the individual known standards and then compute the variance of the mean value of the delta differences as the systematic variance. More precisely, the model for measuring n different standard values is

$$X_i = \mu_i + \alpha_i + \varepsilon_i \qquad i = 1, 2, \ldots N$$

where $X_i$ is the measured value of the $i^{th}$ standard

$\mu_i$ is the assigned value of the $i^{th}$ standard

$\alpha_i$ is the systematic error variation

$\varepsilon_i$ is the random error variation with zero mean

Define, the delta difference as

$$\Delta_i = X_i - \mu_i$$

Therefore, the model becomes

$$\Delta_i = \alpha_i + \varepsilon_i$$

$$\text{Define } \bar{\Delta} = \sum_{i=1}^{N} \Delta_i / N$$

The variance of $\bar{\Delta}$ is the systematic error variance of the measuring method.

So far, we have only explained the application of one-way ANOVA; its extension to two-way ANOVA is also incorporated in the LEID computation program.

## Organization of the Computation Process

The process consists of three parts: the ANOVA program which collects data from the replicate files and computes the relative variances of the strata; the data base application program (MICS LEID) which selects all the transactions data from MICS data base, classifies them into sub-strata and strata, and establishes the relationships between relative variances and strata; the LE program which computes the variance and limit of error of the inventory difference, and generates various limit of error reports.

The detailed structure of the programs and files are shown in Figure 1. All processing is performed on a Honeywell 6000 computer.

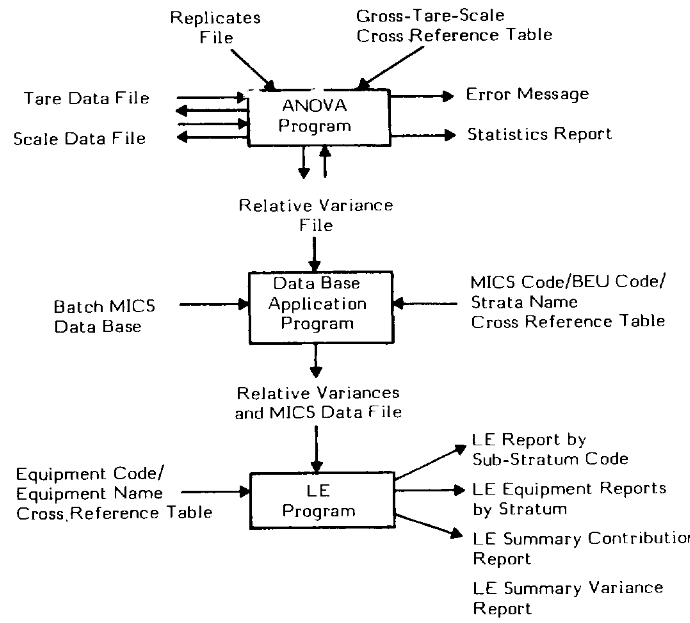


Figure 1 The Structure of LEID Program

ANOVA is a FORTRAN IV program which can be run in either time sharing or remote batch, as a user option. It is run frequently throughout the year, as data are available, to generate the strata relative variance files which are used at inventory time. It generates eight files, as follows:

| Mode | Variance Files |
|---|---|
| Bulk Measurements | Random<br>Systematic |
| U Factor | Random Analytic<br>Random Sampling<br>Systematic |
| Enrichment | Random Analytic<br>Random Sampling<br>Systematic |

ANOVA is extremely flexible - depending on the replicates type, the nature of the stratum, the way the data was collected, and whether or not comparison values are used, it selects the proper statistics routines and computes the specified random or systematic variances. Table 1 shows the various routines of the ANOVA Program.

The MICS LEID program is a set of COBOL programs which were developed for batch processing. It is run monthly and processes some 11 million items of data to obtain beginning inventories, additions, removals, and ending inventories. This program extracts the appropriate data from the MICS System data base, batches items, classifies and sorts the batches by substrata, formats the data, and writes a tape containing about 100,000 batches of data.

Table 1

ROUTINES OF ANOVA

| | |
|---|---|
| 1: | One-way Anova, 2 analyses per item. |
| 1G: | General one-way Anova. The Replicates data can have a variable number of analyses per item. |
| 1GXMU: | General one-way Anova with $\mu$ associated with each measurement (X). The Replicates data can have a variable number of X-$\mu$ pairs per item. |
| 2G: | General two-way nested Anova. The number of samples per item and the number of analyses per sample is read in at the beginning of each stratum. Thus it does not allow for an unbalanced experimental design. |
| 2GXD: | General two-way nested Anova with a $\mu$ associated with each measurement (X). However, only X and (where $=\mu$-X) are known. This does not allow for an unbalanced experimental design. |
| 2P: | Two-way nested Anova for paired data. There are 2 samples per item and 2 analyses per sample. Replicates data can contain zeroes. |

LE is a FORTRAN IV program which was developed in time sharing and is run in remote batch. It is run at inventory time and computes variances of ID and the resultant LEID. LE reads sub-strata weight data from the MICS tape, generated by the MICS LEID Module, looks up the proper strata variances and computes the sub-strata random and systematic variances using the built-in statistics formulas. At the same time it accumulates the strata variances. After all sub-strata data have been processed, the strata variance data are accumulated by measuring equipment and the total variances and LE are computed for U and U235.

Summary reports are printed of variances and percent variances by equipment. In addition, detailed reports of variances are printed by sub-strata and for each equipment by strata. The summary reports present the overall picture and the detailed reports are invaluable for analyses of sources of error.

## Conclusions

A LEID computation process has been automated for GE's Wilmington Manufacturing Department. The prime impact is that it speeds up the LEID computation and permits the plant to meet the 30 day Nuclear Regulatory Commission (NRC) report requirement. It also provides a number of other tangible and intangible benefits:

- Eliminates 35 percent of lab tests
- Eliminates manual labor of LE computations, estimated at 1 man year
- Eliminates possibility of human error in hand calculations
- Load levels strata variance computations and MICS data batching over the inventory time period

This automated process is possible because of the MICS system which was developed and installed in 1973. MICS performs the data collection and storage functions required to provide input data to LEID. The automation of the LEID computation process will in turn spawn additional automated computation processes in the future, e.g., to estimate the cumulative bias effects on LEID, and to plot and predict control charts of the cumulative LEID over several years.

This project demonstrates the successful application of a theoretical technique in a practical factory environment. We hope that the method explained in this paper can help in other related situations; in particular, the criteria for grouping strata, the application of error propagation methods, and the method of estimating systematic error variances and net weight variances considering factory constraints. Potential applications are characterized by the need to track material processing and estimate the cumulative statistical errors of the measurement equipment. Some suggested areas include: manufacture of parts to very small tolerances and processing of precious materials, such as diamonds and gold.

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# Preliminary Evaluation Of a Perimeter Intrusion Detection And Assessment System

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**ABSTRACT**

The design and implementation of a Perimeter Intrusion Detection and Assessment System (PIDAS) for a large material storage site was described in a report presented at the 1977 INMM Conference.* Several new design concepts were incorporated into this system which were intended to reduce the number of nuisance alarms requiring on-site investigation by a security force. In the 10 months since installation and initial debugging were completed, evaluation of PIDAS has continued. Based on the insights gained through monitoring operational performance, correcting equipment deficiencies, and transferring responsibility to the using organization, an initial assessment of the design concepts has been completed.

## INTRODUCTION

The basic function of the Perimeter Intrusion Detection and Assessment System (PIDAS) is to provide timely warning to the security force in the event that unauthorized entry is attempted at any point along the 3.3-km perimeter surrounding the site. PIDAS is composed of three major subsystems: perimeter intrusion sensors, alarm assessment, and control and display. Security-in-depth for each subsystem is provided by the use of multiple sensors in each sector, by the requirement that alarm assessment be performed by at least two operators, and by the use of physically separated redundant control and display equipment. To the maximum possible extent each subsystem was designed to use off-the-shelf components. In general all components or an equivalent version are commercially available; the only significant exception is the use of the Small Permanent Communications and Display Segment (SPCDS) as a major element in the control and display subsystem.

**Table 1**
**Alarm Interpretation**

| Event Priority | Alarm Sequence |
|---|---|
| 3 | Any single alarm |
| 2 | Any 2 of the 4 sensors in the same sector alarming within a prescribed time window |
| 1 | Any 3 of the 4 sensors in the same sector alarming within a prescribed time window |

The intrusion sensor array consists of two lines of detectors located within the exclusion zone between the double fenced perimeter. The primary line is located between the two fences and the secondary line is located at the inner fence. To localize the origin of an alarm, the sensor array is divided into 33 sectors each about 100 metres long. Four different types of sensors are used in the two detector lines: a microwave (MW) sensor and a MAID/MILES* (M/M) buried line sensor for the primary line and an electric field fence (EFF) proximity sensor and a fence disturbance sensor (FDS) for the secondary line.

These particular sensors were chosen for their complementary detection ability and differing nuisance alarm susceptibility. To take advantage of this multisensor system, an alarm interpretation hierarchy was developed to assign priorities to different alarms and alarm sequences or events.** These priorities are also modified by prevailing weather conditions. Table 1 is a simplified illustration of the alarm interpretation hierarchy.

Because even well-designed intrusion sensors alarm in response to non-intruder sources; i.e., wildlife or en-

*"Perimeter Intrusion Detection and Assessment System," by **M.J. Eaton, J. Jacobs,** and **D.E. McGovern,** Institute of Nuclear Materials Management, Vol. VI, No. III, Fall 1977, p. 380. This article provides the basis for understanding the terminology and data presented herein.

*MAID/MILES—Magnetic Anti-Intrusion Detector/Magnetic Intrusion Line Sensor.

**An event consists of one or more alarms from a given sector that occur within a specified time window.

**Table 2**
**Conditions for Dispatching Response Forces**

| Event Priority | Assessment | Response |
|---|---|---|
| 3 | Assessment attempted but not required | Not required |
| 2 | Both video and tower assessments required | Required for events assessed as unknown during periods of reduced visibility |
| 1 | Both video and tower assessments required | Always required regardless of assessment. If good visibility exists and the event is assessed as unknown or nuisance, then only nearby response forces are required. If conditions are otherwise, then an all-out response is indicated. |

vironmental conditions, rapid and effective assessment of all alarms is essential so that the cause can be determined and the appropriate response initiated. In PIDAS, alarm assessment is accomplished through closed-circuit television (CCTV) coverage of each sector and complementary visual surveillance of the sectors from two manned towers. The resolution of the CCTV system is such that throughout the sector one can discern an object as small as a rabbit. Table 2 describes one set of possible responses to the various priority events. In the present context, a response is considered to be the dispatch of one or more guards to an alarmed sector.

The control and display subsystem presents alarm signals, automatically switches CCTV cameras for display or video recording, processes local meteorological data, records sensor and system information for data base use, and provides diagnostic information to the operators. The primary interface for operator control is a special purpose keyboard and a computer-driven cathode ray tube (CRT) display. In addition, two pictorial map displays present detailed alarm signals, and each assessment tower has a simplified alarm display. The primary control and display system, which consists of the computer-controlled CRTs and video monitors, and a backup map display system are situated in a Security Command Center, which is located 1.6 km from the storage site. A second, independent map display system is contained in the guard house, which is

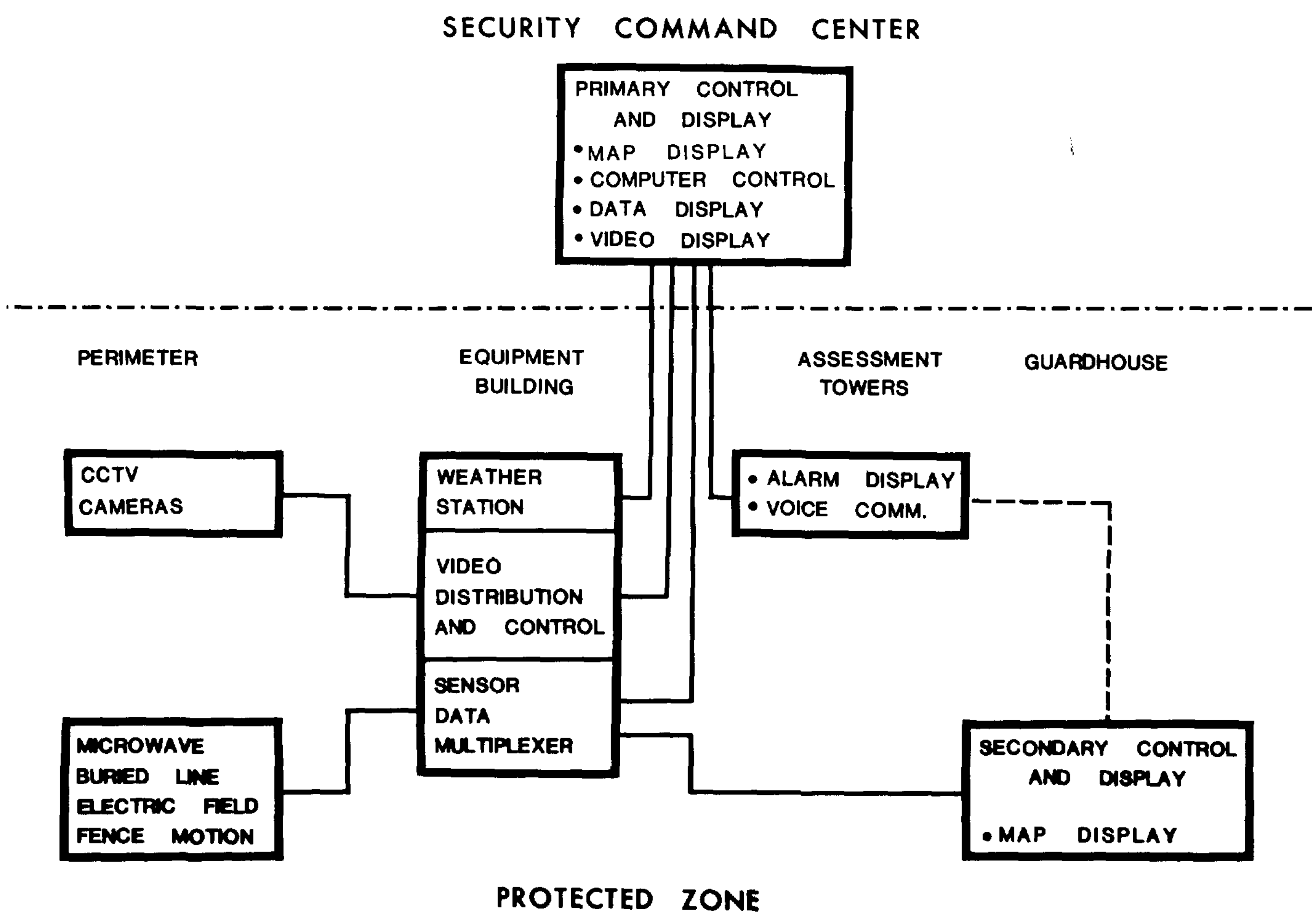



Figure 1. Simplified Security System Block Diagram

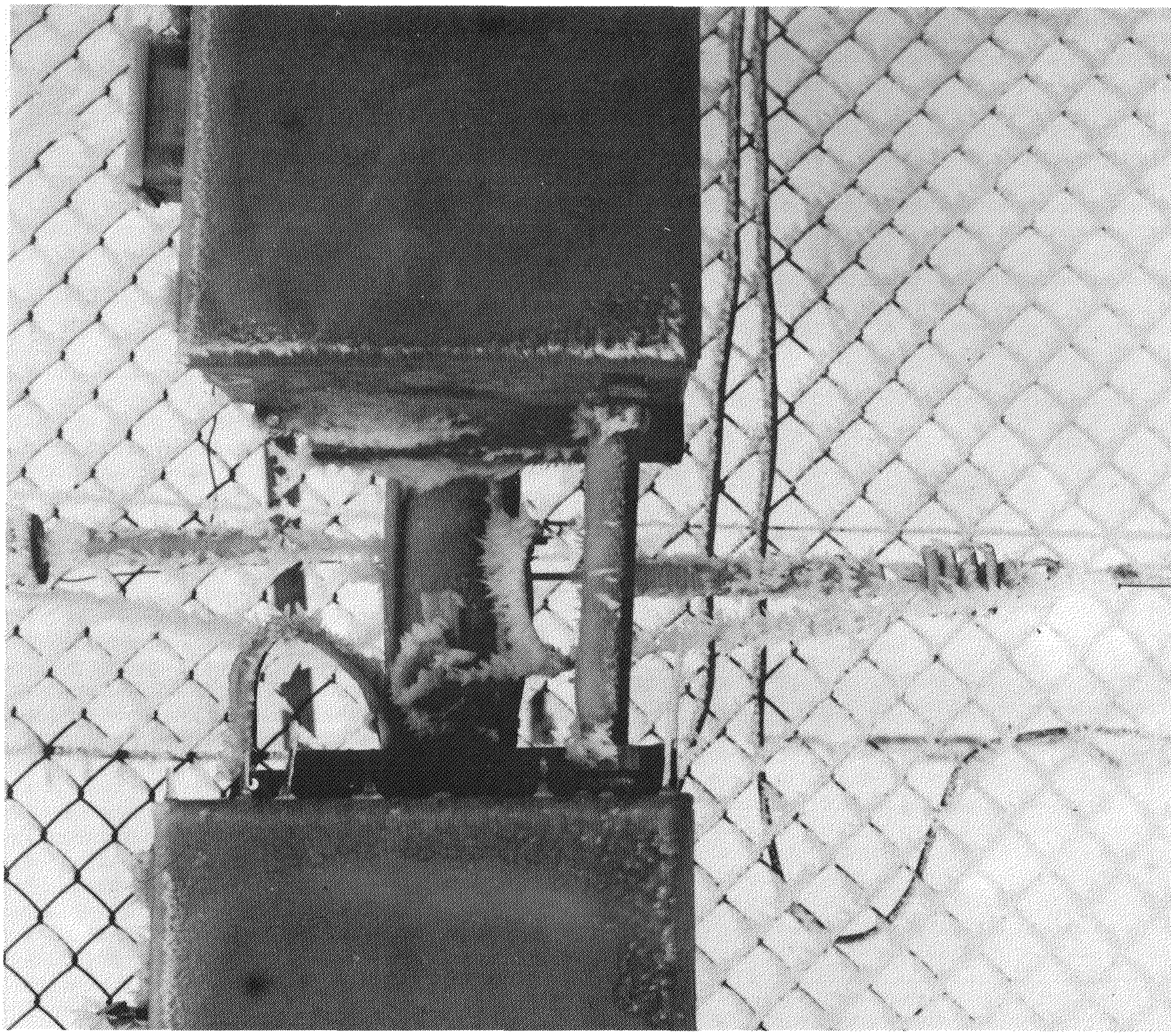


Figure 2. Ice-covered EFF Installation

located within the protected site. Figure 1 shows a block diagram of PIDAS.

## EVALUATION OF SYSTEM PERFORMANCE

### Initial Evaluation

From November 1977 through February 1978, PIDAS underwent a shakedown and familiarization period to acquaint operational personnel with the characteristics of the system. Some known installation deficiencies existed at this time such as holes in the rabbit barriers at two gates and incomplete construction of the new guardhouse at the main entrance. As expected during this period, other deficiencies were identified which required subsequent adjustment or redesign to achieve desired performance.

In November a series of tests were conducted to verify that basic functional requirements had been satisfied. One objective was to determine the probability of detection for the sensor array. For this functional test the intruder performed a normal, upright walk at about 1 m/sec. (The influence of other intrusion modes and speeds had been evaluated earlier during sensor selection tests.) Walk tests across the sensor bed were conducted at 3 metre intervals around the entire perimeter. The results are listed in Table 3.

**Table 3**
**Average Probability of Detection**
**(Walk Test — 3 Metre Intervals)**

| Sensor | $P_D$ |
|---|---|
| MAID/MILES | .99 |
| Microwave | 1.00 |
| EFF | 0.99 |
| FDS | 0.96 |

In another study, all alarms occurring during a twenty-five day period beginning in early January were carefully assessed to identify their cause. In an operational situation the purpose of assessment is primarily to distinguish intruder generated alarms from those due to spurious sources and only secondarily to identify the spurious source. Accordingly, under normal operations there are only three assessment categories available for operator response; Intruder, Nuisance, and Unknown. An alarm is categorized as Nuisance when a cause can be readily observed, such as rabbit, tumbleweed, or train. When no cause is apparent, for example electrical interference, the operator designates the alarm as Unknown.

Such simple classification, while adequate for operational purposes, is of limited use to system designers in analyzing performance characteristics. Therefore, in a 25-day period in early January the operators were asked to assess and annotate alarms in as much detail as possible, an effort that requires considerable care and patience in correctly identifying the source of a nuisance alarm. The result of this alarm evaluation is shown in Table 4.

**Table 4**
**Alarm Evaluation, Jan. 9 Through Feb 2, 1978**
**(25 days—75 shifts)**

**Assessment**

161—Rabbit
102—Ice/wind
53—Switching transients, perimeter lights
20—Windblown weeds
7—Hawk
5—Raccoon
2—Trains
22—Unknown (5.9% of total)

**Totals**

Priority 1—0
Priority 2—1 (caused by raccoons)
Priority 3—372
Average alarms/shift—5

The ice accumulation on the fence (see Figure 2) persisted for nearly a week and significantly reduced the effectiveness of the EFF. For much of this week the EFF's were placed in the access mode to delete distracting nuisance alarms. However, the FDS was not as seriously degraded, and adequate fence climbing detection was maintained throughout that period. The rabbit barrier is now complete at the gates and the number of nuisance alarms attributed to rabbits is near zero.

## Data Base Evaluation

A long-term data base is being generated to study the performance of the intrusion detection sensors. Incoming alarms are collected by the system minicomputer, time tagged, and then recorded for subsequent analysis. The data base also includes assessment and current meteorological data.

The data base was used to summarize system activity during April and May 1978. Because recordings for the data base were not made continuously due to power failures, tape drive failures and operator inexperience with mounting the tapes, only 369 hours of data are available for April and 333 hours for May. However, these hours are believed to be typical of the entire period.

As shown in Table 5, application of the priority concept, based on combinations of alarms from the four sensor types, resulted in relatively few priority 1 and 2 events.

**Table 5**
**Events by Priority, April and May**

| | Priority 1 | Priority 2 | Priority 3 |
|---|---|---|---|
| April (369 hrs.) | 0 | 43 | 1075 |
| May (333 hrs.) | 1 | 15 | 770 |

It should be noted that Table 5 does not include events in the three sectors which contain gates. These sectors contribute a large number of events caused by authorized traffic. The table also does not include alarms from tamper switches, which are defined as Priority 1 events, because several tamper switches were known to be malfunctioning during April and May.

As shown in Table 5 only one priority 1 event occurred. This event was assessed by the security guards as a nuisance event. Of the priority 2 events shown in Table 5, almost half of the events each month were assessed as nuisance events. Approximately 15 of the priority 2 events in April occurred on days when the wind was over 25 knots. Over 90% of the events in Table 5 are priority 3 events. This data indicates that the priority algorithm is significantly reducing the number of events requiring physical response by the guard force.

In reviewing the performance of the system in April and May, it is of significance to consider the distribution of events with respect to time. During the majority of the time less than 30 events per day occur. For example, for the shift from midnight to 8 a.m. on April 25, no alarms occurred on any of the 130 sensors. By contrast, when the weather is unfavorable (due to high winds, lightning storms, etc.), many events can occur in a very short period of time. Table 6 shows alarm activity for approximately 4 hours on April 5 from 1000 hours to 1400 hours.

**Table 6**
**Number of Events in a Selected Four Hour Period**
**(Gate Sectors Deleted)**

| Priority 1 | Priority 2 | Priority 3 |
|---|---|---|
| 0 | 15 | 354 |

This data includes events in all non-gate sectors for the 4 hour period and illustrates the high rate at which events may occur during bad weather. Thirteen of the priority 2 events in Table 6 resulted from simultaneous EFF and FDS alarms. This is not unexpected since the EFF and FDS are both susceptible to wind induced fence motion.

To reduce the operator workload resulting from weather induced nuisance alarms, PIDAS was designed to progressively screen these alarms in accordance with prevailing meteorological conditions. Wind speed, direction, and gustiness, rate of rainfall, and atmospheric potential gradient were identified as the parameters most likely related to nuisance alarms. Whenever an alarm occurs, weather data is sampled and compared to pre-set limits which differ for each parameter and type of sensor. If a limit is exceeded, the alarm may be assigned a reduced priority or even suppressed under programming control of the display processor.

Analysis of the data base clearly demonstrates the potential of the screening concept; however, its implementation proved to be more complex than anticipated. The most effective performance has been achieved in applying wind limits to the EFF and FDS alarms. In April, which was a windy month, about 16% of the events involving these two sensors were suppressed and not displayed. The screening levels currently used are based on original engineering estimates and will be modified as long term analysis of alarm patterns becomes available. In contrast, all efforts to correlate potential gradient data with lightning induced alarms, a susceptibility of the M/M and EFF, have been unsuccessful. A more effective lightning detector is needed, or possibly the affected sensors can provide a self-diagnosis, i.e., if a significant fraction of the sensors alarm nearly simultaneously, lightning is the probable cause. This latter alternative has been incorporated into the software and is being investigated, but insufficient data is yet available to judge the effectiveness. Modification of the priority algorithm and screening levels is easily accomplished in PIDAS because they are programmed in the form of look-up tables. This feature is clearly beneficial in a system undergoing continued refinement.

Another factor responsible for spurious alarms is malfunction within the sensor or communications and display equipment. (Such alarms are often labeled "False Alarms".) Preventive maintenance and periodic testing is required to minimize these alarms. For example, the M/M is battery powered, and as the voltage decreases, the sensor becomes more sensitive and eventually goes into constant alarm. One way to eliminate this type of malfunction would be to replace the batteries on the M/M sensors more frequently. Alternatively, another solution would be to operate the sensors on line power and use batteries only as a backup power supply which would increase operational reliability and decrease maintenance.

The closed-circuit television equipment installed to enable remote assessment has functioned well in reducing the amount of physical inspection required at the perimeter; however, the video subsystem has required more maintenance and repair than any of the other subsystems. The silicon diode vidicons (image sensing devices in the video camera) had to be replaced after 10 months of service because of degraded quality of the picture under low light-level conditions even though picture quality was still adequate in daylight. The artificial illumination for nighttime surveillance is marginal due to the fact that existing poles of non-optimum spacing were used to support the lamps. As a result, the light fixtures require critical adjustment to obtain uniform ground illumination.

The lighting/vidicon life problem is being addressed through an on-site evaluation of a new vidicon tube that has a zinc-selenium target. This new vidicon operates at lower light levels than the silicon diode type and still provides a good image in bright daytime illumination. The vidicons are presently being operationally evaluated to determine performance and operational life characteristics.

The major problems in the video system have occurred in the environmental camera housing and the 135-mm lenses used in the cameras. Extensive redesign was required to eliminate performance deficiencies in the lenses which caused the irises on the cameras to stick. Operational problems and constraints associated with the environmental camera housings required redesign of the defroster, wiper and control functions.

## GENERAL EXPERIENCE AND CONCLUSIONS

A great deal of experience was gained during the design, installation, and testing of PIDAS. Some of the more important conclusions gained from that experience are briefly summarized in the following paragraphs.

Even though PIDAS was developed almost entirely with off-the-shelf components, considerable effort was expended in the design and development of specialized hardware and software interfaces required to integrate these components into a system. As a result, more effort was expended in this area than had been anticipated.

Approximately half of the total system cost was for equipment and construction; the remainder was for manpower. Approximately one-fourth of the overall budget was apportioned to each of the following areas: (1) site construction, (2) the sensor subsystem, (3) the assessment subsystem, and (4) the control and display subsystem. The first item, site construction, comprises a substantial part of the overall implementation effort, and should not be underestimated. In many locales, the cost of site construction may substantially exceed the costs expended at this site. Site features such as rock outcroppings, location of utility lines, proximity of sidewalks and parking lots, soil composition, terrain profiles, etc., determine the amount of effort required to provide trenching for cables and a uniform surface in the isolation zone.

Trenching costs alone may become significant for a perimeter detection system. At the PIDAS site, nearly 20-km of trenches containing 100 km of cable were required to support a 3.3-km detection and assessment system. Since installation techniques and tolerances for perimeter systems are not traditional or well-established, site construction costs are further increased because significant design team interaction with the general contractor is required during this phase.

The four different perimeter sensor types used in each sector of the PIDAS are divided into a primary and secondary line. The use of multiple sensors in this configuration allows the logical combination of alarm data, using hardware or software, to attempt to increase system effectiveness and minimize the operational impact of nuisance alarms. The number of sensors required to implement this type of system is debatable. However, because all presently available sensors are susceptible to nuisance alarms, more than one sensor is required. The cost of adding additional sensors, when compared to total system cost, is not a pivotal factor in considering the number of sensors that should be used. As part of the selection criteria for sensors, sensors should be chosen, where possible, such that environments which cause nuisance alarms on one sensor will not affect the other chosen sensors. With presently available sensors, this desire for independence will only be partially successful. For example, the MM, EFF, and FDS used in this system are all susceptible to some degree to wind-caused nuisance alarms. However, the selection of sensors that are the most compatible with the site, environmental conditions, and operational constraints is critical to the ultimate performance of the system and should be the first consideration in generating a systems concept.

The adjustment of sensor sensitivities for PIDAS was more time consuming than was anticipated. Each sensor must be activated according to some standard procedure. To complete these adjustments, the range of the different environmental conditions which prevail at the site must be experienced and large amounts of data must be logged and analyzed. This latter activity could be simplified by the development of a stand-alone software module designed solely to support sensor testing.

The development of an automated control and display system is another task that is easily underestimated. The system used in PIDAS required a dual minicomputer with 128,000 16-bit words of memory to handle the throughput requirements in near real time. The larger user software package consists of approximately 15,000 lines of FORTRAN 5 code and required 3.5 manyears of development effort. The use of a computer system with the ability to directly address more than 32,000 words of memory would have significantly reduced this development time. Initial installation and maintenance presented some problems, but once they were resolved, the dual computer system worked both reliably and well. Timely maintenance provided by the computer manufacturer is difficult to obtain if the user is at a site remotely located from the manufacturer's maintenance personnel. However, manufacturer supported maintenance is desirable, at least initially, for any of the larger computer systems.

Maintenance of the overall system in general is more demanding and is somewhat different than that required by presently available security systems at most facilities. Preventative maintenance, continued operational testing, and effective system operation are the keys to maintaining system reliability. The system designer must be prepared to conduct, for some period, extensive and continuing classes in these three areas in order to enable achievement of optimum system performance. In practice, a large portion of the designer's total effort from the start to the finish of the project will be spent in interfacing with the personnel who will ultimately utilize and maintain the system. The success of the project depends equally on project management and technical expertise. The manner in which the organizational interfaces, systems integration, transfer of responsibility, etc., are handled is equally as important as whether or not the system is technically adequate and reliable. To ensure a smooth transfer of responsibility from designer to user, system operation and testing should be continued by the design team until all major problem areas have been resolved so that a near "turn-key" system is delivered to the user for operation.

## SUMMARY

PIDAS has been operational since November when system checkout and initial training was completed. In this time, the feasibility of such a system has been well established. Further analysis of this system may suggest methods for simplifying future systems. The experience gained from the installation of PIDAS and observation of its operation has provided insight into a number of areas of concern in the implementation of a perimeter intrusion detection system. This knowledge should prove helpful in the installation and operation of other perimeter systems.

# Steve Barrett Joins NUSAC

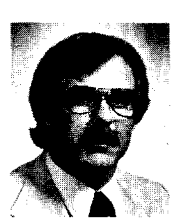
McLean, Virginia—Dr. **Ralph F. Lumb,** President of NUSAC, has announced the appointment of **Steve R. Barrett** as Senior Technical Associate in the Quality Programs Division of the firm. NUSAC provides consulting services to the nuclear industry.

Mr. Barrett's responsibilities will include quality assurance audit and surveillance services during fabrication of fuel assemblies at nuclear facilities as well as auditing to confirm proper quantities of basic elements of fuel assemblies.

Mr. Barrett will work under Quality Programs Division Manager **Wilkins R. Smith** and will also manage programs for training of quality assurance experts for clients and for development of quality assurance procedures and program manuals.

Mr. Barrett worked previously for Carolina Power & Light Company. He holds degrees in mechanical engineering technology from Gaston College and the University of North Carolina at Charlotte.

NUSAC was acquired in December as a wholly-owned subsidiary of The Wackenhut Corporation, the Coral Gables, Florida, security firm. NUSAC headquarters, however, remain at McLean, Virginia, and the company maintains an independent autonomous operation.



**Steve Barrett**

# Experience with IAEA Safeguards at a Japanese LEU Fuel Fabrication Facility

**By Takeshi Osabe**
Japan Nuclear Fuel Company, Ltd.

Presented at the INMM Workshop on the
Impact of IAEA Safeguards
Washington Hilton Hotel
Washington, D.C.
December 7, 1978

## INTRODUCTION

Japan ratified the NPT and concluded a Safeguards Agreement under the NPT between Japan and IAEA in March 1977. In consequence of this, Japanese government safeguards-related regulations were revised to meet all NPT safeguards requirements, and the new regulations were put into force in December 1977; this was immediately followed by the action of all the facilities to adapt themselves to the NPT requirements. Figure 1 shows the relationship between the various elements of safeguards under the NPT.

The basic concept for implementation of NPT safeguards in a facility is that the IAEA shall utilize national safeguards as much as possible to verify that there has been no diversion of nuclear material from peaceful use. The Agency, however, has the right to perform independent measurements and observations of nuclear materials in the facility.

Certain administrative arrangements are completed prior to the application of safeguards to the facility in accordance with the agreements. Figure 2 shows the sequence of these administrative arrangements.

First, the submission of the Design Information to the IAEA is requested. The design information includes data on the facility such as annual throughput, process description, storage inventory, accounting system, measurement system and accuracy, statistical procedure for evaluation of MUF, etc.

The design information is studied by the Agency to establish the inspection strategy for detection of diversion, including allowable limits of error of MUF and required frequency of physical inventory for the facility.

Next, the Facility Attachment has to be submitted to the Agency. This document contains explanations of the facility's MBA and KMP structure, records and reports, inspection frequency, inventory procedure, etc. This document is negotiated by the government and the IAEA to ensure adequacy; NPT safeguards for the facility are officially put in force when the Facility Attachment is agreed upon by the Agency. Upon completion of the Facility Attachment, the facility then submits the initial inventory report to the Agency. The Agency then performs an inspection to confirm that the facility's safeguards program is as stated in the design information.

## OUTLINE OF THE FACILITY

The JNF facility produces BWR type nuclear fuel for commercial nuclear power plants under license from the General Electric Company of the United States. There is no conversion facility; the feed material is delivered to the facility as a $UO_2$ powder with a maximum licensed enrichment of 4% U-235.

The plant consists of five major areas as shown in Figure 3: Warehouse; Pellet Process; Assembly Area; Tube Area; and Office Area. The material flow of this plant shown in Figure 4 is very typical of a fuel fabrication plant.

## MATERIAL BALANCE AREA(S)

In the negotiation of the Facility Attachment, the IAEA requested that at least three MBAs be defined for the facility. Normally, for a fabrication plant of this type, the three MBAs used are a Shipper-Receiver Difference MBA, a Process MBA in which all MUF is isolated, and a product Storage MBA. However, we decided that it would be most suitable to divide our plant into the three MBAs shown in Figure 4 (an S/R Difference MBA, a MUF MBA which contains the process from powder inspection through rod loading, and a Book MBA for rod storage, bundle assembly, and shipping) because once pellets are loaded into fuel rods no MUF can occur and all material can be controlled by item counting.

From the safeguards point of view, we understand that the MBA is a functional area and not a specific area divided by any physical barrier or building. In other words, if two containers of feed material are located side by side, and one container was measured by the facility

Application of NPT Safeguards

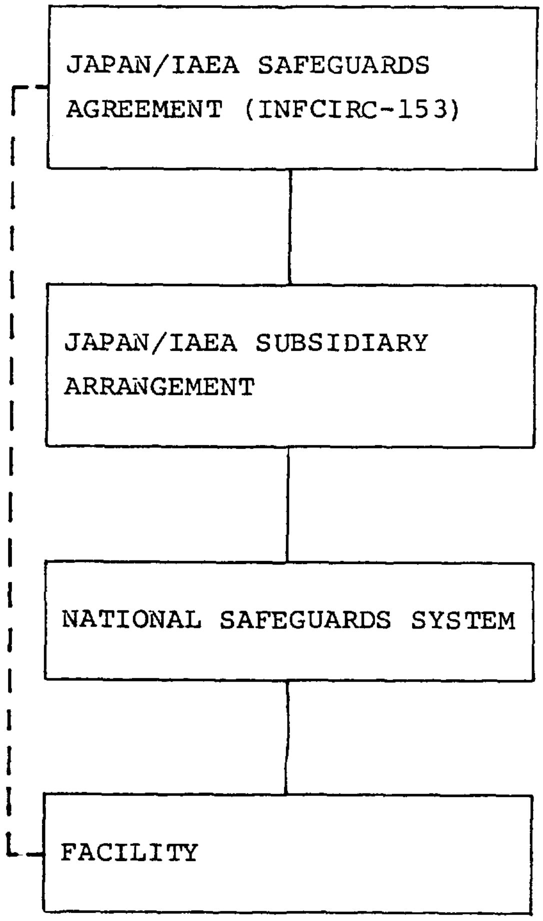



**Figure 1**

SEQUENCE OF SAFEGUARDS APPLICATION

**SUBMIT FACILITY DESIGN INFORMATION TO IAEA**
—ACCOUNTING SYSTEM
—MEASUREMENT SYSTEM
—CONTAINMENT SURVEILLANCE
—PHYSICAL PROTECTION
—STATISTICAL EVALUATION OF MUF

**EVALUATION OF DESIGN INFORMATION BY IAEA**
—DETERMINE ALLOWABLE LIMITS OF ERROR OF MUF FOR THE FACILITY

**SUBMIT FACILITY ATTACHMENT TO IAEA**
—DETERMINE DETAILS OF INSPECTION METHOD AND FREQUENCY OF INSPECTION

**SUBMIT INITIAL INVENTORY (PHYSICAL) REPORT**

**ADHOC INSPECTION TO CONFORM FACILITY DESIGN INFORMATION**

**Figure 2**

and the other was not, then the former container is in MBA-2 and the latter in MBA-1. This concept must be clearly understood so as to avoid trouble at the time of inspection.

**KEY MEASUREMENT POINT(S):**

We have 9 flow KMPs (KMP-1 through KMP-9) and 8 inventory KMPs (KMP-A through KMP-H) as shown in Figure 4. The total number of KMPs is limited by the Agency's safeguards information system that is described in Code 10 of the Subsidiary Arrangements.

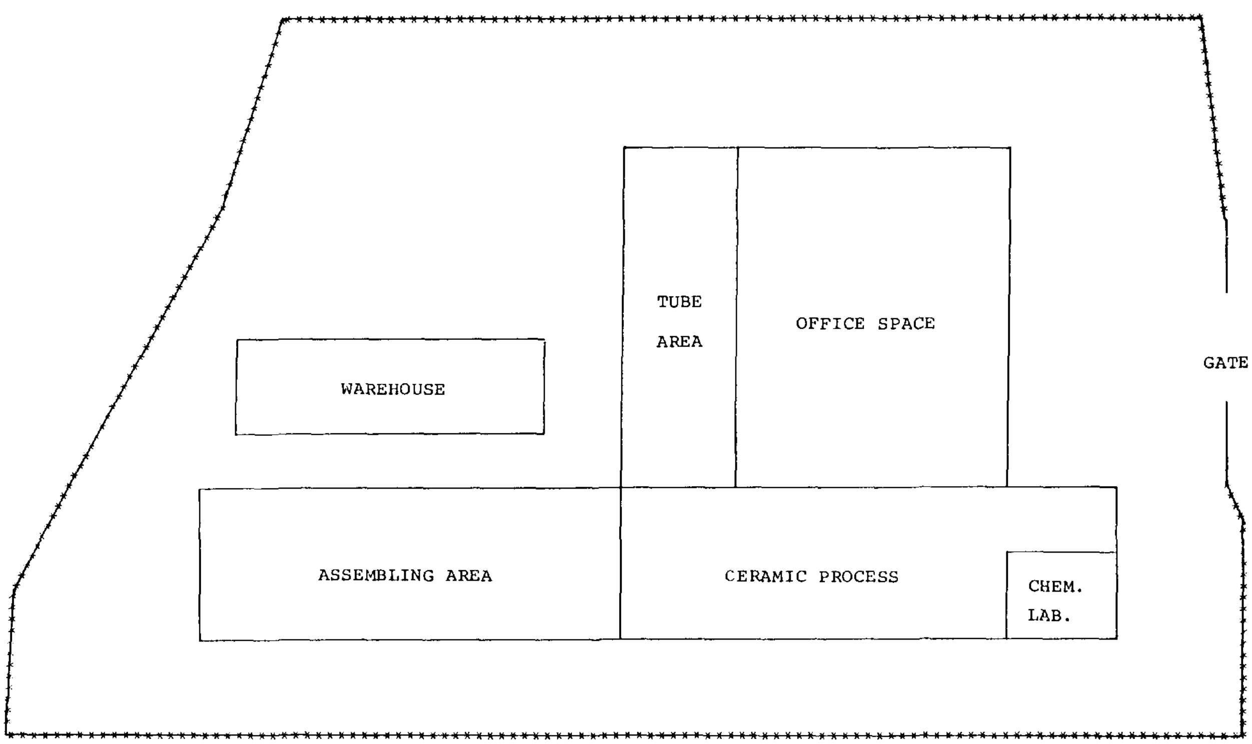



**Figure 3**

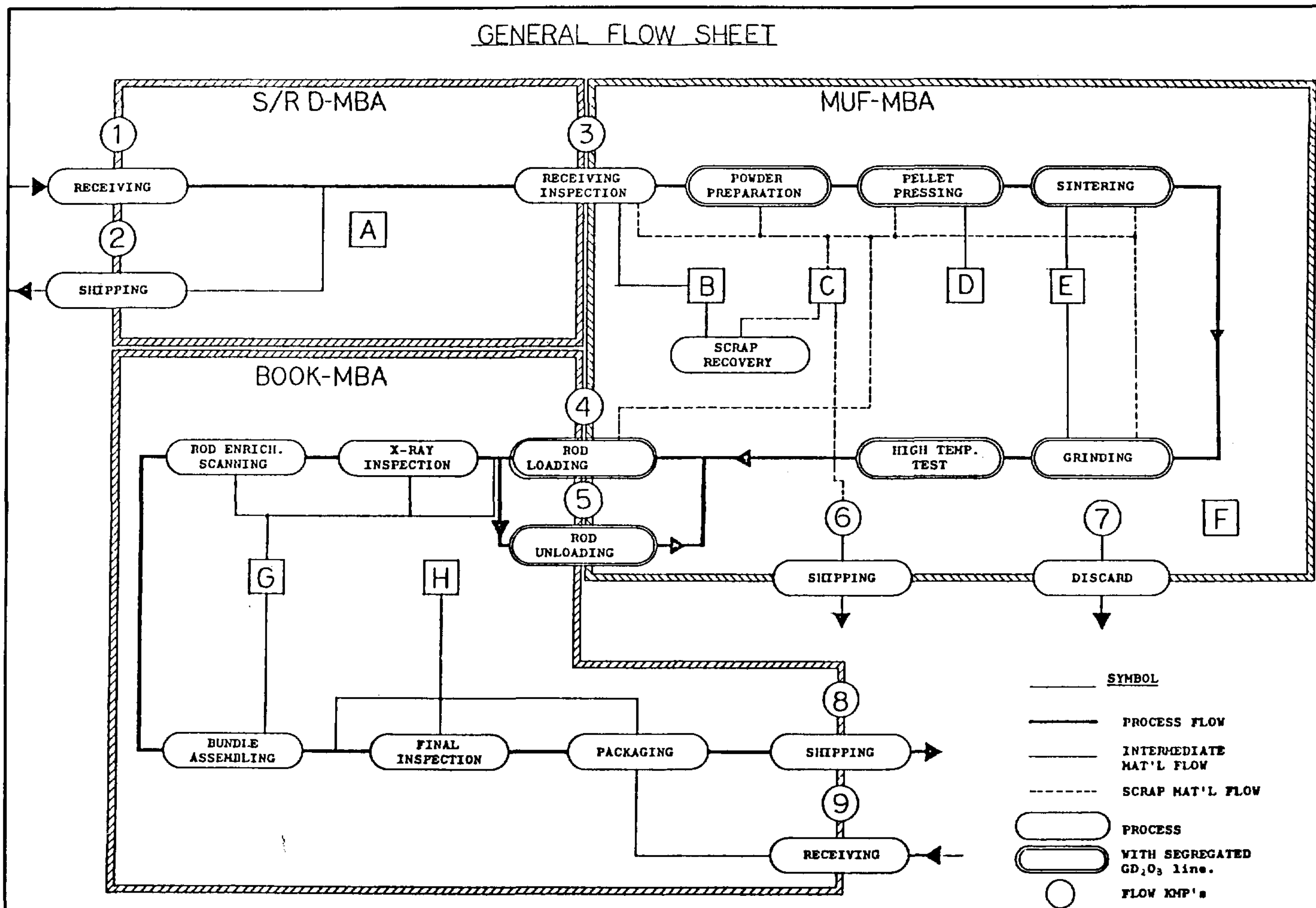



Figure 4

Under Code 10, a total of 9 flow KMPs and 26 inventory KMPs can be established. As shown in the figure, KMP-1 is for all SNM received at the facility, and all receipts are recorded in MBA-1 on the basis of shippers' accountancy data. KMP-2 is for shipments of SNM back to the previous shipper due to rejection, etc. The shipment value to be used for this KMP is the shipper's data which were previously received. KMP-3 is the first measurement point at the facility; all receipts of SNM must be measured at this point except small quantities (less than 10 gms. of U-235).

The results of facility measurements are reported to the IAEA by means of Inventory Change Reports (discussed further below). One report is filed for shipment from MBA-1 to MBA-2 and another is filed for receipt in MBA-2 from MBA-1. The Agency's computerized safeguards information system can then automatically calculate the shipper-receiver differences based on ICRs. KMP-4 is a rod loading station. Rod loading data are collected and the total amount of uranium loaded is reported for each batch. The definition of batch for this KMP is one consignment of fuel rods with the same specifications. KMP-5 is for returning fuel rods from MBA-3. KMP-6 is for shipment of SNM other than fuel bundles to outside the facility. This KMP is mainly used for scrap shipments to the outside recovery facility. KMP-7 is for accounting for normal operational losses categorized as measured discards or retained waste. KMP-8 is used for product shipment. The batch definition for this KMP is that each fuel bundle is to be accounted for as one batch. Therefore, if for example we ship 300 fuel bundles, then 300 entries are required on the Inventory Change Report. KMP-9 is for returns of fuel rods or bundles from power plants.

All KMPs are established as one way flow points. This is not, however, a regulatory requirement.

For inventory, we have 8 KMPs, which are basically statistical strata. KMP-A is for feed material stored at shipper's values. Thus, this material is still in MBA-1. KMP-B is also for feed material storage, but the material at this KMP has been measured by the operator, and therefore the material is in MBA-2. KMP-C is recoverable scrap storage. KMP-D is green pellet storage. KMP-E is sintered pellet storage. KMP-F is assigned for various materials in the chemical lab. KMP-G is for rod storage, and KMP-H is fuel bundle storage. Note that this KMP structure does not include any KMP for holdup on inventory. A KMP for holdup is necessary so that holdup does not contribute to MUF.

**ACCOUNTING RECORDS**

* INVENTORY CHANGES
* MEASUREMENT RESULTS USED FOR DETERMINATION OF PHYSICAL INVENTORY
* ADJUSTMENTS AND CORRECTIONS
* CHANGES IN BATCH IDENTITIES

**Figure 5**

## RECORDS AND REPORTS

I. Accounting Records

Four major types of accounting records (shown in Figure 5) are maintained by the facility. For inventory changes, all external shipments and receipts, materials transferred between MBAs within the facility, measured discards, retained waste, accidental loss or gain, and all information concerning changes in the MBA inventory must be recorded.

For physical inventory, all information which is used for determination of ending physical inventory, such as sampling and analytical results, weight verification data, etc., must be recorded. The Shipper/Receiver differences and material unaccounted for are to be recorded as adjustments. Changes due to detection of errors in previous records, results of more precise measurements, or corrections for measurement bias are to be recorded as corrections. In cases where batch identifications are changed, it is necessary to record the previous batch identification, and the new batch identification must have traceability.

**OPERATING RECORDS**

* ROD LOADING DATA
* BUNDLE ASSEMBLING DATA
* LIST OF SEALS REMOVED
* ENRICHMENT BLENDING
* ACCIDENT THAT RESULTS IN LOSS OR GAIN
* CALIBRATION OF TANKS & INSTRUMENTS, SAMPLING & ANALYSIS PROCEDURES TO CONTOL THE QUALITY OF MEASUREMENTS, DERIVED ESTIMATORS OF RANDOM & SYSTEMATIC ERRORS.

**Figure 6**

II. Operating Records

At least 6 types of operating records (shown in Figure 6) are maintained. For the rod loading operation, all accountancy data relevant to determination of the uranium and isotopic weight for each fuel rod (e.g., rod loading records and pellet analysis results) are recorded. For the bundle assembly operation, all the relevant data for the rods which are assembled into each fuel bundle are recorded, and uranium and fissile weight for each fuel bundle are calculated.

Whenever the facility operator removes a seal which has been installed by an IAEA inspector for any safeguards purpose, the date and seal identification number and the reason for removal are recorded. Whenever enrichment blending is performed, accountancy data on the original materials used for blending and material created by the blending is recorded. If a new batch identification is assigned, the information regarding batch identification is recorded. For accidental losses or gains of nuclear material, information relevant to the accident such as date, cause and features of the accident, and estimated or known amount of nuclear material which has been lost or gained is recorded. For measurement equipment or instruments, all relevant data for the facility measurement control program that is used for the determination of random and systematic error for each inventory change is recorded.

**SAFEGUARDS REPORTS**

INVENTORY CHANGE REPORT—ICR
MATERIAL BALANCE REPORT—MBR
PHYSICAL INVENTORY LISTING—PIL
CONCISE NOTE
SPECIAL REPORT

**Figure 7**

III. Safeguards Reports

Regulatory reports are required in connection with paragraphs 59 to 69 of NPT safeguards agreements. Specific requirements on reports are stipulated in Code 10 of the Subsidiary Arrangements and Facility Attachment. These reports (listed in Figure 7) are: Inventory Change Reports; Material Balance Reports; Physical Inventory Listing; Concise Notes; and Special Reports.

**ICR:** This report is used to report all inventory changes including changing of batch identification, blending, and corrections, etc. The report must be dispatched to the IAEA within 30 days after the end of the month in which the inventory change has occurred.

**MBR:** This report is used to report the material balance for each MBA for the period between two physical inventories. The report must be submitted for each type of nuclear material for which the facility keeps a separate account.

**PIL:** This report shall be attached to each MBR. All accountancy data for items on inventory must be entered by batch.

**Concise Note:** In case unusual inventory changes or corrections to previous reports need to be reported, Concise Notes must be attached to the report. Concise Notes may also be used to explain any other information included in the report.

**Special Report:** The requirements and timing for issuance of this report are stipulated in the Facility Attachment. (In our case, Special Reports are required when operational losses exceed allowable limits specified in the Facility Attachment or when the facility operator removes IAEA seals or surveillance equipment without advance notification.)

These reports are submitted to the Japanese government office. The reports are then processed and compiled by the computerized information system which was developed by the government. This system is a computer based system for handling and processing of all information provided for national safeguards activities. The reports are checked for misuse of material code, inconsistency of batch identification between the shipper and receiver, etc., by the computer and the data in the reports are sent to the IAEA by means of magnetic tape.

Figure 8 shows the number of reports submitted to the IAEA in 1978. For inventory changes, 3,164 line items were reported within the last 6 months, an average of approximately 600 line items per month. For physical inventory, 1725 line items were reported. The number of entries in a report will vary depending upon the number of MBAs and the criteria for construction of batches. Plant throughput also affects number of entries; the

NUMBER OF SAFEGUARDS REPORTS

SUBMITTED TO IAEA

APRIL '78 - SEPTEMBER '78

I. INVENTORY CHANGE REPORT

| MBA \ MONTH | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|
| JM1A | 188 | 86 | 89 | 113 | 111 | 80 |
| JM2A | 122 | 126 | 128 | 262 | 291 | 188 |
| JM3A | 163 | 85 | 61 | 167 | 608 | 746 |

II. PHYSICAL INVENTORY LISTING

JM1A . . . . . . . . . . 50

JM2A . . . . . . . . . . 383

JM3A . . . . . . . . . 1,292

**Figure 8**

numbers given above are based on 210 tons of plant throughput. Figures 9, 10, and 11 are examples of our ICR, MBR, and PIL forms.

## INSPECTION

Agency inspection activities can be categorized as routine inspection and inspection for inventory verification. Inspections are usually performed together with Japanese government inspectors. Figure 12 summarizes IAEA inspection activities at our plant during 1977 and 1978. Nine routine inspections were performed during the year 1977, and nine routine inspections have been performed through November 1978, for a total routine inspection effort of 15 man-days for 1977 and 17 man-days for 1978.

For inventory verification, 25 man-days were spent in 1977, and 18 in 1978. This means that about 6 inspectors participated each day, because it took 3 days for inventory verification.

## SAM-II

This equipment is used as a two channel gamma spectrometer to assay uranium 235 content. Feed $UO_2$

在庫変動報告(ICR)
INVENTORY CHANGE REPORT

様式 R. 01. 1/J

事業者又は使用者
名称 日本ニユクリア・フユエル株式会社
所在地 神奈川県横須賀市内川2丁目3番1号
施設名 日本ニユクリア・フユエル株式会社
物質収支区域名名 MBA-1

報告期間 53年 9月 1日から 53年 9月 30日まで
報告番号 25
扱者名 長部猛

| 事業者又は使用者コード ORGANIZATION | 施設コード FACILITY | 物質収支区域コード MBA | 報告期間 年月日から 年月日まで PERIOD COVERED BY REPORT FROM | TO | 報告番号 REPORT No. | エントリー行数 No. OF LINE ENTRIES 計量データ ACCOUNTANCY DATA | 同位体データ ISOTOPE DATA | 注釈データ CONCISE NOTE DATA | 扱者氏名 SIGNATURE |
|---|---|---|---|---|---|---|---|---|---|
| JNF- | JMA- | JM1A | 780901 | 780930 | 0025 | 70 | 00 | | OSABE TAKESHI |

| 物質収支区域コード MBA | 報告番号 REPORT No. | エントリー番号 ENTRY No. | データ継続コード CONTINUATION | 在庫変動年月日 DATE OF INVENTORY CHANGE | 相手側核物質収支区域又は国別コード MBA/COUNTRY FROM | TO | 在庫変動種別コード TYPE OF INVENTORY CHANGE | 主要測定点コード KMP | バッチ名又は番号 NAME OR NUMBER OF BATCH | バッチ単位件数 NUMBER OF ITEMS IN BATCH | 物質記述コード MATERIAL DESCRIPTION | 供給国コード ORIGIN OF MATERIAL | 元素コード ELEMENT | 元素重量 WEIGHT OF ELEMENT | 単位 UNIT | 核分裂性物質重量 WEIGHT OF FISSILE ISOTOPES | 同位体コード ISOTOPE CODE | 測定ベースコード MEASURE BASIS | 注釈コード CONCISE NOTE | データ修正 CORRECTION TO 報告番号 REPORT No. | エントリー番号 ENTRY No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JM1A | 0025 | 01 | | 780901 | JM1A | JM2A | SD | B | JHJ80601 | 1 | V008 | U | E | 26 | G | 0 | G | M | | | |
| JM1A | 0025 | 02 | | 780901 | JM1A | JM2A | SD | B | JHJ80602 | 2 | V008 | U | E | 52 | G | 1 | G | M | | | |
| JM1A | 0025 | 03 | | 780901 | JM1A | JM2A | SD | B | JHJ80603 | 3 | V00B | U | E | 78 | G | 2 | G | M | | | |
| JM1A | 0025 | 04 | | 780901 | JM1A | JM2A | SD | B | JHJ80604 | 5 | V00B | U | E | 130 | G | 4 | G | M | | | |
| JM1A | 0025 | 05 | | 780908 | JM1A | JM2A | SD | B | R1780805 | 1 | RUKD | U | E | 14913 | G | 444 | G | M | | | |
| JM1A | 0025 | 06 | | 780908 | JM1A | JM2A | SD | B | R1780806 | 1 | RQKD | U | E | 22481 | G | 666 | G | M | | | |
| JM1A | 0025 | 07 | | 780908 | JM1A | JM2A | SD | B | R1780807 | 2 | RUKD | U | E | 22109 | G | 659 | G | M | | | |
| JM1A | 0025 | 08 | | 780909 | U | JM1A | RF | 1 | YLJ33701 | 16 | GQKB | U | E | 439465 | G | 9864 | G | N | | | |
| JM1A | 0025 | 09 | | 780909 | U | JM1A | RF | 1 | YLJ33702 | 16 | GQKB | U | E | 433405 | G | 9706 | G | N | | | |
| JM1A | 0025 | 10 | | 780909 | U | JM1A | RF | 1 | YLJ33703 | 16 | GQKB | U | E | 426484 | G | 9493 | G | N | | | |
| JM1A | 0025 | 11 | | 780909 | U | JM1A | RF | 1 | YLJ33704 | 16 | GQKB | U | E | 438710 | G | 9766 | G | N | | | |
| JM1A | 0025 | 12 | | 780909 | U | JM1A | RF | 1 | YLJ33705 | 16 | GQKB | U | E | 419871 | G | 9360 | G | N | | | |
| JM1A | 0025 | 13 | | 780909 | U | JM1A | RF | 1 | YLJ33706 | 16 | GQKB | U | E | 433301 | G | 9694 | G | N | | | |
| JM1A | 0025 | 14 | | 780909 | U | JM1A | RF | 1 | YLJ33707 | 16 | GQKB | U | E | 417744 | G | 9324 | G | N | | | |

**Figure 9**

# 物質収支報告 (MBR)

MATERIAL BALANCE REPORT

様式 R : 03/J

| | |
|---|---|
| 事業者又は使用者 名称 日本ニユクリア・フユニル株式会社 | 報告期間 53年 2月 1日から |
| 所在地 神奈川県横須賀市内川2丁目3番1号 | 53年 8月 2日まで |
| 施設名 日本ニユクリア・フユニル株式会社 | 報告番号 27 |
| 物質収支区域名 MBA-2 | 扱者名 長部猛 |

| 事業者又は使用者コード ORGANIZATION 1–4 | 施設コード FACILITY 5–8 | 物質収支区域コード MBA 9–12 | 報告期間 年月日から PERIOD COVERED BY REPORT FROM 13–18 | 年月日まで TO 19–24 | 報告番号 REPORT No. 25–28 | エントリー行数 No. OF LINE ENTRIES 計量データ ACCOUNTANCY DATA 29–30 | 注釈データ CONCISE NOTE DATA 33–34 | 扱者氏名 SIGNATURE 63–77 | 80 |
|---|---|---|---|---|---|---|---|---|---|
| JNF- | JMA- | JM2A | 780201 | 780802 | 0027 | 35 | 05 | ØSABE TAKESHI | 6 |

| 物質収支区域コード MBA 1–4 | 報告番号 REPORT No. 5–8 | エントリー番号 ENTRY No. 9–10 | データ継続コード CONTINUATION 11 | 収支項目名(エントリー名) ENTRY NAME 26–29 | 計量データ ACCOUNTANCY DATA 供給国コード ORIGIN OF MATERIAL 47–50 | 元素コード ELEMENT 51 | 元素重量 WEIGHT OF ELEMENT 53–60 | 単位 UNIT 61 | 核分裂性物質重量 WEIGHT OF FISSILE ISOTOPES 63–70 | 同位体コード ISOTOPE CODE 71 | 注釈コード CONCISE NOTE 73 | データ修正 CORRECTION TO 報告番号 REPORT No. 74–77 | エントリー番号 ENTRY No. 78–79 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JM2A | 0027 | 01 | | PB | U | E | 7340914 | G | 1639157 | G | | | | 7 |
| | | 02 | | RD | U | E | 61056306 | G | 1593068 | G | | | | 7 |
| | | 03 | C | | U | E | 61056305 | G | 1593067 | G | | | | 7 |
| | | 04 | | SF | U | E | 1731 | G | * 38 | G | | | | 7 |
| | | 05 | | SD | U | E | 58531314 | G | 1461773 | G | | | | 7 |
| | | 06 | C | | U | E | 58531314 | G | 1461772 | G | | | | 7 |
| | | 07 | | TW | U | E | 135085 | G | 3460 | G | | | | 7 |
| | | 08 | | LD | U | E | 170 | G | 6 | G | | | | 7 |
| | | 09 | | BE | U | E | 78313911 | G | 1898243 | G | | | | 7 |
| | | 10 | | PE | U | E | 78025725 | G | 1891038 | G | | | | 7 |
| | | 11 | | MF | U | E | 288186 | G | 7205 | G | | | | 7 |
| | | 12 | | PB | U | N | 1004.600 | K | | | | | | 7 |
| | | 13 | | PB | Q | N | 0.086 | K | | | | | | 7 |
| | | 14 | | PB | CN | N | 74.453 | K | | | | | | 7 |
| | | 15 | | RD | U | N | 0.078 | K | | | | | | 7 |
| | | 16 | | SD | U | N | 246.892 | K | | | | | | 7 |
| | | 17 | | BE | U | N | 757.786 | K | | | | | | 7 |
| | | 18 | | BE | Q | N | 0.086 | K | | | | | | 7 |
| | | 19 | | BE | CN | N | 74.453 | K | | | | | | 7 |
| | | 20 | | PE | U | N | 757.786 | K | | | | | | 7 |
| | | 21 | | PE | Q | N | 0.086 | K | | | | | | 7 |
| | | 22 | | PE | CN | N | 74.453 | K | | | | | | 7 |
| | | 23 | | MF | U | N | 0 | | | | | | | 7 |

**Figure 10**

# 実在庫明細表 (PIL)
PHYSICAL INVENTORY LISTING

様式 R 02/J

| 事業者又は使用者 名称 | | 棚卸し実施日 | |
|---|---|---|---|
| 所在地 | | 報告番号 | |
| 施設名 | | 扱者名 | |
| 物質収支区域名 | | | |

| 事業者又は使用者コード ORGANIZATION | 施設コード FACILITY | 物質収支区域コード MBA | | 棚卸し実施日 DATE OF PIL | 報告番号 REPORT No. | エントリー行数 No. OF LINE ENTRIES 計量データ ACCOUNTANCY DATA | 注釈データ CONCISE NOTE DATA | 扱者氏名 SIGNATURE |
|---|---|---|---|---|---|---|---|---|
| JHF- | JMA- | JM3A | | 780803 | 0042 | 64 | | OSAUE TAKESHI |

| 物質収支区域コード MBA | 報告番号 REPORT No | エントリー番号 ENTRY No | データ継続コード CONTINUATION | 主要測定点コード KMP | バッチ名称又は番号 NAME OR NUMBER OF BATCH | バッチ単位体数 NUMBER OF ITEMS IN BATCH | 物質記述コード MATERIAL DESCRIPTION | 計量データ ACCOUNTANCY DATA: 供給国コード ORIGIN OF MATERIAL | 元素コード ELEMENT | 元素重量 WEIGHT OF ELEMENT | 単位 UNIT | 核分裂性物質重量 WEIGHT OF FISSILE ISOTOPES | 同位体コード ISOTOPE CODE | 測定ベースコード MEASURE BASIS | 注釈コード CONCISE NOTE | データ修正 CORRECTION TO: 報告番号 REPORT No. | エントリー番号 ENTRY No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JM3A | 0042 | 17 | | H | HAD-839 | 1 | BV2F | U | E | 184360 | G | 5132 | G | M | | | |
| JM3A | 0042 | 18 | | H | HAD-840 | 1 | BV2F | U | E | 184316 | G | 5132 | G | M | | | |
| JM3A | 0042 | 19 | | H | HAD-841 | 1 | BV2F | U | E | 183911 | G | 5132 | G | M | | | |
| JM3A | 0042 | 20 | | H | HAD-842 | 1 | BV2F | U | E | 184488 | G | 5131 | G | M | | | |
| JM3A | 0042 | 21 | | H | HAD-843 | 1 | BV2F | U | E | 184470 | G | 5132 | G | M | | | |
| JM3A | 0042 | 22 | | H | HAD-844 | 1 | BV2F | U | E | 184619 | G | 5132 | G | M | | | |
| JM3A | 0042 | 23 | | H | HAD-845 | 1 | BV2F | U | E | 184509 | G | 5132 | G | M | | | |
| JM3A | 0042 | 24 | | H | HAD-846 | 1 | BV2F | U | E | 183908 | G | 5132 | G | M | | | |
| JM3A | 0042 | 25 | | H | HAD-847 | 1 | BV2F | U | E | 183841 | G | 5132 | G | M | | | |
| JM3A | 0042 | 26 | | H | HAD-848 | 1 | BV2F | U | E | 184148 | G | 5135 | G | M | | | |
| JM3A | 0042 | 27 | | H | HAD-849 | 1 | BV2F | U | E | 184430 | G | 5128 | G | M | | | |
| JM3A | 0042 | 28 | | H | HAD-850 | 1 | BV2F | U | E | 184385 | G | 5128 | G | M | | | |
| JM3A | 0042 | 29 | | H | HAD-851 | 1 | BV2F | U | E | 184438 | G | 5128 | G | M | | | |
| JM3A | 0042 | 30 | | H | HAD-852 | 1 | BV2F | U | E | 184331 | G | 5128 | G | M | | | |
| JM3A | 0042 | 31 | | H | HAD-853 | 1 | BV2F | U | E | 184465 | G | 5128 | G | M | | | |
| JM3A | 0042 | 32 | | H | HAD-854 | 1 | BV2F | U | E | 184581 | G | 5128 | G | M | | | |

**Figure 11**

FREQUENCY OF INSPECTION

BY IAEA ONLY

☆ ROUTINE INSPECTION ☆

| YEAR | NO. OF INSPECTIONS | INSPECTION M. D. |
|---|---|---|
| 1977 | 9 | 15 |
| 1978 (JAN. - NOV.) | 9 | 17 |

☆ INVENTORY VERIFICATION ☆

| YEAR | NO. OF INSPECTIONS | INSPECTION M. D. |
|---|---|---|
| 1977 | 1 | 25 |
| 1978 | 1 | 18 |

**Figure 12**

powder in 5 gallon containers, green pellets, sintered pellets, and fuel rods are measured by this equipment. In order to measure the U-235 contents for feed material, green pellets, and sintered pellets in the process area, a specially designed collimator is used to prevent a high gamma ray background. The actual stack length of each fuel rod is measured by another single channel gamma ray spectrometer (NIS-322) and enrichment of each rod is measured by SAM-II. For rod measurement, the equipment is calibrated by means of IAEA-owned standard rods.

## NIS-322 SINGLE CHANNEL GAMMA SPECTROMETER

This is just a go/no-go check of enrichment. This equipment is also used for the measurement of feed material which is in shipping containers.

## PAPER SEAL

Paper seals are used for bundle shipping containers at inventory verification. The IAEA intends to use metal cap & cup type seals for shipments in the future because the paper seal is inadequate for shipment.

## SCOPE OF ROUTINE INSPECTION ACTIVITIES

A normal inspection practice for routine inspection activities is stipulated in the Facility Attachment. Figure 13 summarizes these activities. The schedule for routine inspection will be given to the facility in advance, normally one week prior to the inspection date. Normal inspection time spent at the plant is approximately 5 hours. Most inspections start with a records audit. The inspectors bring their records which are prepared by the IAEA data processing system, based on Inventory Change Reports that were previously submitted by the operator. By means of this output, the correctness of the facility's records is confirmed. At the same time, all inventory changes which are recorded in the operators books are checked for self-consistency in the records. Upon completion of the records audit, item counting and measurements are performed as needed. During routine inspections, most of the time feed material and product are the subject of this activity. The number of drums of feed material and the number of product items in storage is counted by the inspector and the number is compared with the operator's records. At the same time, these materials are checked by the NIS-322 gamma spectrometer for verification of enrichment, using a random sampling plan.

In addition to this, inventory verification of fuel rods is also performed as needed. However, this stratum is a most difficult area for inspection because normally 7,000 to 10,000 fuel rods are in store and therefore no actual number can be obtained by routine inspection. In this case, verification for this stratum can be done only by random sampling. Inspectors count the number of fuel rods in the rod trays selected randomly, compare the count with the data attached to each tray, and contirm that there is no inconsistency between the actual number and the records.

Material sampling for distructive assay for uranium content and enrichment is also conducted for feed $UO_2$ powder and sintered pellets as required. The frequency of this activity is usually twice a year. Samples are shipped to the Seibersdorf laboratory of the IAEA in Austria. The calibration of weighing scales in key measurement points is also observed by the inspector, but the standard weights for this purpose are provided by the facility.

**SCOPE OF ROUTINE INSPECTION ACTIVITIES**

* EXAMINATION OF RECORDS, VERIFICATION OF SELF-CONSISTENCY AND CONSISTENCY WITH REPORTS
* ITEM IDENTIFICATION, COUNTING AND MEASUREMENTS
* CALIBRATION OF ALL MEASUREMENT EQUIPMENTS FOR SAFEGUARDS PURPOSE
* VERIFICATION OF THE QUALITY OF OPERATOR'S MEASUREMENTS
* TAKING REPRESENTATIVE ANALYTICAL SAMPLES
* FLOW VERIFICATION OF NUCLEAR MATERIAL AT THE FLOW KMPs
* APPLICATION, EXAMINATION, REMOVAL AND RENEWAL OF SEALS
* SERVICING AND REVIEW OF SURVEILLANCE EQUIPMENT

**Figure 13**

Here I would like to mention that material flow verification at each flow key measurement point is a most important activity under NPT safeguards, because the present MUF verification procedure of the IAEA requires verification of the actual number of material movements between MBAs within the period of the material balance, in order to establish the appropriate MUF verification strategy at the physical inventory inspection. However, I don't see any adequate inspection procedure to meet this requirement yet today, and it is one of the subjects for future study.

## PHYSICAL INVENTORY VERIFICATION

The required frequency of complete physical inventory for our plant is stipulated in the Facility Attachment. The normal frequency of complete physical inventory taking is twice a year. However, when the an-

**SCOPE OF INVENTORY VERIFICATION ACTIVITIES**

* VERIFICATION OF THE OPERATOR'S PHYSICAL INVENTORY TAKING FOR COMPLETENESS AND ACCURACY
* WEIGHING OF CONTAINERS WITH NUCLEAR MATERIAL ON THE BASIS OF RANDOM SAMPLING PLAN
* TAKING ACCOUNTABILITY SAMPLES
* IDENTIFICATION AND COUNTING OF FUEL ASSEMBLIES AND THE USE OF NDA TECHNIQUES
* USE OF "IN-LINE" NDA SYSTEM
* APPLICATION, EXAMINATION, REMOVAL AND RENEWAL OF SEALS
* SERVICING AND REVIEW OF SURVEILLANCE EQUIPMENT

**Figure 14**

nual throughput is less than 300 tons of uranium per year and when the IAEA has continued assurance that the material balance is closed with limits of error of MUF of not more than 0.3% absolute, then the frequency of physical inventory taking may be reduced to one per year. When we take the physical inventory, normally the production process is in complete shutdown status for 3 days, and approximately 190 man-days are required for this activity. The manufacturing processes are released for normal operation one by one upon completion of safeguards inspection activities. Figure 14 shows the scope of inventory verification activities by the IAEA which is stipulated in the Facility Attachment.

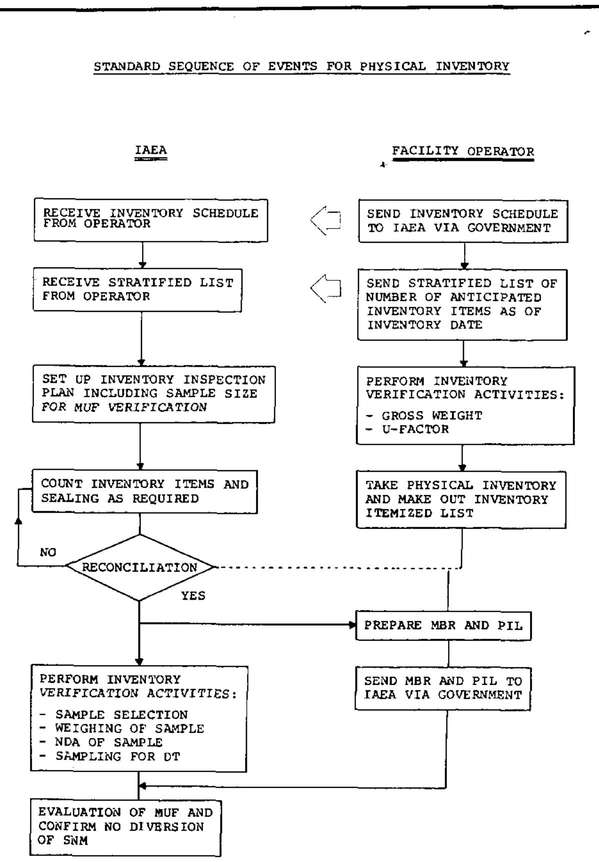



**Figure 15**

## STANDARD SEQUENCE OF EVENTS FOR PHYSICAL INVENTORY

The standard sequence of events for physical inventory is shown in Figure 15. Advance notification of the facility's inventory schedule is sent to the IAEA through the Japanese government office. The advance notice is sent to the Agency within 30 days prior to the physical inventory date, and when the inventory date is changed the information must be given to the IAEA immediately. For the next stage, the facility must submit a "Stratified List" to the IAEA. The purpose of this stratified list is to establish the IAEA's inspection plan including required sample sizes for inventory verification activities. The sampling plan for inventory verification will be established for two types of measurement methods. One is an instrumental method in which the inspector can quickly check individual items for medium size to gross discrepancies with a high degree of certainty. The other method is a more accurate measurement which is capable of detecting small differences. These two methods are referred to as the attribute method and the variable method respectively. The facility operator will perform his own pre-inventory activities such as container gross weight verification, sampling, and analysis of uranium content for various intermediate materials. These activities are usually completed prior to the inventory date in order to complete the physical inventory within the allowed shutdown period.

When the inventory starts, the facility's inventory item counting and IAEA's item counting are performed at the same time. Upon completion of the item counting for each stratum, the operator reports the number of inventory items counted by the operator to the IAEA inspector. When the numbers of inventoried items are agreed to by the IAEA, the IAEA will move to the following activities. At this stage, if a large number of inconsistencies is observed between the previously submitted stratified list and the actual inventoried number, the sample size for measurements will be re-calculated. When the IAEA is satisfied with their sample size, then the materials will be selected on the basis of the sampling plant for each stratum. After this activity, gross weight verification, NDA measurements, and sampling for chemical analysis are performed. The facility operator, upon reconciliation of the inventory item counting data with the inspector, then processes the inventory data by computer to prepare the official Material Balance Report and Physical Inventory Listing. The Material Balance Report and Physical Inventory Listing are submitted to the Agency within 30 days after the inventory taking.

Finally, the MUF which is stated in the MBR will be evaluated by the IAEA to confirm that no diversion has occurred at the facility. A book audit is also performed by the inspection team to verify the operator's ending book inventory; source data inspection is performed to confirm various operator's data which are used for determination of ending physical inventory.

## SNM STRATIFIED LIST

There is no specific format for this list. As shown in Figure 16, the anticipated number of items which will exist at the time of physical inventory is listed. The list is prepared by each nominal enrichment in the stratum. The nominal net weight and nominal uranium content are also to be listed.

## INVENTORY VERIFICATION ACTIVITIES

Inventory verification activities carried out during August 1978 are shown in Figure 17. Twenty-eight items were selected from feed materials for attribute mode measurements which were performed by NIS-322 gamma spectrometer, and 13 items out of 28 items for variable mode measurement, including weight verification, enrichment measurement by SAM-II, and sampling for chemical analysis. For scrap materials, 13 samples were selected for attribute and 5 samples were selected out of 13 for variable mode measurements, gross weight examination, enrichment check by SAM-II, and sampling for chemical analysis.

For green pellets, 13 samples were selected for both attribute and variable mode measurements. For attribute measurements, 5 pellets were randomly selected from each pellet boat which was selected and 5 pellets were placed on the collimator of the NaI detector of the SAM-II for measurement of the enrichment of these pellets.

For fuel rods, a total of 37 rods were selected out of 10,766, and uranium content and enrichment for each rod was measured by SAM-II and NIS-322 gamma spectrometer. The length of the $UO_2$ column inside the rod was measured by NIS-322, and the uranium content was determined by measuring the 766 KeV gamma originating from the U-238 chain, using the SAM-II gamma spectrometer. The enrichment of each rod was measured by SAM-II also.

For fuel bundles, 13 fuel bundles were randomly selected from the population of 1,012 and the enrichment for these bundles was checked by NIS-322. In addition to this, of the fuel bundles which were already packed into shipping containers at the inventory date, 20 bundle shipping containers (40 fuel bundles) were randomly selected and paper seals were applied for subsequent verification at the power station, because some bundles were already packed, making verification at the inventory date almost impossible.

## CONCLUSION

*It is recognized that there are improvements to be* made as a result of our experience in application of the present MUF verification program which has been developed by the IAEA, because the operator and inspector have different objectives in verification and evaluation of MUF.

There are three (3) major areas to consider.

**The first one** is that the present MUF verification system has been developed on the assumption that the facility operator is a potential diverter of SNM with an adequate strategy of such diversion. On the other hand, the inspector must have the capability of detection of

[X] Enriched
[ ] Natural
[ ] Depleted

SNM STRATIFIED LIST

Anticipated Inventory at PIT Date

Issued Date: 53 / 7 / 28

KMP Code: C    Description of Material: Nuclear Fuel Material Other Than Feed Material

Unit in Grams

| Nom. Enrich & Gd203(%) | Mat. Type | Total Element Wt. | Total No. of Batch | Total No. of Items | Avg. No. of Items in Batch | Nom. Net Wt of Item | Nom. Element Factor(%) | Nom. Element Wt. of Item |
|---|---|---|---|---|---|---|---|---|
| 1.18 | Various Scrap | 50,099 | 1 | 5 | 5 | 25,000 | < 88.2 | 22,050 |
| 1.21 | | 85,415 | 1 | 13 | 13 | | | |
| 1.33 | | 261,173 | 2 | 20 | 10 | | | |
| 1.45 | | 309,630 | 8 | 38 | 5 | | | |
| 1.49 | | 51,742 | 1 | 10 | 10 | | | |
| 1.55 | | 294,025 | 3 | 32 | 11 | | | |
| 1.58 | | 218,466 | 1 | 21 | 21 | | | |
| 1.69 | | 86,237 | 2 | 10 | 5 | | | |
| 1.87 | | 606,941 | 12 | 64 | 5 | | | |
| 1.94 | | 165,081 | 2 | 16 | 8 | | | |
| 1.99 | | 951,065 | 1 | 59 | 59 | | | |
| 2.10 | | 108,412 | 2 | 18 | 9 | | | |
| 2.14 | | 312,915 | 2 | 23 | 12 | | | |
| 2.22 | | 687,428 | 7 | 58 | 8 | | | |
| 2.50 | | 197,933 | 4 | 25 | 6 | | | |
| 2.79 | | 105,948 | 3 | 13 | 4 | | | |
| 2.87 | | 685,786 | 3 | 47 | 16 | | | |
| 2.93 | | 1,090,686 | 2 | 62 | 31 | | | |
| 3.01 | | 502,636 | 4 | 41 | 10 | | | |
| 3.07 | | 87,879 | 2 | 13 | 7 | | | |
| Grand Total | | — | — | — | | | | |

Figure 16

INVENTORY VERIFICATION ACTIVITIES

AUGUST 1978

| KMP | STRATA | NO. OF INV. ITEMS | ATTRIBUTE | | VARIABLE | |
|---|---|---|---|---|---|---|
| | | | NO. OF TEST | TYPE | NO. OF TEST | TYPE |
| A | FEED MAT. | 435 DRUMS | 28 | NDA BY NIS-322 | 13 | 1. WEIGHING 2. NDA BY SAM-II 3. SAMPLING FOR DT. |
| B | FEED MAT. | 1,560 CANS | | | | |
| C | SCRAP | 1,079 CANS | 13 | NDA BY NIS-322 | 5 | 1. WEIGHING 2. NDA BY SAM-II 3. SAMPLING FOR DT. |
| D | GREEN PELLET | 247 BOATS | 13 | NDA BY SAM-II | 13 | 1. WEIGHING 2. SAMPLING FOR DT. |
| E | SINTERED PELLET | 3,074 TRAYS | 13 | NDA BY SAM-II | 13 | 1. WEIGHING 2. SAMPLING FOR DT. |
| F | LAB. SAMPLE | - | - | - | - | - |
| G | FUEL ROD | 10,776 RODS | | | 37 | 1. NDA BY NIS-322 & SAM-II |
| H | *FUEL BUNDLE | 1,012 BUNDLES | 13 | NDA BY NIS-322 | - | - |

* 20 BUNDLE CONTAINERS (40BUNDLES) WERE SEALED

**Figure 17**

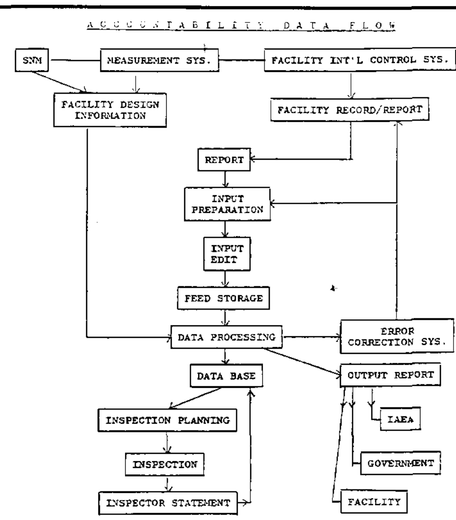



**Figure 18**

any diversion at a given probability, no matter how good such a strategy may be. However, since the commercial operator of LEU fuel fabrication facilities seeks the best SNM management for the purpose of nuclear safety, SNM asset control, fuel quality control, etc., he is not in a position to divert SNM for his own interests. Therefore, coupled with the relatively small significance of LEU in terms of final target of diversion, it is desirable to seek to minimize the economic impact when putting the MUF verification program into effect.

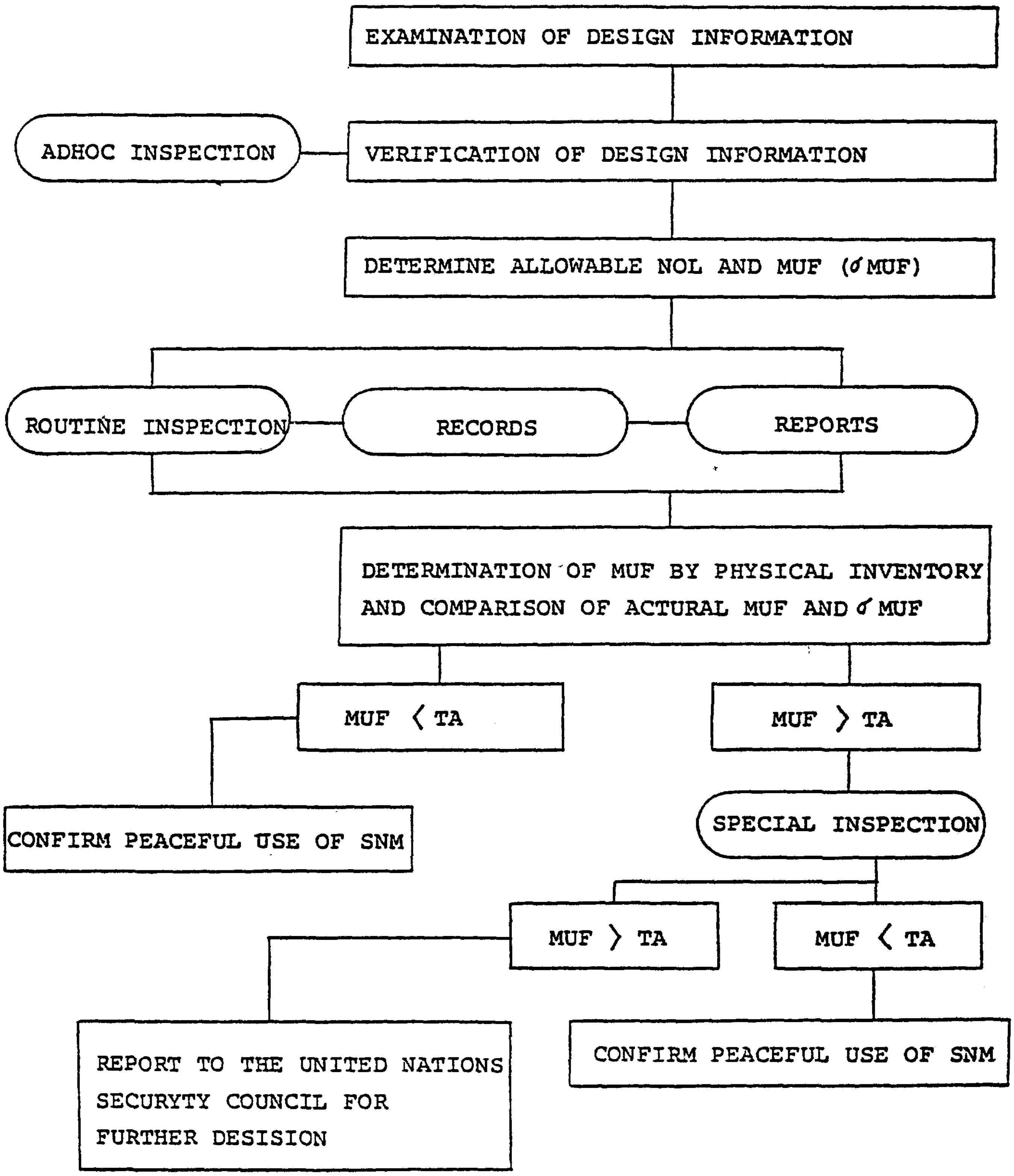
**The second one** is the technical problem of the inspector's independent measurements. Since the operator's MUF is evaluated on the basis of his or her independent measurements, the measurement capability of the inspector must be reliable in order to avoid incorrect judgment of the operator.

**The third one** is the need for close communication between the inspector and the operator. For example, when the inspector intends to use his equipment at the facility, pre-examinations on location for the equipment set-up, background of gamma rays in the process area, electric voltage fluctuation, etc., is necessary in order to minimize potential problems in the inspection activities. Also, if the inspector can provide his inspection program to the operator in advance, some strategic problems may probably arise. But the facility operator will find having the program ahead of time useful.

The facility operator would find it helpful to have prior information on the sampling plan, type of equipment, the number of inspectors assigned, and so on. Such advance information may minimize the duplication of sampling by the operator and the inspector, assist in the facility's manpower planning, and possibly reduce the verification cost.

It must be admitted that there can be a difference in standpoint between the inspecting party and the facility operator. However, in the light of the continued need for both safeguards and SNM management, it is of vital importance to seek the best way to narrow differences in the future.

MUF VERIFICATION SYSTEM




TA = THRESHHOLD AMOUNT

Figure 19

# An Introduction To the Structure of Safeguards Under the US/IAEA Agreement

**By Alan M. Bieber, Jr., and Sylvester C. Suda**
Technical Support Organization
Brookhaven National Laboratory
Upton, New York 11973

**I. Introduction**

Pending Senate approval, nuclear facilities throughout the United States will begin to implement International Atomic Energy Agency (IAEA) safeguards under the terms of the agreement negotiated between the U.S. and the IAEA. Some of the basic concepts and documents used in IAEA safeguards are new to the U.S. nuclear community. In the following, we present a brief overview of the basic structure of IAEA safeguards as they are to be applied in the U.S., with explanations of the concepts and documents required. It is our hope that this brief discussion will serve to clarify some areas where there may be problems and thus ease the overall process of implementation of IAEA safeguards in the U.S.

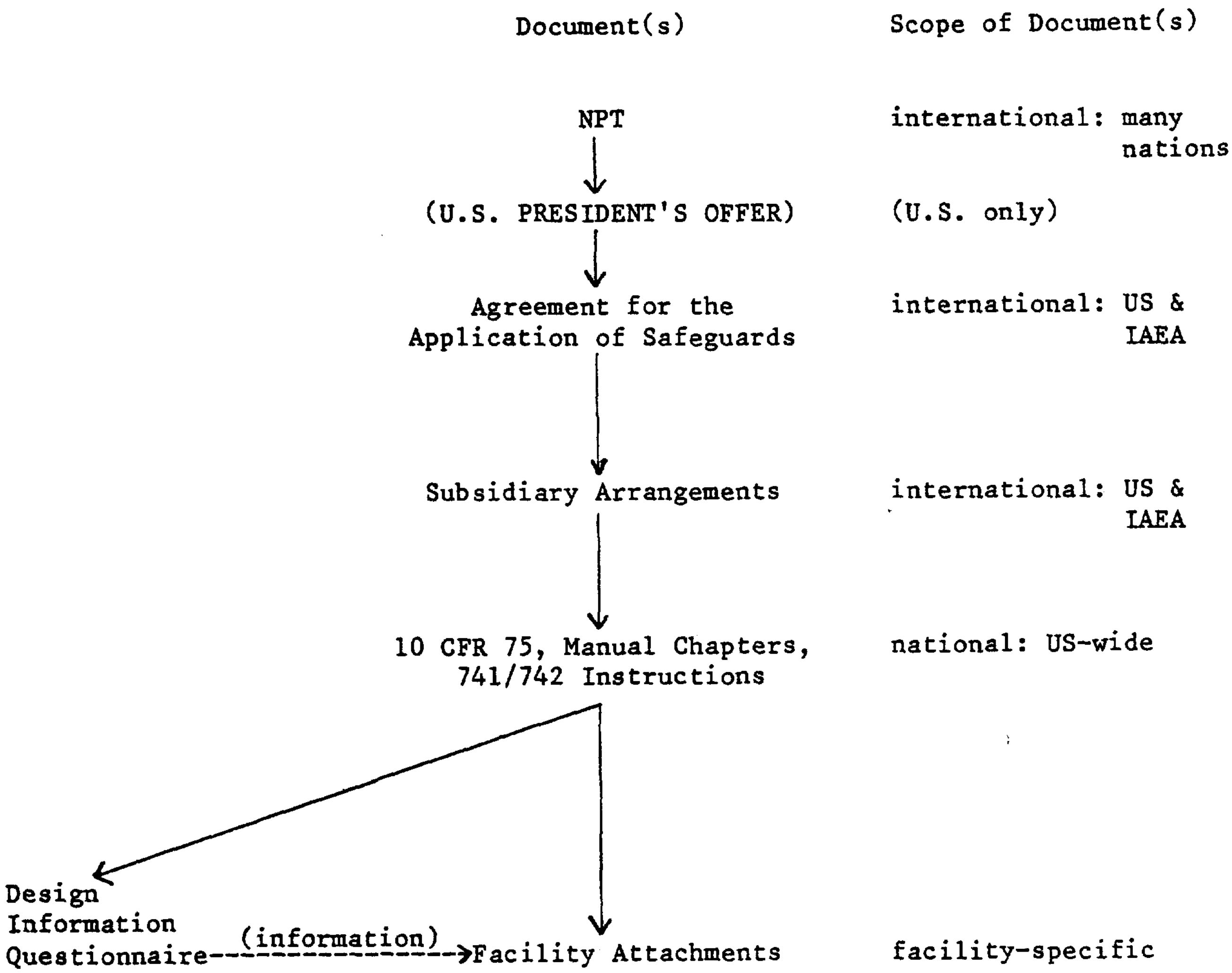
**II. Basic Legal Framework**

Figure 1 shows the basic hierarchy of legal documents which implement IAEA safeguards in the U.S. IAEA safeguards activities are mandated for non-nuclear-weapons states under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), but weapons states (the U.S., USSR, UK, France, and China) are not obligated to accept IAEA safeguards. However, in order to encourage wider adherence to the NPT, the U.S. volunteered to place all its nuclear activities under IAEA safeguards, excluding only those activities with direct national security significance. In order to implement this voluntary offer ("The President's Offer"), an Agreement for the Application of Safeguards[1] has been negotiated by the U.S. and the IAEA. This Agreement defines in general terms the purpose of IAEA safeguards in the U.S., the responsibilities of the U.S. and the IAEA, and the structure of the safeguards to be applied. In overall form, the Agreement follows INFCIRC/153,[2] the IAEA model for safeguards agreements under NPT, but it differs in detail to take into account the fact that the U.S. is a nuclear weapons state.

The next legal instruments for implementation of IAEA safeguards in the U.S. are the Subsidiary Arrangements and Transitional Subsidiary Arrangements,[3] which are formally part of the Agreement, but which are separate documents negotiated after the content of the Agreement has been finalized. Where the Agreement defines the structure of safeguards in a general way, the Subsidiary Arrangements define the details of the application of safeguards on a country-wide basis. The US/IAEA Agreement specifies that not all facilities in the U.S. will necessarily have full IAEA safeguards applied; most facilities will not be inspected by the IAEA but will have to fulfill IAEA records, reports, and accountability requirements. (Note that under the terms of the US/IAEA Agreement, the IAEA will choose from a list of eligible non-national-security related facilities those to which it will apply full or partial safeguards.) Thus there are two sets of Subsidiary Arrangements for the U.S.: one set, the Subsidiary Arrangements proper, which define full safeguards including IAEA inspection; and another set, the Transitional Subsidiary Arrangements, which define safeguards for those facilities which will not be inspected initially. The IAEA will be allowed to change the list of facilities to which inspection will be applied.

In order to implement the provisions of the Subsidiary Arrangements and Transitional Subsidiary Arrangements, some changes were necessary in U.S. safeguards regulations. The new regulations which incorporate these changes are proposed 10 CFR Part 75 and conforming amendments to 10 CFR 40, 50, 70, and 150;[4] revised instructions for completion of Forms 741 and 742 by NRC licensees; and revisions in the DOE manual chapters (especially those parts dealing with Forms 741 and 742). It is important to note that these changed U.S. regulations, although they are domestic law rather than being international agreements, nonetheless must conform in their effects with the internationally-agreed (and therefore rather difficult to change) US/IAEA Agreement. Thus, while it may appear that the U.S. domestic regulations could be modified fairly easily to take into account possible problems, in some cases the U.S. regulations are constrained by the Agreement, so that any such changes would require formal IAEA approval.

Figure 1: Hierarchy of Legal Documents for the US/IAEA Agreement

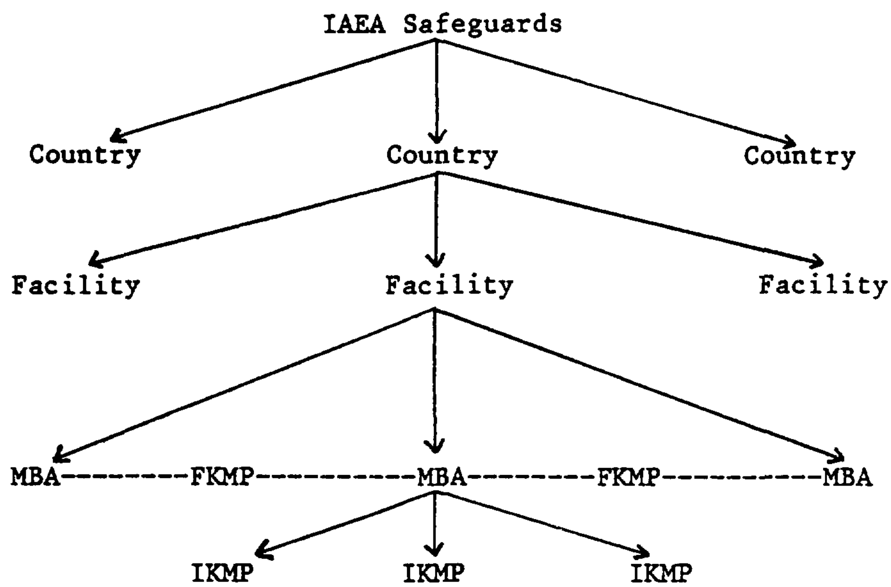



Taken together, the US/IAEA Agreement, the Subsidiary Arrangements and Transitional Subsidiary Arrangements, and the new U.S. regulations define on a U.S.-wide basis the structure and content of the implementation of IAEA safeguards in the U.S. Two other documents remain which define the information required for implementation. The first is the Design Information Questionnaire, or DIQ, which is to be prepared by the facility and submitted via the U.S. government to the IAEA. DIQ's are basically detailed descriptions of facilities and their nuclear materials measurement and accounting systems and procedures (including typical values of and calculation procedures for measurement uncertainties). The subject of DIQ's has been discussed at length elsewhere.[5] The DIQ is required to be submitted under the terms of the US/IAEA Agreement.

The purpose of the DIQ is to provide the IAEA with sufficient information about a specific facility to allow the IAEA to formulate the facility-specific details of the safeguards to be applied. These details are contained in the last of the set of documents which define IAEA safeguards, the Facility Attachment. Formally, Facility Attachments are part of Subsidiary Arrangements, so that as was the case for the Subsidiary Arrangements, there are two types of Facility Attachments: regular Facility Attachments, for those few facilities which will be under full IAEA safeguards including inspection; and Transitional Facility Attachments, for the majority of facilities, which will comply with IAEA records and reporting requirements but which will not be inspected.

Facility Attachments and Transitional Facility Attachments, since they are formally part of the US/IAEA Agreement, are negotiated documents which must be agreed to by the U.S. government and the IAEA. Spokesmen for the NRC have said that it is the intention of the NRC to consult with licensed facilities and allow them to review Facility Attachments for their facilities

Figure 2: Hierarchy of Entities Under IAEA Safeguards




prior to final approval. This is quite important, because the topics covered in the Facility Attachment (e.g., MBA and KMP structure, definition of typical batches, and if appropriate, containment and surveillance measures, and inspection effort) are very facility specific and can have a profound effect on the impact of safeguards at a facility.

Taken together, the US/IAEA Agreement, Subsidiary Arrangements, domestic regulations, and Facility Attachments form the legal basis which defines the structure and content of IAEA safeguards in the U.S. In the following section of this paper, we will outline briefly this structure and discuss the major concepts and activities required under IAEA safeguards.

**III. Basic Concepts in the IAEA Safeguards System**

The goal of IAEA safeguards in the U.S. is defined in Article 2(a) of the US/IAEA Agreement as

> " . . . enabling the Agency to verify that [source or special fissionable] material is not withdrawn except as provided in this Agreement, from activities in facilities while such material is being safeguarded under this Agreement."

In order to achieve this goal, the IAEA has constructed a conceptual framework for organizing world nuclear activities and tracking the flow of nuclear materials under its safeguards. In this section of this paper, we present definitions and discuss concepts necessary to understand the IAEA safeguards system.

Figure 2 presents the basic structure of entities within the IAEA system. The totality of world nuclear activities under IAEA safeguards is divided by country, since safeguards agreements are between individual countries and the IAEA. Within countries are facilities, where a facility is defined in Article 90I of the US/IAEA Agreement as:

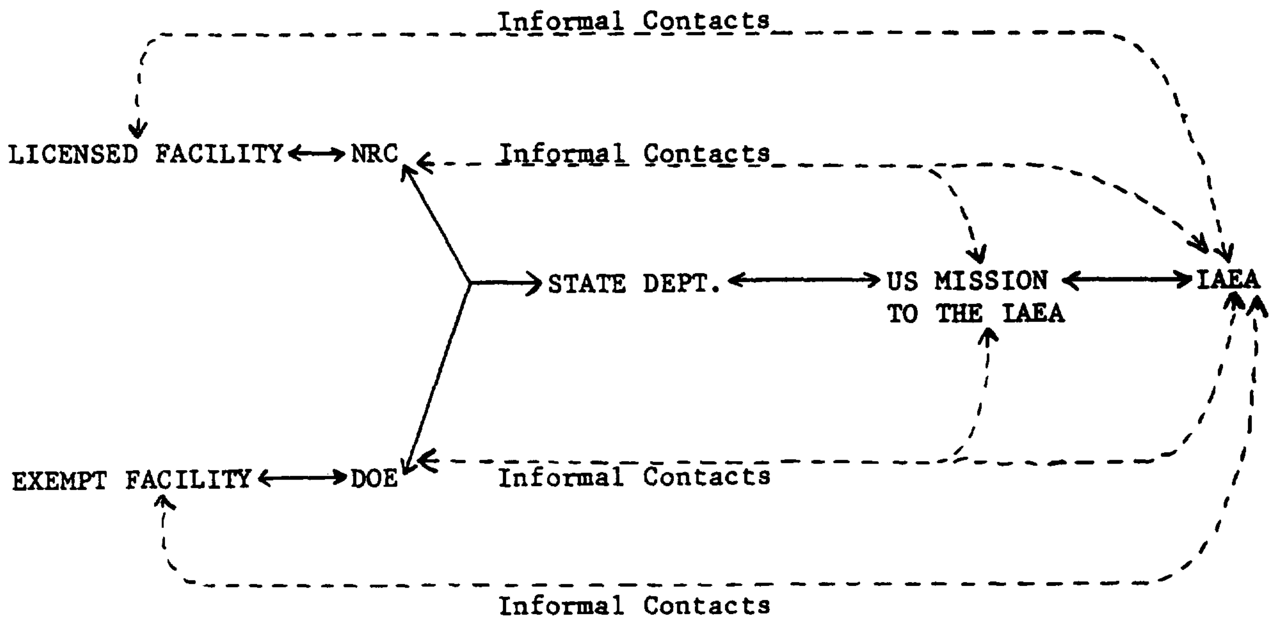
> "(a) A reactor, a critical facility, a conversion plant, a fabrication plant, a reprocessing plant, an isotope separation plant or a separate storage installation; or
>
> (b) Any location where nuclear material in amounts greater than one effective kilogram is customarily used."

Facilities are further subdivided into material balance areas (MBAs), which are defined in Article 90N of the US/IAEA Agreement as:

> " . . . an area in or outside of a facility such that:
>
> (a) The quantity of nuclear material in each transfer into or out of each material balance area can be determined; and
>
> (b) The physical inventory of nuclear materials in each material balance area can be determined when necessary in accordance with specified procedures, in order that the material balance for Agency safeguards purposes can be established."

Note that this definition of MBA differs significantly from the U.S. definition of MBA, especially in that there is no mention of localization of losses and that the IAEA definition would include both MBAs and ICAs as they are defined in the U.S. In general, IAEA MBAs are much larger than U.S. MBAs; in many cases, an entire facility would be but one IAEA MBA, and in fact in some cases several facilities each possessing only small quantities (less than one effective kg) of nuclear material may be

Figure 3: Information Flow Under the US/IAEA Agreement




grouped together into one IAEA MBA.

At the boundaries of IAEA MBAs are flow key measurement points (FKMPs), used for accounting and reporting of transfers into or out of MBAs, and within MBAs are inventory key measurement points (IKMPs) used for partitioning the MBA inventory for verification. Article 90K of the US/IAEA Agreement defines key measurement point as

> " . . . a location where nuclear material appears in such a form that it may be measured to determine material flow or inventory. Key measurement points thus include, but are not limited to, the inputs and outputs (including measured discards) and storages in material balance areas."

The concept of key measurement point is basic to the IAEA safeguards system. In practice, IKMPs are usually defined by the IAEA not as locations but rather as broad material types having similar measurement uncertainties (e.g., in an LWR fuel fabrication plant, $UO_2$ powder, sintered pellets, or complete fuel assemblies). These broad material types form the basic stratification used by IAEA inspectors for planning sampling for inventory verification. FKMPs, in contrast, are basically used for calculation of the additions and removals terms in the MUF equation.

Of fundamental importance to the IAEA system of reporting and data analysis is the definition of batch. In the U.S., nuclear materials are accounted for basically in terms of items (broadly defined, so that an "item" may for example be one container of $UO_2$ powder on inventory). In contrast, the basic accountability and reporting unit in the IAEA system is the batch, defined in Article 90C of the US/IAEA Agreement as

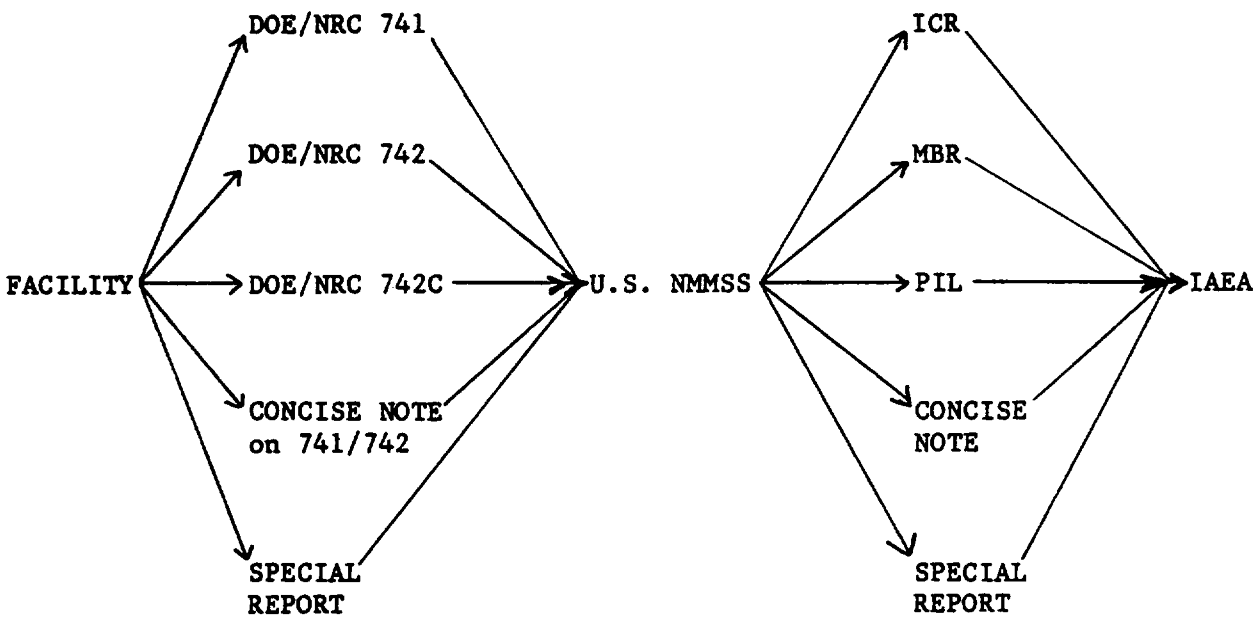
> " . . . a portion of nuclear material handled as a unit for accounting purposes at a key measurement point and for which the composition and quantity are defined by a single set of specifications or measurements. The nuclear material may be in bulk form or contained in a number of separate items."

While precise, this definition of unique batches using IAEA's Code 10 format (discussed below) may in some cases be difficult to apply. The definition of typical batches (given in the Facility Attachment) may be different for the same material depending upon whether the material is being transferred at a FKMP or is on inventory in an IKMP. The operational principle to be borne in mind, however, is that fundamentally the batch is always the unit of nuclear material which can be treated uniquely for purposes of tracking material from one MBA to another, of defining measurement entities on hand at the time of physical inventory, and of propagating measurement error in calculation of LEMUF.

**IV. Reporting and Information Flow Under the US/IAEA Agreement**

Figure 3 shows schematically the formal structure of information flow between the U.S. and the IAEA under the Agreement. Formally, since the Agreement is an international agreement between the U.S. government and an international agency, all communications between the U.S. and the IAEA are via the State Department through the U.S. Mission to the IAEA (in Vienna). The

Figure 4: Data Flow for Routine Reporting Under the US/IAEA Agreement




NRC and DOE do not formally communicate directly with the IAEA, but rather only through the State Department and the U.S. Mission; as shown in the figure, there are of course informal contacts between the NRC or DOE and the U.S. Mission and/or the IAEA (the State Department may also formally set up procedures for direct communication between the NRC or DOE and the IAEA, but this has not yet been done). Similarly, all communications (including reporting) between U.S. facilities and the IAEA flow formally via the NRC or DOE, as appropriate, and then through the State Department and the U.S. Mission, to the IAEA. Again, there are informal direct contacts between the facility and the IAEA (especially in connection with inspections), but the formal structure for information flow is via the chain shown in Figure 3.

Note that the flow of information shown in the figure is two-way. Not only is the U.S. obligated under the terms of the Agreement to supply data to the IAEA, but the IAEA is also required to provide the U.S. with certain information concerning its safeguards activities and conclusions. As before, the formal lines of communication are via the U.S. Mission and the State Dept., but the IAEA may in some cases communicate informally directly with NRC, DOE, and/or facilities.

Figure 4 shows the flow of reporting data from U.S. facilities to the IAEA under the Agreement. As shown, there are five different types of reports (described in detail in Code 10 of the Subsidiary Arrangements and Transitional Subsidiary Arrangements) which are required. All of these reports are submitted by the facility on U.S. forms to the Nuclear Materials Management and Safeguards System (NMMSS), located in Oak Ridge, Tennessee. The NMMSS then processes the reported data, and uses them as required for domestic safeguards purposes. The data are then reformatted and converted to the reports specified in Code 10 of the Subsidiary and Transitional Subsidiary Arrangements, and transmitted to the IAEA in Vienna. The five types of reports required are:

A. **Inventory Change Reports.** Any change in the inventory of nuclear material in an IAEA MBA is required to be reported to the IAEA in the form of an Inventory Change Report (ICR). Present U.S. plans are to implement this requirement through modification of the DOE/NRC Form 741 to include the four additional data elements for each batch required by the IAEA.

B. **Material Balance Reports.** After a physical inventory has been taken in an IAEA MBA, the IAEA requires a Material Balance Report (MBR) to be supplied which summarizes the material balance. The MBR is essentially equivalent to the DOE/NRC Form 742 (except that an MBR is required to be filed after each physical inventory, and reports physical inventory data in addition to book data). Present plans are to modify the present 742 to allow it to be reformatted by NMMSS to prepare MBRs.

C. **Physical Inventory Lists.** Each MBR is required to have attached to it a Physical Inventory List (PIL). The PIL reports the result of a physical inventory in an IAEA MBA in the form of a listing by batch (as defined in the Facility Attachment) of all material on inventory in the MBA. There is now no U.S. equivalent to the PIL, but the NRC has proposed a new form, the 742C, which would be attached to each 742 submitted and would contain the data necessary for the NMMSS to construct a PIL. For those facilities under IAEA inspection, the facility book inventory list showing each item with its location, identification and other data becomes the PIL after it has been updated to include recent transactions and verified by the inspectors during the physical inventory.

D. **Concise Notes.** Concise Notes are submitted whenever there is a need to explain more fully any entry in an ICR, MBR, or PIL. They are in the form of a free-text explanation, and present plans are to use the Miscellaneous block in the 741 or 742 Form to transmit information from the facility to the NMMSS.

E. **Special Report.** In the event that there is some unusual circumstance such as loss of significant quantities of safeguarded nuclear material or change in containment of safeguarded nuclear material such that its loss becomes possible, the U.S. is obligated under Article 66 of the Agreement to file a Special Report with the IAEA which explains the circumstance. Special Reports are free-format reports which probably would be in the form of a letter rather than a fixed reporting form.

As mentioned above, the details of the timing, content, and format of reports from the U.S. to the IAEA are contained in the Subsidiary Arrangements and Transitional Subsidiary Arrangements. The final format of the revised 741, 742, and 742C and their respective instructions has not yet been decided, but the NRC has distributed drafts of the new forms and instructions for comment.

### References


1. **Agreement with the International Atomic Energy Agency for the Application of Safeguards in the United States of America, with Protocol,** transmitted by President Carter to the U.S. Senate, February 9, 1978.
2. **The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons,** International Atomic Energy Agency, INFCIRC/153 (corrected), Vienna, June 1972.
3. **Subsidiary Arrangements and Transitional Subsidiary Arrangements to the Agreement between the Government of the United States of America and the International Atomic Energy Agency for the Application of Safeguards in the United States of America,** drafts initialed by representatives of the U.S. and the IAEA, June 1, 1978.
4. "Proposed 10 CFR Part 75 and Conforming Amendments to 10 CFR Parts 40, 50, 70, and 150," Federal Register, Vol. 43, No. 102, May 25, 1978.
5. "DIQs: An Introduction to IAEA Facility Information Requirements," Alan M. Bieber, Jr., **Nuclear Materials Management,** Vol. VII, No. 3, Fall 1978.


# Menlove Appointed LASL Group Leader

Los Alamos, N.M.—**Howard O. Menlove** has been appointed group leader of a new International Safeguards Group Q-5 at the Los Alamos Scientific Laboratory. Work in support of international safeguards has been underway at LASL for the past eight years, and recently, the magnitude of this effort reached a level to merit a separate group directly identified with the effort.

Menlove has been working with the Nuclear Safeguards Program at LASL for the past eleven years. During this period he has been actively engaged in R&D on advanced techniques for nondestructive assay of fissionable materials. Before being named to his new post, Menlove was Alternate Group Leader for Group Q-1, Safeguards Technology, International Safeguards and Training.

**Dr. Menlove**

Prior to working at LASL, Menlove had considerable experience in the areas of neutron and fission physics as well as gamma-ray spectroscopy. After receiving his Ph.D. Degree in Nuclear Engineering at Stanford, he spent a year at the Kernforschungszentrum in Karlsruhe, Germany, supported by a Fulbright Award. He has numerous publications in the areas of neutron cross section measurements, activation analyses techniques, and the application of nuclear methods to the nondestructive assay of fissionable materials.

The International Safeguards Group at LASL will be working in the areas of inspector instrumentation development and implementation, NDA standards and calibration, spent fuel verification techniques, training, IAEA utilization of in-plant NDA, and technology transfer. Additional international activities that can best be performed in the other safeguards groups at LASL will continue to be performed there. These groups are Safeguards Technology and Training, Q-1, Detection, Surveillance, Verification and Recovery, Q-2, Safeguard Subsystem Development and Evaluation, Q-3, and Integrated Safeguards Systems and Technology Transfer, Q-4.

## SIXTH IN A SERIES

# Titles and Abstracts Of Recent Safeguards R&D Publications and Reports From New Brunswick Laboratory

Editor's Note—This is the sixth in a series of listings of titles and abstracts of recent safeguards R&D publications and reports from agencies and R&D laboratories. It has been compiled by the professional staff of the New Brunswick Laboratory, Argonne, Illinois. The Summer Issue (Volume VIII, No. 2) will have a similar listing from Canadian facilities. If your agency or R&D laboratory is interested in being included in this series, please contact the editors (William A. Higinbotham (516-345-2908) at Brookhaven National Laboratory or Thomas A. Gerdis (913-532-5837) at Kansas State University, Manhattan.

*The Chemical and Isotopic Analysis of Uranium, Plutonium, and Thorium in Nuclear Fuel Materials*, C.E. Pietri, J.S. Paller and C.D. Bingham, presented at the American Nuclear Society Topical Meeting, May 15-17, 1978, Williamsburg, VA. Published in *Analytical Methods for Safeguards and Accountability Measurements of Special Nuclear Materials*, NBS Special Publication 528, edited by H.T. Yolken (NBS) and J.E. Bullard (B&W), 1978.

**ABSTRACT**

The New Brunswick Laboratory (NBL) has developed or modified and used highly precise and accurate methods for the determination of uranium, plutonium and thorium content and isotopic abundances in a wide variety of nuclear fuel cycle materials in support of nuclear safeguards programs. The dissolution, separation and subsequent precise chemical analysis of these materials with an accuracy of 0.1% or less is achieved using gravimetric, titrimetric, spectrophotometric and coulometric techniques. Isotopic abundance measurements on uranium and plutonium are accurately measured with a relative limit of error (95% confidence limit) of approximately 20 to 0.007% for the isotope weight range of 0.001 to 97 weight percent using thermal ionization mass spectrometers. Other methods such as isotope dilution mass spectrometry, fluorimetry and radiochemical analysis are used where the uranium and plutonium sample content is in the microgram range. Many of the analytical methods used at NBL are in various stages of automation or mechanization to provide greater efficiency and productivity at existing levels of accuracy and precision. Quality assurance programs employing unknown control standards for the analysis of nuclear materials are used at NBL to maintain a high level of reliability.

*Preparation of Test Materials for an Interlaboratory Comparison Program on NDA Physical Standards*, A.M. Voeks, N.M. Trahey, J.M. Scarborough.

**ABSTRACT**

A number of synthetic materials simulating the types of samples measured by current NDA techniques are being developed and tested by New Brunswick Laboratory for use in an interlaboratory comparison program. Under investigation are several inorganic and organic compounds to determine their abilities to provide suitable matrix properties amenable to the fabrication of SNM-bearing standards. Details of the preparation, characterization, and encapsulation studies performed are described.

*Standards for Chemical or NDA Measurement for Nuclear Safeguards—A Review*, C.D. Bingham, presented at the 175th Annual Meeting, ACS, Anaheim, CA. Published in *Nuclear Safeguards Analysis—Nondestructive and Analytical Chemical Techniques*, ACS Symposium Series 79, edited by E.A. Hakkila (LASL), 1978.

Papers presented at 21st Gatlinburg Conference (1977). Published in *Analytical Chemistry in Nuclear Fuel Reprocessing*, edited by W.S. Lyon (ORNL), 1978.

*The Mission and Responsibilities of a National Safeguards Laboratory*, Carleton D. Bingham.

**ABSTRACT**

Safeguarding of nuclear materials has taken on increased international, as well as domestic, dimensions during the past decade. The activities of the New Brunswick Laboratory and laboratories from other nations which are working closely with the IAEA are reviewed.

Missions include providing service measurements for the Safeguards Regulatory authorities, evaluation, assessment, materials standardization, and training and indoctrination of Safeguards inspectors.

*An Evaluation of an Automated Titration System for the Determination of Uranium*, K. Lewis, D.L. Colwell, C.G. Goldbeck (U.S. DOE NBL), J.E. Harrar (LLL).

**ABSTRACT**

A computer-controlled automated titration and data handling system for the determination of uranium, built by the Lawrence Livermore Laboratory for the New Brunswick Laboratory, has been evaluated. The analytical method is based on a modification of the Davies-Gray titration using constant current coulometry with potentiometric and point detection. The instrument functions reliably. Results are precise to 0.1% over the range of 40 to 140 mg of uranium. The recovery of uranium varies with the quantity titrated, but it is consistent at each level over the range studied allowing calibration with standards. The titrator has been shown to be capable of reliably handling a variety of actual sample materials encountered at the New Brunswick Laboratory.

*Techniques for Decreasing the Controlled-Potential Coulometric Determination Time for Plutonium*, Michael K. Holland, Jon R. Weiss, and Charles E. Pietri.

**ABSTRACT**

For many practical applications, it may be desirable to decrease the time required in the controlled-potential coulometric determination of plutonium without employing elaborate cell and stirring assemblies or expensive computer prediction equipment. This goal has been achieved by using a control potential adjustment technique with simplified background current corrections. Accordingly, the time for plutonium determination has been decreased to the several minute range. Results calculated using an electrical calibration factor were precise to less than 0.05% relative standard deviation (RSD) without significant bias when greater than 99% of the sample was electrolyzed.

J.M. Scarborough, Editor, *Progress Report for the Period July 1975—September 1977*, New Brunswick Laboratory Report NBL-289 (March 1979).

NBL-289 contains summary information of the nuclear materials measurement development, improvement and evaluation activities of NBL, primarily related to safeguards measurements, and of efforts related to the preparation, characterization and certification of reference materials which are traceable to the national measurement system.

The following titles are descriptive of the information included:

**Investigation of Residual Reducing Materials in Solution During the Oxidation Step of the NBL Titrimetric Method of Determining Uranium.**

**Manganese Interference and the Conversion of Manganese to Non-Interfering Species in the NBL Titrimetric Procedure for Uranium.**

**Characterization of Phosphoric Acid for Use in the Titrimetric Determination of Uranium.**

**The Determination of Uranium in Uranium-Fissium Alloy and in Uranium-Fissium Dross.**

**Determination of Chromium in Uranium by Gas Chromatography.**

**Boron Dissolution After Heating with Gallium.**

**An Evaluation of the Automatic Uranium Titration System.**

**An Automated Passive Gamma System for the Measurement of $^{235}U$ Content of Small Samples.**

**Comparison of Techniques for Deriving Self-Absorption Correction Factors for Passive Gamma Measurements.**

**Measurement of $^{235}U$ by Non-Destructive Analysis Using a NaI(Tl) Detector System.**

**Determination of $^{241}Am$ by Gamma Ray Counting.**

**The Determination of the Alpha Activity Ratio $^{238}Pu/(^{239}Pu + ^{240}Pu)$ in $PuO_2$.**

**The Effect of Methyl Borate Volatilization on the Determination of Impurities in Elemental Boron.**

**Preparation and Evaluation Samples for the Determination of Impurities in Elemental Boron.**

**The Determination of Magnesium (Mg) in Beryllium (Be) by Atomic Absorption Spectrophotometry (AAS).**

**The Determination of Impurities in Elemental Boron by X-Ray Fluorescence Spectrometry.**

**Comparison of Solution and Dry Techniques for the Preparation of Spectrochemical Calibration Standards.**

**A Comparison of Sample Preparation Techniques for the Determination of Uranium in Calcined Ash Materials by X-Ray Fluorescence Spectrometry.**

**The Determination of Silicon in Elemental Boron by a Direct Spectrographic Method.**

**Application of a Correction Factor for Unelectrolyzed Species in Controlled-Potential Coulometry.**

**Determination of Plutonium by Controlled-Potential Coulometry.**

**A Controlled-Potential Adjustment Technique for the Determination of Plutonium.**

**Techniques for Decreasing the Time Required for the Coulometric Determination of Plutonium.**

**Calibration and Corrections for Electrical Phenomena of a Controlled-Potential Coulometer.**

**Improvements in Techniques for Preparing Plutonium Samples for Coulometric Analysis.**

**An Improved Anion Exchange Purification Procedure.**

**The Effect of $NaHSO_4$ Fusion Salts on the Ion-Exchange Separation of Plutonium.**

**Elimination of Zirconium Interference in the Controlled-Potential Coulometric Determination of Plutonium.**

**A Faster and More Efficient Method for the Ion-Exchange Separation of Plutonium and Impurities for Mass Spectrometric Analysis.**

**An Automated Mini Ion-Exchange Exchange System (AUTOSEP).**

**An Automated Coulometry System (AUTOCOULOMETRY) for the Determination of Plutonium.**

**Comparison of Calibration Alternatives for the Calorimetric Assay of $PuO_2$.**

**Plutonium Metal Exchange Program.**

**Weight Loss on Ignition (LOI) of Low-Fired Plutonium Dioxide.**

**Determination of Plutonium in Caustic Scrubber Solutions.**

A Tornado-Resistant Storage Container for Use in Plutonium Gloved Box Operations.

Evaluation of an Automated Titration System for the Determination of Uranium.

A Programmable Calculator Data Acquisition System for a Thermal Ionization Mass Spectrometer.

An Effective Ion-Exchange Separation of Plutonium in $PuO_2UO_2$ for Mass Spectrometric Isotopic Analysis.

Development of a Digitally Integrated Controlled-Potential Coulometer.

Uranium Metal Chip Standard—NBL Analyzed Sample No. 112.

Uranium Hexafluoride Standard—NBL Analyzed Sample No. 110.

Preparation of Synethetic Calcined Ash Standards.

Uranium Counting Calibration Sources—NBL Analyzed Sample Nos. 101-105.

Thorium (Uranium) Counting Calibration Sources—NBL Analyzed Sample Nos. 106-110.

Uranyl Nitrate Solution Standard (SALE).

Low Enriched $UO_2$ (SALE).

Enriched Scrap Recovery Material (GAE).

Design of Evaluation Standards for Interlaboratory NDA Comparison.

Safeguards Analytical Laboratory Evaluation Program.

General Analytical Evaluation (GAE) Program.

Miscellaneous Measurement Evaluation Programs.

# First Nuclear Test Conducted In Loft Reactor

The first in a series of about 20 nuclear tests in the LOFT (Loss of Fluid Test) reactor was conducted successfully on December 9 in Idaho.

This test achieved its major objectives. It was an important step in the Nuclear Regulatory Commission's LOFT program, which is one element in a large program designed to study the effectiveness of systems intended to provide emergency core cooling (ECC) for light water-cooled reactors in the unlikely event of a pipe-break accident. This large program includes many experiments to gather data needed to develop and test computer programs which will be used to predict the performance of ECC systems in large reactors, and increase NRC's ability to confirm independently the margins of safety that have been estimated during licensing reviews.

The 50 thermal megawatt LOFT reactor is the largest facility in the NRC's program of confirmatory research, and the only complete experimental nuclear reactor system in the world performing loss-of-coolant experiments. It is operated by EG&G, Idaho at the Department of Energy's Idaho National Engineering Laboratory.

The first nuclear experiment in LOFT permitted the direct measurement of fuel temperature in a reactor during a simulated loss-of-coolant accident, thus allowing the comparison of predicted temperatures with measured temperatures.

During the past 32 months, a series of five experiments was successfully completed in which there was no nuclear heat generation. This latest experiment was the first to be performed with an operating nuclear core. It simulated the rupture of a large pipe supplying cooling water to the core. Many instruments recorded pressures, fuel-rod temperatures, coolant flow rates and the time required to again cover the core with emergency coolant to keep the nuclear fuel cooled.

The experiment began with the opening of the two large blowdown valves in about 18 thousandths of a second, simulating the instant shearing of the coolant pipe. Steam and water were rapidly discharged through the break to a suppression tank where the steam was condensed.

Although the experiment was conducted at a power level of about 1/120th that of a commercial power reactor, the power density in the LOFT core in this test was about two-thirds that of a commercial reactor.

While examination of the data is just beginning, initial results indicate that the emergency core cooling system functioned generally as expected. The measured temperatures of the fuel cladding were significantly lower than the predicted peak value. Although the data must be analyzed further, it appears that the peak temperature of the fuel cladding was about 400 degrees fahrenheit below that predicted.

Austrian, Dutch, Finnish, German and Japanese scientists, on assignment to INEL, observed the December 9 experiment and will assist in the detailed analysis of test data during the next several months. The results will be used to help in analyses of the adequacy and accuracy of computer codes used by the NRC to evaluate the safety of commercial nuclear power plants.

Nuclear experiments in LOFT will continue at higher power levels and higher power densities and will deal with a variety of pipe break sizes and locations and with alternate emergency cooling systems. They are expected to continue into the 1980's.

# A Non-Ideal Use of a Segmented Gamma-Ray Scanner

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ABSTRACT

A segmented gamma-ray scanner has been found to be usable for a type of a sample totally at variance with that for which it was designed. The significant nonlinearity, caused by the inapplicability of the automatically computed correction factors, can be compensated for by subsequent calculation.

INTRODUCTION

In this report, we describe our experience with a Canberra Model-2220 segmented gamma-ray scanner in an application quite different from the ideal on which the theory of such a device is based [1]. We found that it could be used by correcting, in the manner to be described, for the fact that the absorption factors calculated by the instrument in its usual mode of operation do not apply to the clad fuel-tube samples we wished to measure.

Briefly, the segmented gamma-ray scanner was designed to measure the amount of finely divided, suitably gamma-emitting material which is uniformly dispersed in some inactive, but absorbing, matrix, all contained in a cylindrical drum. The container is rotated during measurements, and the detector is shifted in height at stages during the measurement process in order to scan each of several segments of the drum.

It is assumed that the nuclear material of interest is so fine that self-absorption can be ignored and that the only absorption is by the matrix and the container wall. An external source, the transmission source, which emits gamma rays of energies spanning that of the assay source, is located opposite the detector with the container between the two. The transmission, $T_c$, corrected to the energy of the assay-source radiation, of two walls of an empty container is measured. With the sample in place, the transmission, T, again corrected to the assay-source energy, of walls and sample is measured. From these, the transmission of the matrix material, $T_M$, is

$$T_M = T/T_c.$$

With the assumption that the finely divided source material is uniformly dispersed throughout the absorbing matrix, an approximate attenuation correction factor, CF, is computed from

$$CF = -\beta \ln T_M/(1 - T_M^{\beta}) \qquad (1)$$

With β equal to unity, this expression is exact for a slab far from the detector. For cylindrical matrices with $T_M$ of the order of 0.01 or greater, at practical distances, this expression has been found to be usefully accurate if $\beta = 0.823$.[2] Then, if n is a count observed by the detector after correction for background, the corrected net count from the assay material is

$$n \times CF/T_c^{\frac{1}{2}}.$$

The instrument is calibrated with a container of known content which is similar in all other respects to the samples to be assayed. All the operations described above are performed automatically under the control of the attendant circuitry.

We originally tried to derive correction factors appropriate to our annular samples, clad fuel tubes in which there is no matrix in the sense used above. We would then have checked to see whether we could have the scanner use some other constant value of $\beta$ than 0.823 in Eq. 1 to find sufficiently accurate values of CF for the range of samples we had. Some progress on the derivation was made, but attempts at numerical evaluation proved discouraging. We resigned ourselves to use of the scanner in its usual manner with an attempt at subsequent correction of the "assays" calculated by the scanner circuitry. We had to learn how to make that correction, and we had to evaluate three tubes that were to be retained as standards for assay of newly manufactured tubes.

## SAMPLE MATERIAL

The fuel-tube samples to be discussed here were greatly different from the finely divided material uniformly dispersed throughout a solid cylindrical matrix for which the scanner was designed. Our samples were hollow cylinders of uranium-aluminum alloy, clad inside and out with aluminum, and with aluminum filler in the annulus at each end. They were of three types, described as inner, intermediate, and outer. The total tube length specification was 27-9/16 in. (0.700 m) for the inner and intermediate tubes, and 32-5/32 in. (0.817 m) for the outer tubes. The cladding thickness and total wall-thickness specifications were the same for the inner and intermediate tubes, but the diameters were different. The total $^{235}U$ content specifications were $62 \pm 3$, $73 \pm 3$, and $35 \pm 3$ g for the inner, intermediate, and outer tubes, respectively.

## MOUNTING AND MEASURING

The first problem is the evaluation of the tubes which were to be retained as standards. A special jig was constructed by which the tubes were mounted in the center of a 55-gal drum. The measurements were made in the usual way. The instrument handled the drum transmission as the container transmission, and the transmission of the fuel tube as the matrix transmission.

The measurements to be described were made on two outer tubes and on one each of inner and intermediate tubes. While making the NDA measurements, we had available the masses of $^{235}U$ generated from ingot weights, and so on, during tube manufacture; we will refer to these as the nominal values. Subsequently, one of the outer tubes was destructively analyzed.

In turn, each tube was used as a standard. That is, each tube was put in place and the calibration phase run through with the machine having been given the nominal value for that tube as its $^{235}U$ content. Then it, and each of the others, was run through the assay phase as a sample to be measured. During the course of our investigation, this process was repeated several times. Further, several measurements were made on each "sample" during the assay phase so that we could compare the internally and externally calculated standard deviations. They agreed to the extent to be expected statistically.

Initially, we had one difficulty. Whether proper correction factors are calculated or not, the instrument should return the nominal value as the assay when a "sample" is run against itself as the "standard." This was not the case, within the statistical expectation, until the collimation was removed. Thereafter, it was found that 11 of 12 results (92 percent) were within the 95-percent confidence limits, and that the assay was less than the nominal value in 5 of the 12 cases. These results, plus the agreement between the internally and externally calculated standard deviations, give us confidence that the instrument was behaving normally.

## RESULTS AND ANALYSIS

A typical set of the results produced by the scanner is shown in Table I. The column headings, or the row headings, show the tube designations and the nominal masses of $^{235}U$. In the body of the table are the average assay results, A, and the standard deviation in A calculated with the larger of the internal or external standard deviations of an observation of unit weight. For instance, $35.879 \pm 0.144$ g is the assay on 9S when the scanner was calibrated with 12P. In every set of this sort that we collected, the pattern apparent in this table showed up. The larger the standard mass is by comparison with the sample mass, the larger is the assay, and *vice versa*, within the scatter. We would not expect, of course, such a pattern to occur uniformly in the comparison of 3J23 and 9S, for instance.

Given our expectation that the nominal masses were nearly correct, this pattern, first noticed in a table of this sort, would mean that, as the standard mass is increased, the count per gram, or count rate, computed by the attendant scanner circuitry is decreased. The instrument did not respond linearly, as was verified also by a subsequent examination of the count rates reported by the scanner following the calibration phase. The response, however, was orderly.

In the following analysis, we need not carry the drum transmission along; it is handled correctly by the scanner. Then, if the true count from mass m were bm, and if the true attenuation correction factor were C, the uncorrected, observed count would be

$$n = bm/C$$

If one knew C, he would multiply n by C to get the corrected count. Since we use the scanner in its usual mode of operation, however, it finds a "corrected" count, N, to be

$$N = bm(CF)/C$$

where CF is the factor given by Eq. 1.

TABLE I. Comparative Assays of Fuel Tubes

| Sample \ Standard | 3J23 33.66 g | 9S 33.80 g | 12P 73.63 g | 15B 61.70 g |
|---|---|---|---|---|
| 3J23 33.66 g | 33.561 0.170 | 33.667 0.155 | 35.625 0.133 | 34.227 0.196 |
| 9S 33.80 g | 33.926 0.127 | 33.897 0.132 | 35.879 0.144 | 34.636 0.132 |
| 12P 73.63 g | 69.902 0.220 | 69.387 0.226 | 73.695 0.226 | 71.030 0.225 |
| 15B 61.70 g | 60.569 0.198 | 60.697 0.282 | 63.920 0.299 | 61.602 0.202 |

What we found was that we could set

$$C = 1/(1 - \mu m)$$

and use the same b and $\mu$ for all the tubes. In effect, then, we set

$$n = bm(1 - \mu m) \qquad (2)$$

but need the values of CF to make the required correction to the assay reported by the instrument.

The mass of $^{235}U$ in one of the tubes is the same, of course, whether the tube is currently being called a sample or a standard. That mass appears differently in the equations, however, depending on its usage. Thus a different notation will be used for the same mass, dependent on that usage. The numerical equality is ultimately recognized during the formation of the normal equations for the least squares evaluations.

Let j designate a column of Table I, and let i designate a row. When an item is used as a standard, let its true $^{235}U$ content be $S_j^0$ and its nominal value be $S_j$. When an item is used as a sample, let its true mass be $g_i^0$. The destructive analysis of 3J23 gave 33.50 g $^{235}U$,[3] which is the value, then, of $S_0^0 = S_0 = g_0^0$ to be used in the calculations. This and all the values, $S_j$, are nonrandom variables. The random variables are the assay results and the subsequent estimates of the true values.

We proceed now as though the uncorrected counts were of the form of Eq. 2 and describe what the scanner does. "Corrected count" in what follows means "corrected" by the scanner. Then the corrected count on a standard is

$$N_j = bS_j^0(1 - \mu S_j^0)(CF)_j$$

and the scanner computes the count rate to be

$$F_j = b(S_j^0/S_j)(1 - \mu S_j^0)(CF)_j \qquad (3)$$

The corrected net count on a sample is

$$N_i = bg_i^0(1 - \mu g_i^0)(CF)_i$$

and the scanner reports the assay to be

$$A_{ij} = g_i^0(S_j/S_j^0)\frac{(1 - \mu g_i^0)}{(1 - \mu S_j^0)}[(CF)_i/(CF)_j] \qquad (4)$$

None of the observation equations of the form of Eq. 4 will have i = j.

An exact solution of our least squares problem is inherently impossible. In effect, we must determine two parameters, the b and the $\mu$ of Eq. 2, with the single known mass obtained from the destructive analysis of 3J23. On the grounds that the nominal masses could be expected to be nearly correct and that any error to be reasonably expected in $\mu$ would make a negligible contribution to the error in a final assay, we used the two values of the count rate, F, that we had for each of the four tubes, with $S_j^0 = S_j$ in Eq. 3, to find

$$\mu = (2.576 \pm 0.076) \times 10^{-3}\ g^{-1}.$$

We then used this value of $\mu$ as a nonrandom variable in the observation Eq. 4 to find the least squares estimates of the true mass values, those with the zero superscripts. Individual observations, rather than averages as shown in Table I, were used, and they were weighted inversely proportionally to the squares of the errors reported by the scanner. We had 72 observation equations on the three masses; only two of the latter, of course, appears in each equation. It is when setting these equations up that one must remember that, for instance, tube 9S has the same mass whether it appears as $g_1{}^0$ or $S_1{}^0$.

Since the observation equations are nonlinear in the superscripted masses, an iterative procedure was set up. Four passes were required, and the final results were

$$S_1(9S) = 33.716 \pm 0.045 \text{ g},$$
$$S_2(12P) = 73.234 \pm 0.111 \text{ g},$$
$$S_3(15B) = 60.682 \pm 0.087 \text{ g}.$$

These, then, are the values to be used instead of the nominal masses during the calibration phase when newly manufactured tubes are to be assayed.

## ASSAY

The assay equation is found from Eq. 4 by setting $S_j = S_j{}^0$ and dropping subscripts and superscripts, except that distinction between the two values of CF must be maintained. It is convenient to define r as the ratio of CF for the standard to that for the sample. Then the assay reported by the scanner is

$$A = g\,\frac{1 - \mu g}{1 - \mu S} \cdot \frac{1}{r}$$

and

$$g = \frac{1}{2\mu}\{1 - [1 - 4\mu r A(1 - \mu S)]^{\frac{1}{2}}\}$$

is the final, corrected assay. Even if the standard tube of the same type as the one being assayed is used in the calibration phase, it is important to recognize the possible differences between g and A. At S = 70 g, for instance, the difference between g and A will be about a quarter of a gram for every gram difference between G and S.

## DISCUSSION

The weak point in the analysis is, of course, the fact that we only had the destructive analysis of one tube available. Although it is true that b does not appear in Eq. 4 explicitly, it appears implicitly in the values of $S_j{}^0$. One needs more than the one piece of information represented by the analysis of 3J23 to determine a slope and an intercept. The other "information" we used was the assumption $S_j = S_j{}^0$ for the determination of $\mu$.

Nevertheless, we think that this approach, or one similar to it, would make the scanner applicable to the assay of almost any type of well-defined samples. Even for samples that do not depart so greatly in form from those for which a scanner is set up, as did ours, we also think it advisable to intercompare two standards in the manner done here whenever the best accuracy is needed.

## REFERENCES


[1] L. V. East, R. Gatti, and S. Wawrowski, *Automated Gamma Ray Scanning System for Waste Drum Assay*, Journal of the INMM, Vol. V, No. III, Fall 1976, p. 137.

[2] J. L. Parker and T. D. Reilly, *Transmission Measurement Correction for Self-Attenuation in Gamma-Ray Assays of Special Nuclear Materials*, Journal of the INMM, Vol. V. No. II, Summer 1976, p. 58.

[3[ We appreciate the efforts of E. R. Ebersole of ANL-West in providing this analysis.


# IAEA Support

**(Continued from Page 1)**

the IAEA should do this or that in other countries, as long as we don't feel any impact here. Without any first-hand experience, we are not in a position to assess the safeguards advantages or disadvantages of proposals which appear to make sense theoretically.

Hopefully the Senate will soon ratify the IAEA agreement and implementation will start. Government agencies, contractors, and licensees will have to devote a considerable amount of effort to get the system started. While this will be a burden, it is also an opportunity. Each individual and organization involved, should give thought to the objectives of this program and to the details of how it is being implemented. Then, we can compare notes with our friends in other countries, who are already involved, and with them work to make the IAEA the effective organ for peace which it should be.

# Extension of Grubbs' Method When Relative Biases Are Not Constant

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## Introduction

The problem of estimating errors of measurement when two or more measurement "methods" are used to measure each of n items has been considered in previous INMM Journal articles [1], [2], [3], [4]. The term "methods" is used in a general sense and may apply to different analytical techniques, different laboratories, etc. In the example in [3], the methods referred to six different scales in a fuel fabrication plant, while in the example in [5], the different methods consisted of two laboratories with several individuals performing measurements of pellet densities using either the geometric or immersion technique. In [6], the example is concerned with the measurement of stress at 600% elongation of seven rubber samples as measured by 13 laboratories, using data reported by Mandel [7].

The general method of estimation under discussion in [1]-[5] is known as Grubbs' method for N instruments [8]. With Grubbs' method, it is assumed that any relative biases among the measurement methods are constant. For example, measurement method 2 may systematically produce readings higher than measurement method 1 by $\Delta$ units; the quantity $\Delta$ must be the same for all items in order for Grubbs' method to apply.

Situations are encountered in which this assumption is not valid. If Grubbs' method for constant relative biases is applied in such a situation, the resulting estimates of measurement precisions are not valid. In order to handle the non-constant bias model, Grubbs' method was extended by the author several years ago and applied to the non-destructive evaluation of reactor fuel element quality for the Hanford production reactors [9]. The same problem had been considered by Mandel and Lashof in an earlier paper [10], but they used a different estimation method, one based on linear regression.

The purpose of this paper is to call to the attention of the INMM Journal readership that Grubbs' method requires constant relative biases among the various measurement methods, to give the procedures for estimating measurement precisions when biases are not constant, and to apply these procedures to an example pertinent to safeguards using recent data reported by Walton [11] on the measurement of uranium in incinerator ash.

## The Model for Constant Bias

Let there be N measurement methods with n items measured by each method. The total number of data points is nN. Let $y_{ji}$ be the measured value for method j on item i: (j=1,2,...,N); (i=1,2,...,n). Then, the model for which Grubbs' method applies is of the form:

$$y_{ji} = \Delta_j + x_i + \varepsilon_{ji} \tag{1}$$

where $\Delta_j$ is the bias for method j, $x_i$ is the true value of the measured characteristic for item i, and $\varepsilon_{ji}$ is the random error of measurement. The quantity $\varepsilon_{ji}$ is a random variable with expected value zero and variance $\sigma_j^2$. The problem under consideration is to obtain the estimates of $\sigma_j^2$.

In what follows, it is assumed that the number of measurement methods, N, is greater than two. This is the only situation in which Grubbs' method can be extended to the non-constant bias model in the absence of further information. For N>2, then, Grubbs' method involves calculating the paired differences for all pairs of methods, j and k:

$$y_{ji}-y_{ki} = (\Delta_j-\Delta_k) + (\varepsilon_{ji}-\varepsilon_{ki}) \tag{2}$$

The variance of these differences is calculated for each pair and denoted by $V_{jk}$. It is readily apparent that $V_{jk}$ has expected value given by

$$E\ (V_{jk}) = \sigma_j^2 + \sigma_k^2 \tag{3}$$

Grubbs' estimates for N>2 are the least squares estimates derived from the N(N-1)/2 equations of the form (3). Step by step procedures for finding these least squares estimates are given in reference [3].

## The Model for Non-Constant Biases

When $\Delta_j$ of (1) is item dependent, and when this dependence is a linear one, then model (1) may be rewritten as follows:

$$y_{ji} = \alpha_j + \beta_j x_i + \epsilon_{ji} \tag{4}$$

First, consider the calculated variance among the $y_{ji}$ values for method j:

$$s_j^2 = \left[\sum_{i=1}^{n} y_{ji}^2 - \left(\sum_{i=1}^{n} y_{ji}\right)^2 \Big/ n\right] \Big/ (n-1) \tag{5}$$

It is easily seen from (4) that this has expected value:

$$E\ (s_j^2) = \beta_j^2\ \sigma_x^2 + \sigma_j^2 \tag{6}$$

Next, consider the calculated covariance between the $y_{ji}$ and $y_{ki}$ values:

$$s_{jk} = \left[\sum_{i=1}^{n} y_{ji} y_{ki} - \left(\sum_{i=1}^{n} y_{ji}\right)\left(\sum_{i=1}^{n} y_{ki}\right) \Big/ n\right] \Big/ (n-1) \tag{7}$$

This has expected value

$$E\ (s_{jk}) = \beta_j \beta_k \sigma_x^2 \tag{8}$$

The estimates of the $\beta_j$ (j=2, 3,...,N) and of $\sigma_x^2$ are derived from equations (8), having arbitrarily set $\beta_1$=1 so that all $\beta$'s are relative to method 1. (Any method may be chosen as the base method in estimating $\sigma_j^2$. It is true that the estimate of $\sigma_x^2$ does depend on which method is chosen as the base method, but $\sigma_x^2$ is only of interest in many applications as the result of a side calculation used in estimating the other parameters). Having found estimates of the $\beta$'s and of $\sigma_x^2$ from equations (8), these are now used in equations (6) to obtain the estimates of $\sigma_j^2$ for j=1,2,...,N.

## Estimating Equations

The estimating equations for the non-constant bias (NCB) model are, first of all, derived as the least squares solutions of (8) after taking logarithms to change to an additive model and replacing $E(s_{jk})$ by $s_{jk}$. There are N(N-1)/2 equations of the form

$$\ell n\ s_{jk} = \ell n\ \beta_j + \ell n\ \beta_k + \ell n\ \sigma_x^2 \tag{9}$$

These N(N-1)/2 equations involve N parameters: $\beta_2$, $\beta_3$, ..., $\beta_N$ and $\sigma_x^2$, since $\beta_1$ was set equal to 1.

The estimating equations are then as follows, as given in [5].

$$\hat{\beta}_j = \left(\prod_{k\neq 1,j}^{N} s_{jk}/s_{1k}\right)^{1/(N-2)} \quad ; j=2,3,\ldots N \tag{10}$$

$$\hat{\sigma}_x^2 = \left(\prod_{\substack{j=3 \\ k<j,\neq 1}}^{N} s_{1j}s_{1k}/s_{jk}\right)^{2/(N-1)(N-2)} \tag{11}$$

$$\hat{\sigma}_1^2 = s_1^2 - \hat{\sigma}_x^2 \tag{12}$$

$$\hat{\sigma}_j^2 = s_j^2 - \hat{\beta}_j^2\ \hat{\sigma}_x^2 \tag{13}$$

For example, if N=3, then

$$\hat{\beta}_2 = s_{23}/s_{13} \qquad \hat{\sigma}_1^2 = s_1^2 - s_{13}s_{12}/s_{32}$$

$$\hat{\beta}_3 = s_{23}/s_{12} \qquad \hat{\sigma}_2^2 = s_2^2 - s_{12}s_{23}/s_{13}$$

$$\hat{\sigma}_x^2 = s_{13}s_{12}/s_{32} \qquad \hat{\sigma}_3^2 = s_3^2 - s_{23}s_{13}/s_{12}$$

As another example, for N=4,

$$\hat{\beta}_2 = \left[(s_{23}/s_{13})(s_{24}/s_{14})\right]^{1/2}$$

$$\hat{\beta}_3 = \left[(s_{32}/s_{12})(s_{34}/s_{14})\right]^{1/2}$$

$$\hat{\beta}_4 = \left[(s_{42}/s_{12})(s_{43}/s_{13})\right]^{1/2}$$

$$\hat{\sigma}_x^2 = \left[(s_{13}s_{12}/s_{32})(s_{14}s_{12}/s_{42})(s_{14}s_{13}/s_{43})\right]^{1/3}$$

The pattern is evident.

The variances of the various estimates and the covariances between pairs of estimates are given in [5]. The expressions are complicated and are not reproduced here. They will not be used in the example to follow.

## Example Application

In a recent report dealing with nondestructive assay measurements in uranium enrichment plants [11], Walton gives results for three methods used in measuring the amounts of U-235 in 10 samples of incinerator ash (Table IX in reference). The three measurement methods are sampling/analytic, gamma ray assay, and neutron coincidence. Deleting the sample with ID number 8452, whose gamma ray assay result appears to the author to be an outlier, the results for the remaining 9 samples are reproduced in Table I.

Table I

U-238 (Grams) for Three Methods of Measuring Uranium in Incinerator Ash

| ID# | Method 1 Sampling/ Analytic | Method 2 Gamma Ray Assay | Method 3 Neutron Coincidence |
|---|---|---|---|
| 8449 | 542 | 509 | 450 |
| 8447 | 1485 | 1461 | 1550 |
| 8450 | 995 | 929 | 870 |
| 8453 | 934 | 877 | 890 |
| 8451 | 925 | 865 | 860 |
| 8444 | 934 | 930 | 960 |
| 8441 | 1361 | 1327 | 1340 |
| 8442 | 343 | 302 | 280 |
| 8443 | 616 | 585 | 560 |

## Analysis by Grubbs' Method

In applying Grubbs' method, which assumes constant biases, the three columns of differences are formed:

| 1-2 | 1-3 | 2-3 |
|---|---|---|
| 33 | 92 | 59 |
| 24 | -65 | -89 |
| 66 | 125 | 59 |
| 57 | 44 | -13 |
| 60 | 65 | 5 |
| 4 | -26 | -30 |
| 34 | 21 | -13 |
| 41 | 63 | 22 |
| 31 | 56 | 25 |

The three variances are calculated with the results:

$$V_{12} = 384.11; \quad V_{13} = 3384.00; \quad V_{23} = 2148.19$$

The following three equations are then solved simultaneously:

$$\sigma_1^2 + \sigma_2^2 = 384.11$$

$$\sigma_1^2 + \sigma_3^2 = 3384.00$$

$$\sigma_2^2 + \sigma_3^2 = 2148.19$$

The solution is

$$\hat{\sigma}_1^2 = 809.96 \text{ g}^2; \ \hat{\sigma}_2^2 = -425.85 \text{ g}^2;$$

$$\hat{\sigma}_3^2 = 2574.04 \text{ g}^2$$

Since a variance cannot be negative, the estimate of $\sigma_2^2$ is set at zero and $\sigma_1^2$ and $\sigma_3^2$ are re-estimated by least squares from the following three relationships.

$$\sigma_1^2 = 384.11$$

$$\sigma_1^2 + \sigma_3^2 = 3384.00$$

$$\sigma_3^2 = 2148.19$$

The least squares estimates reduce to

$$\hat{\sigma}_1^2 = [(2)(384.11) + 3384.00 - 2148.19]/3$$

$$= 668.01 \text{ g}^2$$

$$\hat{\sigma}_3^2 = [-384.11 + 3384.00 + 2\ (2148.19)]/3$$

$$= 2453.09 \text{ g}^2$$

In summary, by Grubbs, the estimates of the parameters are:

$$\hat{\sigma}_1 = 25.8 \text{ g U-238}$$

$$\hat{\sigma}_2 = 0$$

$$\hat{\sigma}_3 = 49.3 \text{ g U-238}$$

## Analysis for NCB Model

For the non-constant bias model, the three variances and three covariances for the Table I data are calculated:

$$s_1^2 = 135705.11 \qquad s_{12} = 136362.38$$

$$s_2^2 = 137403.75 \qquad s_{13} = 148157.78$$

$$s_3^2 = 163994.44 \qquad s_{23} = 149625.00$$

Then, by the equations for N=3 following the more general equations (10)-(13), the pertinent estimates are:

$$\hat{\beta}_2 = 1.0099 \qquad \hat{\sigma}_1^2 = 679.90 \text{ g}^2$$

$$\hat{\beta}_3 = 1.0973 \qquad \hat{\sigma}_2^2 = -309.04 \text{ g}^2$$

$$\hat{\sigma}_3^2 = 1426.82 \text{ g}^2$$

As with Grubbs, the estimate of $\sigma_2^2$ is negative for the NCB model. Replacing this by zero in equations (6) and (8), and replacing $E(s_j^2)$ and $E(s_{jk})$ by $s_j^2$ and $s_{jk}$ respectively gives

$$135705.11 = \sigma_x^2 + \sigma_1^2 \qquad 136362.38 = \beta_2\ \sigma_x^2$$

$$137403.75 = \beta_2^2\ \sigma_x^2 \qquad 148157.78 = \beta_3\ \sigma_x^2$$

$$163994.44 = \beta_3^2\ \sigma_x^2 + \sigma_3^2 \qquad 149625.00 = \beta_2\ \beta_3\ \sigma_x^2$$

The four equations <u>not</u> involving $\sigma_1^2$ and $\sigma_3^2$ are now solved for $\sigma_x^2$, $\beta_2$, and $\beta_3$ by least squares, after taking natural logarithms. These become

$$11.8307 = 2\ \ln \beta_2 + \ln \sigma_x^2$$

$$11.8231 = \ln \beta_2 + \ln \sigma_x^2$$

$$11.9060 = \ell n\ \beta_3 + \ell n\ \sigma_x^2$$

$$11.9159 = \ell n\ \beta_2 + \ell n\ \beta_3 + \ell n\ \sigma_x^2$$

The least squares solutions are easily found to be

$$\ell n\ \hat{\sigma}_x^2 = [-11.8307 + 5\ (11.8231) + 3\ (11.9060) - 3\ (11.9159)]/4$$

$$= 11.8138 \quad ; \quad \hat{\sigma}_x^2 = 135103.98\ g^2$$

$$\ell n\ \hat{\beta}_2 = (11.8307 - 11.8231 - 11.9060 + 11.9159)/2$$

$$= 0.0088 \quad ; \quad \hat{\beta}_2 = 1.0088$$

$$\ell n\ \hat{\beta}_3 = (-11.8231 + 11.9159)$$

$$= 0.0928 \quad ; \quad \hat{\beta}_3 = 1.0972$$

Then, $\sigma_1^2$ and $\sigma_3^2$ are estimated by the remaining two relationships.

$$\hat{\sigma}_1^2 = 135705.11 - 135103.98 = 601.13\ g^2$$

$$\hat{\sigma}_3^2 = 163994.44 - (1.0972)^2\ (135103.98)$$

$$= 1349.81\ g^2$$

In summary, by the NCB model, the estimates of the parameters are:

$\hat{\sigma}_1 = 24.5$ g U-238 (compare with 25.8 by Grubbs)

$\hat{\sigma}_2 = 0$ (compare with 0 by Grubbs)

$\hat{\sigma}_3 = 36.7$ g U-238 (compare with 49.3 by Grubbs)

## Comments on Example

**A plot of the data in Figure (1) indicates why the precision estimates for the neutron coincidence method differ so drastically under the two models. It is evident that the underlying model for the Grubbs' analysis is not valid.**

The actual measurement error for the neutron coincidence method is not properly described by only a random component because of the measurement bias (relative to the other two methods) that is rather strongly dependent on the amount of U-238 in the ash.

## General Comments

As was pointed out in [1], it is important that the validity of the assumptions underlying a given method of statistical analysis be checked before proceeding with the analysis. When applying the Grubbs' method of estimating measurement precisions (random error), it is assumed that any biases that exist among the methods are constant, i.e., are independent of the value for the item being measured. If this assumption is not valid, then the resulting estimate of the measurement precisions are affected. In such a case, the proper error structure is one that includes both a systematic component that is dependent on the value of the item being measured, and a random component. A method of estimating measurement errors in a non constant bias situation may be applied [5].

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[5] Jaech, John L., "Large Sample Tests of Significance for Grubbs' Estimators With More Than Two Instruments," Technometrics, 18, No. 2, May, 1976.

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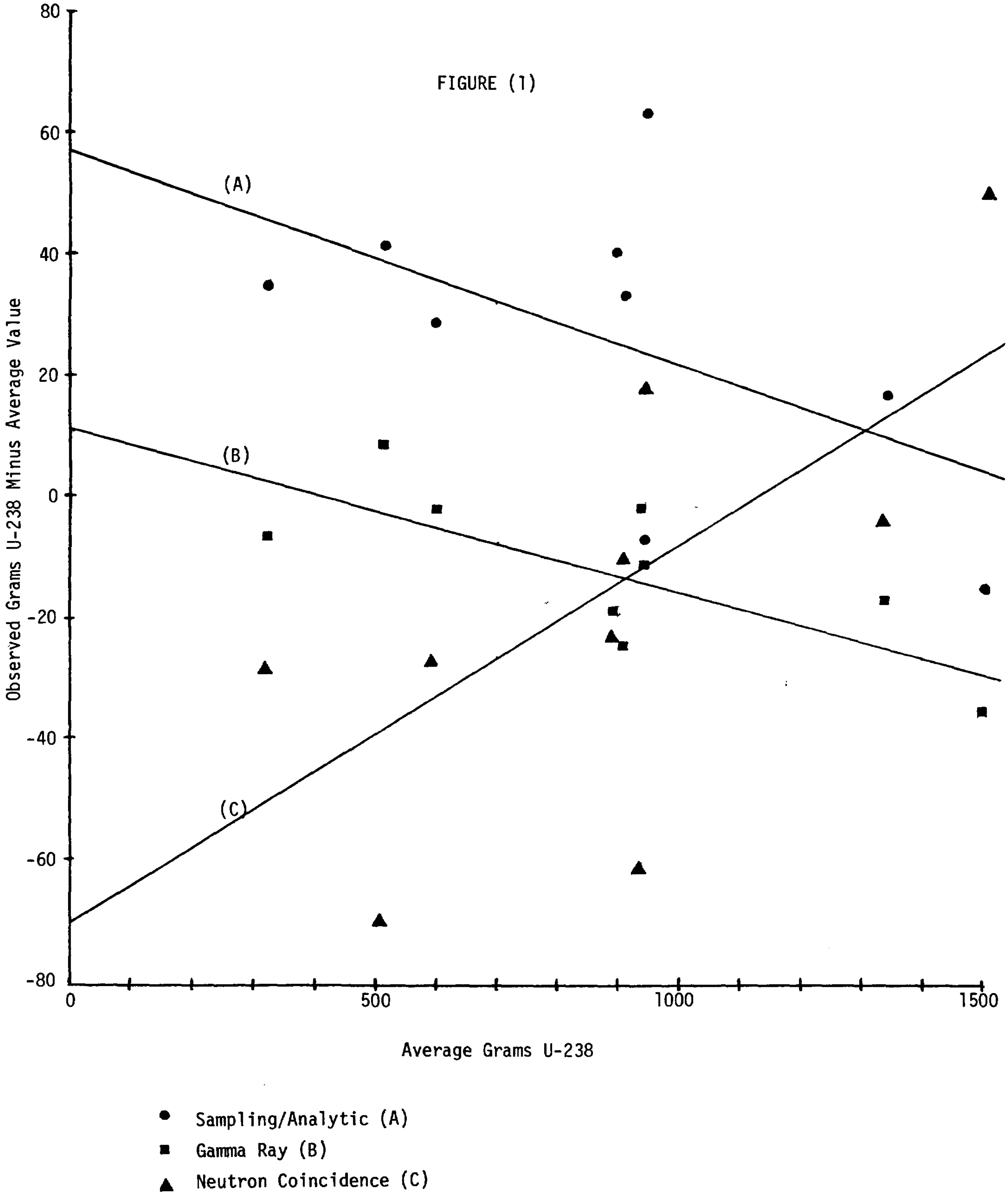


FIGURE (1)
80
60
40
20
0
-20
-40
-60
-80
Observed Grams U-238 Minus Average Value
(A)
(B)
(C)
0
500
1000
1500
Average Grams U-238
Sampling/Analytic (A)
Gamma Ray (B)
Neutron Coincidence (C)

# Improved Isotopic Inventory Prediction Methods

By **R.A. Kramer**
Northern Indiana Public Service Co.
Chesterton, Indiana
and
**O.H. Gailar**
Purdue University
Nuclear Engineering Department
Lafayette, Indiana

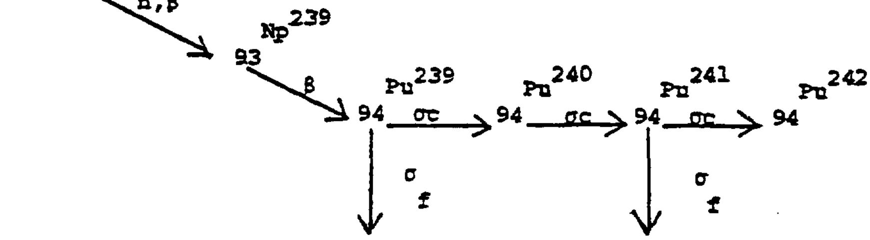
In a previous paper a method was described by which the correlation between the isotopic concentration for $U^{238}$ predicted by the Leopard computer program and reactor data was improved from 12% to -.5% at 20,000 Mwd/T by use of the L-factor technique.[1] This improvement is based on a modification to the method by which the resonance absorption is calculated. A key factor in this work has been the comparison of calculated values with values obtained from the plant process computer of the Quad Cities reactor owned by Commonwealth Edison Co.

In addition to the problem associated with the $U^{238}$ isotopic prediction, there are also problems relating to the other isotopes such as $Pu^{239}$. This problem was not changed appreciably by the L-factor technique for $U^{238}$. Initially, an L-factor was also input for $Pu^{239}$. This change had little effect on the predicted $Pu^{239}$ concentrations. Hence, an investigation of the $Pu^{239}$ burnup chain was started.

The $U^{238}$ chain used by Leopard is as follows.[2]

U-238 Chain, Neglecting
Short-Lived and Low Cross
Section Stages

Captures in Pu-242
result in a zero-cross
section daughter,
arbitrarily.



$\beta$ decay

$t_{1/2} = 0$

The concentration for nuclides can be found as follows:

$$\dot{N}_i(t) = -N_i(t)\int_0^{10\ Mev} \sigma_{a,i}\phi dE + N_{i-1}(t)\int_0^{10\ Mev} \sigma_{c,i-1}\phi dE$$

where the term on the left side is the time rate of change of the nuclide under consideration. The first term on the right side is the loss due to absorption of neutrons by the nuclide under consideration. The second term on the right side is the gain of the nuclide by transmutation of the precursor.

In the $U^{238}$ chain the following equations apply:

$U^{238}$: $\dot{N}^{28} = -N^{28} \int\sigma_a^{28} \phi dE$

$Pu^{239}$: $\dot{N}^{49} = -N^{49}\lambda_{49} - N^{49} \int\sigma_a^{49} \phi dE + N^{28} \int\sigma_c^{28} \phi dE$

$Pu^{240}$: $\dot{N}^{40} = -N^{40} \int\sigma_a^{40} \phi dE + N^{49} \int\sigma_c^{49} \phi dE$

$Pu^{241}$: $\dot{N}^{41} = -N^{41}\lambda_{41} - N^{41} \int\sigma_a^{41} \phi dE + N^{40} \int\sigma_c^{40} \phi dE$

$Pu^{242}$: $\dot{N}^{42} = -N^{42} \int\sigma_a^{42} \phi dE + N^{41} \int\sigma_c^{41} \phi dE$,

where $\sigma a$ = total absorbtion cross section and $\sigma c$ = capture cross section. In the evaluation of these equations, a basic assumption is made that $\int_0^{10\ Mev} \sigma\phi dE$ is constant through the time step.

The above equations can be solved by the method of Laplace Transforms. Laplace transforms of the terms in the $Pu^{239}$ equation are as follows:

$$L(\dot{N}_{49}) = SN_{49}(s) - N_{49}^0$$

$$L(-N_{49}\lambda_{49}) = -N_{49}(s)\lambda_{49}$$

$$L(-N_{49}\int\sigma_a^{49} \phi dE) = -N_{49}(s) \ (\int\sigma_a^{49} \phi dE) \equiv -N_{49}(s)\ A_{49}$$

$$L(N_{28} \int\sigma_c^{28} \phi dE) = N_{28}(s) \ (\int\sigma_c^{28} \phi dE) \equiv N_{28}(s)\ C$$

Replacing the terms in the $Pu^{239}$ concentration equation above with these transformed values gives:

$$SN_{49}(s) - N^0_{49} = -N_{49}(s)\lambda_{49} - N_{49}(s)\ A_{49} + N_{28}(s)\ C$$

or

$$(S + \lambda_{49} + A_{49})N_{49}(s) - N_{49}^0 = N_{28}(s)\ C$$

or

$$(S + A_{49} + \lambda 49)\ N_{49}(s) = N_{49}^0 + N_{28}(s)\ C$$

or solving for $N_{49}(s)$

$$N_{49}(s) = \frac{N_{49}^0 + N_{28}(s)\ C}{S + A_{49} + \lambda_{49}}$$

If we define $A = A_{49} + \lambda 49$ in the above equation, it follows that:

$$N_{49}(s) = \frac{N_{49}^0 + N_{28}(s)\ C}{S + A}$$

since,

$$L^{-1}\left(\frac{1}{s+a}\right) = e^{-at}$$

it follows that

$$N_{49}(t) = Be^{-At}$$

where $B = N_{49}^0 + N_{28}C$

$= N_{49}^0 + N_{28} \int\sigma_c^{28} \phi dE$

and $A = \int\sigma_a^{49} \phi dE + \lambda_{49}$

The above isotopic chain concentration values are evaluated in various subroutines in Leopard and an eventual isotopic concentration is calculated in the MASSED subroutine. One of the basic parameters needed for this calculation is a variable called A. This value is obtained from the BURN subroutine. A is partially calculated from an equation of the form:

$$A(2) = B(2)e^{-A(1)c}$$

where c is constant.
This equation is the same form as that derived above.

In this equation a flux weighting of the cross sections is done of the form:

$$\frac{(\sigma_{a1}\phi_1 + \sigma_{a1}\phi_2 + \sigma_{a1}\phi_3)}{\phi_1 + \phi_2 + \phi_3}$$

where $\sigma an$ = group n absorption cross section and $\phi n$ = group n flux.

In an effort to improve the isotopic prediction consistency for $Pu^{239}$, the above method of flux weighting was changed to the following form:

$$\frac{(\sigma_{a1}\phi_1 + \sigma_{a2}\phi_2 + \sigma_{a3}\phi_3)}{\phi_1 + \phi_2 + \phi_3}$$

With this modification the difference in concentrations (kg/T) between calculated and operating data for $Pu^{239}$ drops from 2% to 1% at 20,000 Mwd/T.

In addition to the reductions in the difference from operating data for $Pu^{239}$, reductions in difference were also noticed for $Pu^{241}$ and $Pu^{242}$. The $Pu^{240}$ difference was increased slightly.

A comparison of this method with other programs has been made. EPRI-CEll[3] was run on an IBM 370/138. Typical execution times were 110 min. CPU time for 14 burnup steps. Similar isotopic calculations can be done on the Leopard system in 4 min. CPU on an IBM 370/158 with less accuracy but with a slight fraction of the computer storage and CPU time required for EPRI-CEll.

A graph of Leopard and EPRI-CEll number densities (atoms/barn-cm) for $Pu^{239}$ is shown in Figure 1 for a general BWR fuel assembly. In this graph the method described above was used for $Pu^{239}$ values. EPRI-CEll was chosen for the purposes of comparison in this case since a large amount of work has been done with EPRI-CEll in regard to isotopic benchmarking. EPRI-CEll is benchmarked against experimental isotopic data from Yankee stainless steel clad, Yankee zincaloy clad, Saxton, and Robinson fuel assemblies.

In an effort to make both the L-factor technique and the method described above converge, an L-factor has been calculated using the version of Leopard modified for the $Pu^{239}$ calculation. This value is then input to the program and burnup cases are run. Using this procedure, an improvement is noticed in both $U^{238}$ and $Pu^{239}$ values over the L-factor technique alone. There are still inconsistencies between the two methods, but it appears that the methods are compatible and that proper changes will be made to benchmark parameters in Leopard in the near future to make the two methods more consistent and hence give better values for both $U^{238}$ and $Pu^{239}$ simultaneously.

A major problem that is facing a variety of groups today is the determination of possible diversions and/or modifications to power reactor fuel. One possible problem of this type could be postulated by assuming that fuel pins are removed from a fuel assembly and are replaced with natural enrichment pins. The Leopard system described above runs quickly and with little computer space required. It could be of aid in this type of an analysis.

This system is also presently being automated by the use of a micro computer system based on the Texas Instruments 9900 16 bit central processor chip. One task of this system is to provide a front end package to Leopard to speed the input of specific fuel design data. Another project is the construction of a data base that will allow the micro computer system to evaluate anticipated isotopic concentrations from previous Leopard cases. Work is further being done to allow condensation of certain parts of the Leopard computer program into the microprocessor itself.

A least squares curve fit routine is used to detect the difference in slopes between anticipated isotopic concentration plots versus burnup and should, after further development, allow the detection of the pin replacement problem that was postulated above. A further expansion of this system to a data base containing power levels correlated with gamma scan data by means of thermal flux and power-sharing fractions is also planned. This seems feasible by use of a nodal computer code such as Flare, the Leopard computer program, and the large amount of gamma scan data that has been published.[4,5,6] The ability of this system to detect the replacement of fuel pins is a function of the number of pins removed. The minimum number of removed pins that is detectable will depend on the accuracy of the calculational model, the accuracy and completeness of the gamma scan data, and the efficiency of the method used to couple the two. Figure 2 is a plot of the number of pins missing versus thermal flux.

It should be stressed that these methods are not anticipated to provide the sophistication or accuracy of some of the presently available systems. They do provide, however, a quick and relatively simple method of verifying some parameters to a known degree of accuracy. The microprocessor system presently operating and under development could be carried in a suitcase and hence could be of use when portability is required.

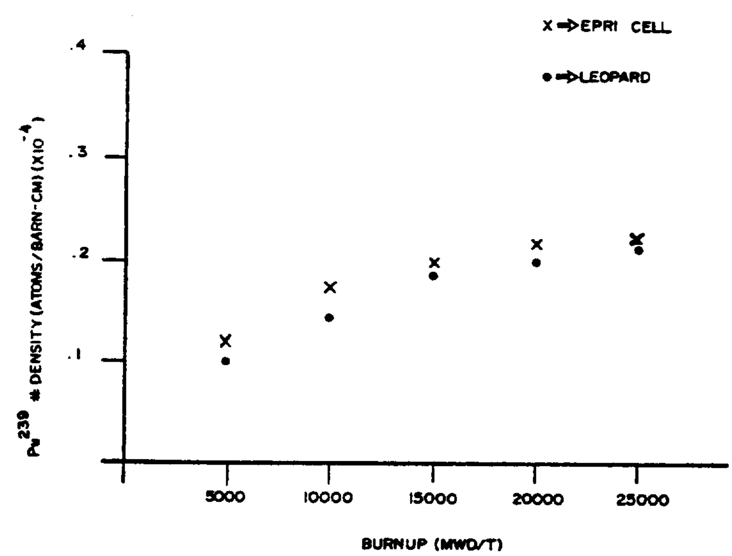



FIGURE 1

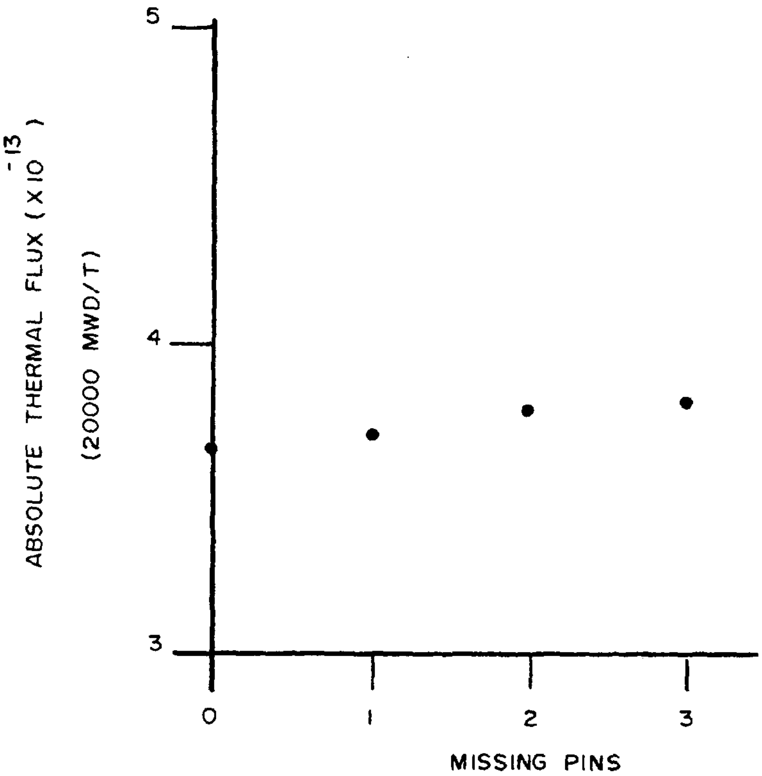



FIGURE 2

## References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# INDEX OF ARTICLES (1972-1979)

**Editor's Note:** For years 1972-1977 (Volumes 1-6 of **Nuclear Materials Management**), No. 3 is the proceedings issue of that year. Beginning in 1978 (Volume VII), No. 3 becomes a regular issue of the Journal. The proceedings of the 1978 annual meeting is designated, Volume VII, Proceedings Issue. Future issues of the INMM Proceedings will be designated similarly, i.e., in 1979 it will be designated Volume VIII, Proceedings Issue. Copies of the tables of contents for INMM Proceedings issues are available on written request to the editors.

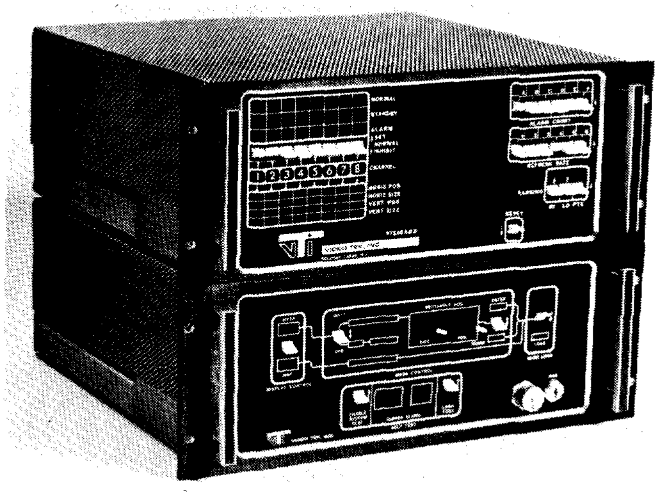
# Measurement of Dissolved Oxygen

Orbisphere Laboratories announces the publication of the book entitled "Measurement of Dissolved Oxygen" by Dr. **Michael L. Hitchman.** The book has been selected for publication by John Wiley & Sons for inclusion in the Science Series.

The text comprises 272 pages with many illustrations and drawings. Membrane covered polarographic oxygen sensors are discussed in detail and their use and application is well explained.

This book is "must reading" for oceanographers, limnologists, water treatment engineers, technical personnel, managers concerned with environmental monitoring, sewage treatment plant engineers, corrosion engineers, medical personnel, food producers, drug manufacturers, agronomists, power plant engineers, researchers of all areas of science where oxygen is an important ingredient for the process or reaction.

The book is priced at $25 and is available from Orbisphere Corporation, York, Maine 03909. Telephone number: (207) 363-4021.



## Motion Detector

Mountain Lakes, N.J.—Video Tek, Inc. announces its new generation of motion detectors, the MDU-2-CPR. This series of equipment is an extremely high resolution digital video intrusion detector which can perform surveillance activities presently performed by guards in large inside and outside areas. The detection probabilities can be in excess of 99.9%. Normal ambient motion is processed to eliminate false alarms.

Detection is based on light measurements made at over 16,000 locations in the monitored scene which are stored and subsequently compared with live incoming video. Locations where differences occur are processed to determine if the size and speed characteristics of the intrusion are in the range of the type of intrusion to be detected; if so, an alarm condition exists.

When alarmed, the equipment outputs alarm signals to devices such as video tape recorders, alarms, computers, etc. and displays the alarmed scene with a flashing history of the path of the intruder up to his present location superimposed on the scene.

One system can handle up to 16 cameras covering areas up to 25 acres and generally is compatible with existing closed circuit television installations.

## IAEA Publications Catalog

Over 800 publications on all areas of nuclear science are listed in this new catalog from the International Atomic Energy Agency (IAEA), available from UNIPUB.

This new 246-page catalog describes in detail publications in such areas as, the applications of nuclear science to medicine, biology, agronomy, chemistry, physics and geology. Nuclear safety, nuclear power, energy, environmental protection, theoretical and plasma physics are also included.

The IAEA is an autonomous intergovernmental organization under the aegis of the United Nations. UNIPUB is the exclusive distributor of IAEA publications in the United States.

The catalog is free upon request from UNIPUB, 345 Park Avenue South, New York, NY 10010.



## Tape Honored by AIF and ANS

AUI President **Gerald F. Tape** has been presented the **Henry DeWolf Smyth** Nuclear Statesman Award by the Atomic Industrial Forum and the American Nuclear Society. He received the gold medal award at a joint banquet of the two leading nuclear energy organizations on November 15 in Washington, D.C.

Named after Dr. Smyth, a pioneer nuclear scientist, policymaker and diplomat, the Nuclear Statesman Award was established in 1972 by the AIF and the ANS to recognize outstanding service in developing and guiding the uses of atomic energy in constructive channels. Dr. Tape was cited for his "reputation as a tireless worker for the policies and programs that would provide the benefits of atomic energy to all peoples of the world."

Besides his service to Brookhaven as deputy director from 1951 to 1962, and his leadership of AUI in the operation of the Laboratory and NRAO, Dr. Tape has held important national and international posts.

In 1963 he was nominated by President Kennedy to fill an unexpired term as a member of the U.S. Atomic Energy Commission, and was reappointed in 1966 by President Johnson. He resigned in 1969 to return to the presidency of AUI.

In June 1973, President Nixon appointed him as U.S. ambassador to the International Atomic Energy Agency, a special agency of the United Nations headquartered in Vienna, Austria. He served in this post until 1977, while continuing as president of AUI.

# NRC Chairman Hendrie Comments on Wilmington Incident

The FBI has reported to the Nuclear Regulatory Commission (NRC) that it has arrested a Wilmington, North Carolina, man on charges growing out of an alleged theft of low-enriched uranium oxide from a General Electric (GE) Company fuel plant at Wilmington. He is a temporary employee of a subcontractor at the plant. The plant is licensed by NRC.

The amount of material involved in the alleged theft is too small for any nuclear reaction. The type of material—low-enriched uranium—cannot be used to make a nuclear bomb. It also represents a minimal health hazard, and is less hazardous than many industrial chemicals.

An anonymous letter addressed to the plant manager was found in front of the manager's office door on January 29th demanding $100,000. The letter alleged that the writer was in possession of low-enriched material from the plant. A sample of the material also was left at the manager's door. The writer gave a time deadline of February 1st to pay $100,000 for return of the material. GE reported this matter to the NRC, which immediately notified the FBI.

The principal radiation hazard from low-enriched uranium oxide of the type used at the Wilmington plant is from inhalation of the material into the body. The uranium oxide would be a conspicuous brown dust if it were present in significant quantities. For an appreciable health hazard from inhalation to exist, an individual would have to remain in a thick cloud of the material for more than 10 minutes. This situation is fairly unlikely since the material is in powder form and would be visible. A large amount, 2 pounds or more, would have to be ingested with food to produce any radiation damage to the intestinal tract. Uranium is a heavy metal and also produces chemical effects similar to lead. Uranium oxide, because of its highly insoluble form, is less harmful than lead oxide as a chemical poison. Experiments on animals have shown no significant toxic effects from uranium oxide at amounts up to 20% (by weight) in the diet.

In view of the minimal health and safety hazards of this low-enriched material, NRC does not prescribe specific details of how it should be protected. NRC requirements for protection of this material are satisfied by reasonable industrial security measures appropriate for material which costs several hundred dollars per pound.

I have called FBI Director **William Webster** to compliment him on the Bureau's excellent work in this case. The quick arrest, which came three days after the FBI was notified, is a splendid example of investigative work.

Weisz

# Weisz Succeeds Lyon At DOE-OSS

**George Weisz** has been appointed as Director of the DOE's Office of Safeguards and Security. Weisz has served for more than 30 years in assignments generally related to national security with the Departments of State and Defense in the United States and abroad.

Weisz will report to Assistant Secretary for Defense Programs **Duane Sewell.** Weisz succeeds **Harvey Lyon,** who resigned January 13.

As director, he is responsible for the direction and conduct of those activities required for assuring adequate protection and response capabilities for DOE operations and other U.S. energy resources of importance to national security, specifically nuclear weapons and associated materials and facilities under the control of DOE, nuclear and non-nuclear energy related operations, classified information, and valuable government property. He will also support the U.S. non-proliferation objectives in the domestic and international areas.

Weisz, born in 1918 in Hungary of American parents, came to the U.S. in 1932. He attended New York University and received his B.A. degree in 1952. He received an M.A. degree in international economics from George Washington University in 1955 and attended the Executive Management Seminar at Columbia University in 1970.

He is married to Etta Joe McEndree of Russellville, KY. They have three grown children; Donald, David, and Nicolaine. Mr. and Mrs. Weisz live in Chevy Chase, MD.

Hawkins

# Hawkins Joins NUSAC

McLean, Virginia—**Ron L. Hawkins** has been named Senior Technical Associate in the Quality Program Division of NUSAC, Inc.

NUSAC President Dr. **Ralph F. Lumb** announced the appointment of Mr. Hawkins and said his responsibilities will include preparation and implementation of quality assurance programs for fabrication of nuclear reactor assemblies and components.

Mr. Hawkins will also be involved in the development of health physics and non-destructive assay programs and precedures. He will report to **Wilkins R. Smith,** Manager of the Quality Programs Division.

Mr. Hawkins comes to NUSAC from Nuclear Fuel Services, Inc., where he was Senior Non-Destructive Assay Specialist. He holds a B.A. degree in mathematics from King College.

NUSAC provides consulting services to the nuclear industry, including audits of various programs, design and implementation of physical security plans and procedures.

# Members Recognized

**C. Leslie Brown** of Battelle Pacific Northwest Laboratories was presented with the Nuclear Criticality Safety Division's Achievement Award during the ANS Winter Meeting in Washington, D.C., in recognition of his contributions in the field of nuclear criticality safety. Mr. Brown's an INMM member.

He has been in management four years and is currently Manager, Nuclear Analysis Section in the Energy Systems Department. His section has responsibility for projects involving safeguards, criticality and neutronics. His early background includes experience as an engineer in plutonium purification and fabrication at Hanford and projects in plutonium storage and transportation. (He says this experience is becoming less and less of an asset, because plutonium seems to be disappearing from the nuclear fuel cycle.)

Brown began his career with General Electric at Hanford as a chemist in the old bismuth phosphate and redox separations plants. He spent the 1950's at the 234-5 Building Plutonium Finishing Plant as a process engineer, which finally led to the field of nuclear criticality safety.

In 1959, he transferred to the Critical Mass Physics Section and trained in nuclear physics. He participated in many criticality experiments and progressed to Senior Criticality Safety Specialist.

His wife, Norma, is an avid follower of the national scene in nuclear energy. She follows the pro and con nuclear events even closer than Les. She is pro nuclear and gets quite upset with news reports that she knows to be biased against nuclear.

Author of 75 technical reports, he was chairman of the third International Symposium on Packaging and Transportation of Radioactive Materials in 1972. He was Co-Chairman of that second conference in 1968.

* * * * * * *

**Duane A. Dunn** is the Nuclear Materials Control Manager and Accountability Representative for Rockwell International, Energy Systems Group at Rocky Flats Plant. He has more than twenty-five years experience in Nuclear Materials Control and Management.

He attended the University of Iowa and Princeton University and received a B.S. degree in Accounting and Finance and a M.S. degree in Geology from the University of Colorado. He served in the U.S. Navy during World War II and the Korean Conflict and retired with the rank of Commander in U.S. Naval Reserve with 35 years service.

Mr. Dunn is a Certified Nuclear Materials Manager.

Brown

Dunn


Ahrens

Bellinger

Bieber

Cropp

Dudding

Edwards

Gailar

Hakkila

# ABOUT THE AUTHORS

**Janet S. Ahrens** (M.S., Electrical Engineering, Stanford University, 1977) is a member of the Security Systems Integration Division at Sandia Laboratories, Albuquerque, New Mexico. She is currently involved in the analysis of data concerning intrusion detection sensor performance at an operational security site.

**Frank O. Bellinger** (M.S., Physics, DePaul University, 1966) is a staff member of the Nondestructive Assay Section of the Special Materials Division at Argonne National Laboratory. His main responsibility is the development and application of radiometric assay techniques for the quantitative measurement of fissionable materials.

Dr. **Alan M. Bieber, Jr.** is with the Technical Support Organization for Nuclear Safeguards at Brookhaven National Laboratory. He has been at TSO since completing his doctoral research at BNL in 1975. Bieber's primary efforts are now involved with implementation of the US/IAEA Safeguards Agreement. His previous work has included development of a computer model for assessing fixed-site physical security and participation in physical security assessments at ERDA facilities. He is the author of "An Introduction to IAEA Facility Requirements" which appeared in the Fall 1978 issue (Vol. VII, No. 3) of this Journal.

**Louis O. Cropp** (M.S. Mechanical Engineering, University of Colorado, 1962) is a staff member in the Nuclear Security Systems directorate of Sandia Laboratories. He was project engineer for the control and display subsystem of the perimeter intrusion detection and assessment system described in the accompanying article. He has been involved in control and display aspects of fixed site and transportation safeguards systems for the past four years.

**Kathryn Eike Dudding** (B.A., Psychology, Tufts University, 1972) is a staff member of Computer Systems and Services at the General Electric Research and Development Center. She is currently providing software support on computer-aided manufacturing projects. As well as maintaining a simulation library, she is working on an automated production schedule generator for assembly line businesses to be used in conjunction with a management planning program. Her previous experience includes scientific, business and real-time instrumentation applications at Fisher Scientific Co., Tufts-New England Medical Center, and Tufts University.

**Lonnie D. Edwards** is a Senior Technician in the Nondestructive Assay Section of the Special Materials Division at Argonne National Laboratory. He is active in the development of nondestructive assay techniques for nuclear reactor fuels. He received extensive training in electronics at the Fort Bliss Air Defense School, Fort Bliss, Texas.

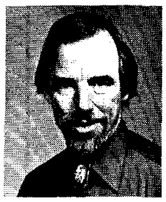
**Owen Gailar** (Ph.D., Purdue University, 1956) worked for Westinghouse Bettis from 1949 to 1957, then moved on to work at Combustion Engineering (1957-1961). He is currently an Associate Professor of Nuclear Engineering at Purdue University where he has taught since 1961.

**E. Arnold Hakkila** (Ph.D., Chemistry, Ohio State University, 1957) is Associate Group Leader of the Safeguards Systems Design Group at the Los Alamos Scientific Laboratory. He has worked in the Analytical Chemistry of the actinides, including development of x-ray fluorescence and absorption edge techniques. Recently, he has been involved with domestic and international safeguards systems design studios for nuclear fuel reprocessing and conversion facilities.

**John E. Hinde** (M.S., Electrical Engineering, University of Illinois) is supervisor of the Intrusion Detection Systems Division at Sandia Laboratories, Albuquerque, New Mexico. For the last twelve years, he has been involved in a variety of remote surveillance and intrusion detection projects for Department of Defense and safeguards applications. He is currently responsible for development of intrusion detection and assessment systems for upgraded physical security programs.

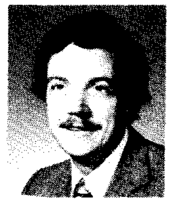
**John L. Jaech** (M.S., Mathematical Statistics, University of Washington, Seattle) is Staff Consultant, Statistics, Exxon Nuclear Co., Richland, WA. A frequent contributor to this journal, Mr. Jaech taught INMM-sponsored courses on statistics with applications to special nuclear materials this spring at Battelle Columbus Laboratories. He is the Technical Program Chairman for the 1979 INMM Annual Meeting July 16-19 at the Albuquerque Hilton. At the 1978 Annual Meeting in Cincinnati, he was presented a plaque "in recognition and appreciation of his outstanding contributions to the advancement of nuclear materials safeguards and to this society."

**Robert Kramer** (M.S., Purdue University, 1973) is a graduate student in Nuclear Engineering at Purdue University and is employed at Northern Indiana Public


Hinde


Jaech

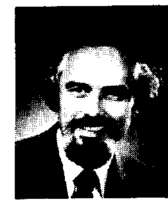

Kramer


Meenan


Osabe


Shu


Staroba


Suda

Service Company, Chesterton, as a Nuclear Fuel Engineer. He is also an associate faculty member at Indiana University, Northwest, in the Physics Department. He joined INMM three years ago, and has been a member of the standards subcommittee on audit techniques for the past two and a half years.

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**Sylvester Suda** is a Safeguards Specialist with the Technical Support Organization for Nuclear Material Safeguards at Brookhaven National Laboratory. From 1964 to 1968, Suda was supervisor of the Nuclear Material Group, Nuclear Fuel Services, Inc., West Valley, New York. A member of INMM since 1965, he was designated a Certified Nuclear Material Manager in 1969. He is Chairman of the Standards Writing Group on volume calibration and chairman of the INMM Safeguards Committee. Suda has served as a consultant to the IAEA, and is currently involved in an international exercise on reprocessing plant safeguards.

**Joe Watson** (B.S.E.E., Purdue University, 1949) is a staff member of the Automation and Control Laboratory at the General Electric Research and Development Center. He is responsible for research and development of advanced computational systems software and serves as Chairman of the Computer Workshops Council for the Company. He is currently involved in the development of Monte Carlo simulation software for financial planning. His previous contributions include creation of software for simulating conveyors and forklift truck operations in GE factories, and co-development of the general purpose ADA (Automated Dynamic Analyzer) computer program for transient analysis of systems.

**George H. Winslow** (D.Sc., Carnegie Institute of Technology) has been with the Nondestructive Assay Section of the Special Materials Division at Argonne National Laboratory since early 1976, having transferred there from the Chemistry Division. He is co-author, with **E.M. Pugh,** of the college text, *The Analysis of Physical Measurements,* Addison-Wesley (1966), and is author of the chapter, *Data Evaluation and Analysis,* Techniques of Metals Research, Volume 7, Part 1, **R.F. Bunshah,** ed., Wiley (1972). He is involved in the development of methods of measurement control, data analysis, and sampling. He maintains a liaison with the high-temperature chemists in the Chemistry and Chemical Engineering Divisions of Argonne.


Watson


Winslow