INMM

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IN THIS ISSUE

17th Annual Meeting, Institute of Nuclear Materials Management, Inc., Washington Plaza Hotel, Seattle, Wash., June 22-24, 1976.

THE INMM CHAIRMAN SPEAKS

Mr. Soucy

INSTITUTE MOVES FORWARD

By Armand R. Soucy, Chairman
Institute of Nuclear Materials Management, Inc.

It is a pleasure to report that during the past three months, INMM moved forward on several fronts. One of the most interesting possibilities is the organization of international chapters of INMM. It is my understanding that at the IAEA symposium held in Vienna in October, a group of about 30 people attended an informal meeting to discuss the initiation of a European Chapter of the Institute. We have also received an inquiry from the Executive Director of the Nuclear Material Control Center, Tokyo, Japan on the possibility of organizing a Japanese Chapter of the Institute. These indications of interest from our foreign members are encouraging, and in my view, the organization of International Chapters is a natural extension of the Institute's activities. It should also be noted that the Institute was extremely well represented at the IAEA symposium. Under the leadership of **Jim Lovett,** our members distributed the INMM Journal and conducted a membership campaign for foreign members.

During the second week of September, your officers held an executive committee meeting in Colorado Springs, Colorado. The meeting was well attended and a number of constructive steps were taken at the executive committee meeting. We are pleased to report that our former treasurer, **Ralph Jones,** has agreed to chair a committee on future planning. It is our view that the Institute has matured as an organization and we must reassess our future goals and commitments. Ralph, with his knowledge of the Institute and its members, together with his experience on both the government and industry sides of the nuclear industry, is well qualified to assess the future goals of the Institute.

We were extremely pleased to hear from **Dennis Wilson** that, based on his survey of our membership, approximately 150 Institute members have offered to participate in an INMM speakers bureau. Because public relations is such an important aspect of the Institute's potential efforts, it would be more effective to separate public relations from the safeguards committee. Organized as a separate committee, the public relations function would then report directly to the executive committee. We are presently considering expanding activities in the public relations area to include projects such as the development of a question and answer booklet which will present the facts on Nuclear Material Safeguards, the publication of unsolicited articles on pertinent topics in the area of safeguards, which would be distributed to magazines and newspapers, and the distribution of video tape discussions on the subject of safeguards. It is expected that we will be in a position shortly to announce the identity of the new Chairman of our Public Relations Committee, and together with the present indications of support from Dennis Wilson's survey, it appears that we will be in a position to embark on a revised public relations program. On the issue of video tape discussions, the executive committee and officers of the Institute had an opportunity to review a taping of our New Orleans meeting panel discussion. It is a pleasure to report that the results are quite impressive and that **Bob Keepin** is currently arranging to finalize a tape which will then be available to members of the Institute for use in our Public Speaking Program.

We are also pleased to report progress in a number of other areas of activities. **Manuel Kanter** reports that the Argonne Safeguards School has again concluded a successful educational program under the auspices of the Institute. For the first time, the educational program included a session on physical security which was extremely well received. Bob Keepin has already organized his program for the Seattle meeting, and our first indications are that it will again be a dynamic and controversial session.

We again invite you to provide us with your thought on how the Institute can be more effective in the area of nuclear materials management. Your input on all matters which relate to the Institute is essential to the continued progress of our organization.

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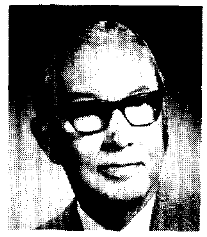


Dr. Higinbotham

EDITORIAL

Headaches and Opportunities

By W.A. Higinbotham

In the near future, the United States will implement the President's offer to put U.S. non-military nuclear facilities under IAEA safeguards. This probably will create some headaches for a number of us. It will also present us with opportunities to strengthen international cooperation.

The International Atomic Energy Agency (IAEA) was created by vote of the UN General Assembly in 1957. A nuclear non-proliferation treaty (NPT) was proposed to the UN by Ireland in 1959, but no significant progress took place until the U.S.A. and the U.S.S.R. agreed on a basic text in the fall of 1966. Many non-nuclear weapon states voiced objections to this draft when it was released. One of the complaints was that the nuclear weapon powers would not be subjected to IAEA inspection; that the inconvenience and the potential exposure of proprietary information which IAEA inspection would impose on non-nuclear weapon states would put them at a disadvantage vis-a-vis the nuclear weapon powers in the world market for nuclear fuels and power plants. In order to encourage these nations to ratify the NPT, the U.S.A. and the United Kingdom agreed to place their non-military nuclear facilities under IAEA. In 1970 the NPT came into force with ratification by the U.S.A., U.K., U.S.S.R. and over 40 other states.

It has taken a lot longer than people had hoped for the states that have ratified the NPT to work out their contracts with the IAEA. The arrangements with Euratom were particularly complicated, involving negotiations between Euratom and its member states in parallel with those between Euratom and IAEA. Also time-consuming are the definition of "facility attachments" which inform the IAEA of the characteristics of individual facilities and define the rights and the limitations for IAEA inspectors on a plant-by-plant basis.

It is not considered likely that the IAEA will elect to inspect all of the U.S. facilities which qualify. That would put a heavy burden on their limited staff. But our potential competitors in the nuclear field will want the selection of facilities to be fair to them. This suggests that few reactors will be selected but that several fuel fabrication facilities will be selected. We, in the U.S.A., will have to decide how the selection process will be fair to our competing companies. Presumably, all qualified plants will be required to supply information on receipts, shipments and inventories to IAEA as they now do to the Oak Ridge nuclear material information system.

The facility attachments and the reports will require some effort to implement, however IAEA requirements regarding material control and accounting are not as onerous as those imposed by ERDA or NRC. It is in these negotiations and in the subsequent cooperation with IAEA inspectors that the opportunities exist. Some other nations have tried to hold out for the absolute minimum of inspection. The U.S. would like

(Continued Inside Back Cover)

Mr. Cardwell

Seattle: Getting An Early Start

By Roy G. Cardwell
INMM Vice Chairman

Some of us are getting an early start for the next Annual Meeting coming up in Seattle in June. **Bill DeMerschman** has been rolling the ball for about eighteen months now, so he wins the FIFO Award . . . first in with plans and activities and first out with a report of what to expect.

And friends, what you can expect is f-a-n-tastic!

First off, Bill tells me that the hotel accommodations this year are much more spacious and suitable than previously. The Washington Plaza has more than adequate meeting space for all of our sessions plus over 600 sleeping rooms. It is located right in Seattle's business and financial district, but only twenty minutes from the Seattle/Tacoma International Airport.

For the "biggie," Bill has really gone all out. In the early evening of the closing day of our meeting (tentatively Thursday) we will all board the cruise ship GOODTIME (Dy-no-mite!) cruising along the Seattle waterfront past many points of interest, then cross Puget Sound passing around the north end of Bainbridge Island into Agate Pass. After this lovely one and one-half hour cruise, we will arrive at the Kiana Lodge in the Garden of the Gods. Awaiting our arrival will be a complete Potlatch Salmon Barbecue. And check this menu! Steamed little neck clams served from iron caldrons on the beach . . . barbecured fresh Neah Bay Salmon prepared over green adler coals . . . campfire style baked potatoes . . . hot garlic bread . . . salad, dessert, and beverage. Wow! I'll be glad to leave my country ham, blackeyed peas, and redeye gravy for that one.

And that ain't all!

Our Program Chairman **Bob Keepin** started work on the Seattle Program during the New Orleans meeting. Elsewhere in this issue Bob will tell you about it in more detail, but the shaping up has really begun and you can look out for our best program yet. Bob also tells me that there is much international interest this year, both in attendence and papers, and due I am sure to the activities of our INMM group at the Vienna meeting in October.

Our Call for Papers has been out for sometime now. Remember the deadline is March 1.

Don't miss Seattle . . . It'll be a great one!

Mr. DeVito

Enlarge Scope Of Public Relations Committee

By V.J. DeVito
Secretary of INMM

An Executive Committee meeting was held on September 11 and 12, 1975, in Colorado Springs, Colorado, at the Antlers Plaza Hotel.

The financial statements presented by **Ralph J. Jones** showed that for the fiscal year 1975 there was a net gain in the INMM financial balance of $3,372. The cash balance at the end of the year in the savings and checking accounts was $22,756. Mr. Jones reported the 1975 annual meeting in New Orleans was a financial success, noting that there were 330 in attendance. This exceeded the previous high in attendance by 80 registrants.

An operating budget of $25,900 has been approved for fiscal year 1976. This excludes the Safeguards School revenues and costs which were approximately $16,300 and $13,000, respectively.

Chairmen for the standing committees and other appointments were approved as follows:

Program	G.R. Keepin
Certification	F. Forscher
Nominating	R.J. Jones
Awards	T.B. Bowie
Journal—Technical Editor	W.A. Higinbotham
Journal—Editor	T.A. Gerdis
N-15 Standards	J.L. Jaech
N-15 Standards Secretary	R.A. Alto
Education	M.A. Kanter
Membership	J.W. Lee
Safeguards & Research	D.W. Wilson
Resolutions	S. Kops
Site Selection	R.E. Lang
Ad Hoc—Long Range Planning	R.J. Jones

It was noted that a substantial amount of effort is expended every year by these committees in conducting INMM business and all Institute members are encouraged to participate in committee activities.

The Executive Committee of INMM approved a modest expenditure for the reproduction of the panel discussion conducted at the annual meeting in New Orleans. The presentation has been edited to approximately 60 minutes and six copies (16 mm film) will be available for showing by an interested group.

Fred Forscher reported that the new certification standard is progressing very well and that funding has been authorized for development of the testing program.

The Executive Committee approved the continuance of the INMM-sponsored Safeguards school at Argonne National Laboratory.

(Continued on page 8)

Mr. Jaech

BALLOTING

By John L. Jaech, Chairman

Individual members of the INMM have on occasion expressed a desire to become more involved in the N15 Committee balloting process, the final step in the development of a standard prior to its submittal to the ANSI Board of Standards Review. The N15 Committee is comprised of representatives of various organizations, as is listed in each approved ANSI Standard. One of these organizations is the INMM, whose designated representative to the N15 Committee is **Harley Toy.**

Each N15 Committee member makes his own decision on whether to cast a positive or negative ballot. The extent to which he involves others in this decision-making process varies from individual to individual, and there are no set procedures that require review of the draft standard prior to the casting of the ballot.

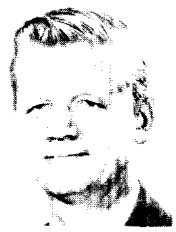
In recognition of the importance of the balloting process, of the desire to consider various viewpoints before voting either positively or negatively, and of the advantages to be gained by involving more individuals in the review of draft standards, the INMM Executive Committee has directed that individual INMM members be given the opportunity to review and comment on such standards before the INMM representative, Harley Toy, casts his ballot.

To accomplish this, it was suggested that any INMM member who wishes to participate in the review process contact Harley Toy directly at the address given below and express his desire to comment on draft standards. If the response is overwhelming, Harley reserves the right to limit the number of reviewers on any particular standard, basing the selection in part on those individuals most qualified, in his judgment, to provide helpful comments on the standard in question. It is emphasized that even though INMM is allowed only the one vote, it is the written comments that accompany the vote that are of great value in improving the quality of the final draft, and the importance of a critical review at this final stage must be emphasized.

The address of the INMM N15 Committee member is:

Mr. Harley Toy
BATTELLE MEMORIAL INSTITUTE
505 King Avenue
Columbus, OH 43201
AC 614 299-3151, Ext. 2250

On another topic, I should like to call your attention to the increasing publicity that INMM is receiving in connection with its standards writing activities. Each standard developed by N15 now carries the notation on the front cover, "INMM-Sponsored Document." Also, elsewhere in this issue you will note that the INMM is being recognized for its contributions to standards work in the ANSI Nuclear Standards Management Board annual report. Now that we are receiving this recognition, let's make certain that we are deserving of it by renewing our efforts to produce high quality standards for the nuclear industry.



Dr. Keepin

INMM'S 1976 ANNUAL MEETING IN SEATTLE JUNE 22-24

By Dr. G. Robert Keepin, Chairman
INMM Annual Meeting Technical Program Committee

The nuclear power controversy continues apace with nuclear materials safeguards and security among the leading issues of contention. Today it's more apparent than ever that the future of the plutonium fuel cycle, and thereby the full promise of nuclear power itself, could in large measure depend on how effectively we are able to safeguard, control and manage strategic nuclear materials and especially plutonium. With anti-nuclear initiatives, legislation, etc., underway in California and some 20 other states, the need is greater than ever for public education on all aspects of nuclear power, including the dissemination of accurate, objective information on the current safeguards posture of the U.S. and the salutary impact of promising new methods and technology in the areas of nuclear materials accountancy, safeguards and physical protection. Such factual information is clearly best provided by the professionals in INMM and elsewhere in the nuclear community who know and understand the promise—and the problems—of nuclear power and who are hard at work bringing about effective solutions to these problems.

As regards the extensive media coverage of the more sensational and sordid aspects of safeguards, i.e., diversion, thefts, "homemade" bombs, nuclear blackmail, terrorism, etc., many of us in INMM and elsewhere have shared a deep concern over the grossly distorted impression given the American public through skillfully manipulated, sensational press stories, TV documentaries, anti-nuclear films, etc. Although the recent British (BBC) 60-minute documentary on plutonium entitled "The Infernal Element" (not yet shown in the U.S.) did in many ways represent a significant improvement over the now-largely-discredited PBS production, "The Plutonium Connection," it seems only fair to say that a truly objective and balanced documentary on plutonium and the whole safeguards issue has yet to be made.

Our own INMM panel on "Safeguards, the Press and the Public" at New Orleans represented a far more balanced and informative interchange of views on nuclear safeguards between distinguished representatives of the press, nuclear critics, government and industry. This type of candid, face-to-face discussion between experts, on **both** sides of a sensitive technical issue, is all too rare, and we of INMM should redouble our efforts to encourage and promote, wherever feasible, more such effective public dialogue and public education activities. Excellent opportunities for direct participation in the public information activities of the INMM are provided by the Institute's newly formed Speaker's Bureau and, of course, by our various individual contributions to newspapers, periodicals, etc. All such activity on our part can only serve the best interests of a better informed citizenry which is absolutely fundamental to the decision making process in any democracy.

Looking forward to our 1976 Annual Meeting in Seattle next June 22-24, the INMM program committee has factored into its planning your comments and suggestions in response to the questionnaire we distributed at New Orleans. Accordingly, at Seattle more time will be allocated for discussion of papers, there will be scheduled coffee breaks for those very valuable "hallway confabs," and rest assured that all meeting rooms will be amply sized (with no centerposts!) for the anticipated large attendance next June.

For the Seattle meeting, we are planning what we believe will be an outstanding program opening on Tuesday, June 22, with a Plenary Session of distinguished leaders and experts from government and industry. We hope to have as our keynote speaker Congressman **Mike McCormack** (D-Wash.), a dynamic and knowledgeable spokesman for nuclear power (and incidentally one of the few if not the only member of Congress with an advanced degree in the physical sciences).

On Wednesday afternoon, June 23, we are planning a panel discussion by experts from industry and government on the timely and crucial topic "The 'Back End' of the Fuel Cycle." The panel will be chaired by a nationally known industrial leader in the reprocessing/recycle field. This is one of many program features at Seattle which we feel sure you won't want to miss. And, of course, there will be a wide range of contributed papers covering all aspects of nuclear materials management and all areas of its nuclear industry (cf "Call for Papers" for the 17th Annual Meeting).

For a number of reasons, including travel considerations for those returning from Seattle to the Eastern U.S., we are scheduling the Annual Meeting this year on Tuesday, Wednesday and Thursday rather than Wednesday through Friday as in the past. Accordingly, the American National Institute (ANSI) committee work is scheduled for Monday and Friday, June 21 and 25.

On the non-technical, lighter side we are planning an INMM-sponsored old-fashioned "Salmon Bake" at picturesque **Kiana** Lodge at the tip of the Olympic Peninsulariors in Puget Sound from Seattle. **Bill DeMerschman,** our Local Arrangements chairman, has already made the necessary advance reservations for this highly popular evening outing for visitors to Seattle. Our INMM headquarters will be the spacious new Washington Plaza Hotel, conveniently located near Seattle's best restaurants, shopping, sightseeing and entertainment.

All in all, it looks like we've got a real **winner** coming up in "Swinging (not Sweltering!) Seattle" next June 22-24. Hope you'll be with us for all the action!

Enlarge Scope of Public Relations

(Continued from page 4)

Due to the increased interest in safeguards and public awareness of safeguards problems, it was agreed that the role of the INMM Public Relations Committee should be enlarged in scope.

The site for the seventeenth annual meeting in Seattle, Washington, June 23-26, 1976, will be at the Washington Plaza Hotel. (Editor's Note: The meeting will begin on Tuesday, June 22 and end Thursday evening.)

The eighteenth annual meeting will be held in Washington, D.C., in June, 1977. The Sheraton Park and the Mayflower Hotels are being evaluated as the meeting site.

D.W. Wilson

THE INSTITUTE RESPONDS

By Dennis W. Wilson, Chairman

There may be more life in the Institute membership than some have previously suggested! This column in previous issues has pointed out the apparent difficulty in getting members involved in safeguards activities from the Institute viewpoint. We have tried to drum up interest by requesting members to give us input: ideas, comments, suggestions or even criticism. These requests have gone essentially unheeded until recently when we finally got input in an interesting manner.

One of the Institute's major activities during the past few months has been to consider ways that the Institute may become more effective in providing public understanding of safeguards as related to special nuclear material. An example of this approach included the large publicity efforts surrounding the last annual meeting held in New Orleans. Consistent with this approach, the primary activities of the Safeguards Committee have been in examining areas for increased public information. One of these areas was examining the feasibility of setting up an INMM Speaker's Bureau. Accordingly, in October a questionnaire was sent to each INMM member. The results were quite revealing, not only in terms of interest in the Speaker's Bureau but also in terms of interest in safeguards.

The questionnaire basically solicited comments on the feasibility of establishing "a cadre of INMM members willing, able, and available as needed to provide accurate and expert information regarding the control, containment, and safeguarding of nuclear materials." Respondents were asked to indicate their feelings in the following categories:

1. I am interested in participating in the proposed INMM Speaker's Bureau.
2. I am unsure of participation but would like more information as it becomes available.
3. I am unable to participate but support the basic concept of INMM involvement in this area.
4. I believe the Institute should not participate in this activity.

Space was also made available for expanded comments and additional information.

As with nearly every imperfect survey, the data obtained can be made to prove or disprove almost anything. However, the "numerical results" (the word "statistics" will not be used since some of our esteemed statisticians may look for non-existent LE's!) make provocative reading. Of the approximate 450 members solicited, 142 (nearly one-third) responded to the above choices as follows:

Category 1: 55
Category 2: 33
Category 3: 53
Category 4: 1

These results show an overwhelming interest in such an activity. More important than the numerical data were the accompanying comments. Supporting comments such as the following were included:

- "Never before has there been such a need for INMM to expound safeguards practices"
- "Welcome addition to INMM activities"
- "Such activities are needed"
- "Should have started years ago"
- "No time to lose"
- "Hope we can make it work"

Others interested in helping included such comments as:

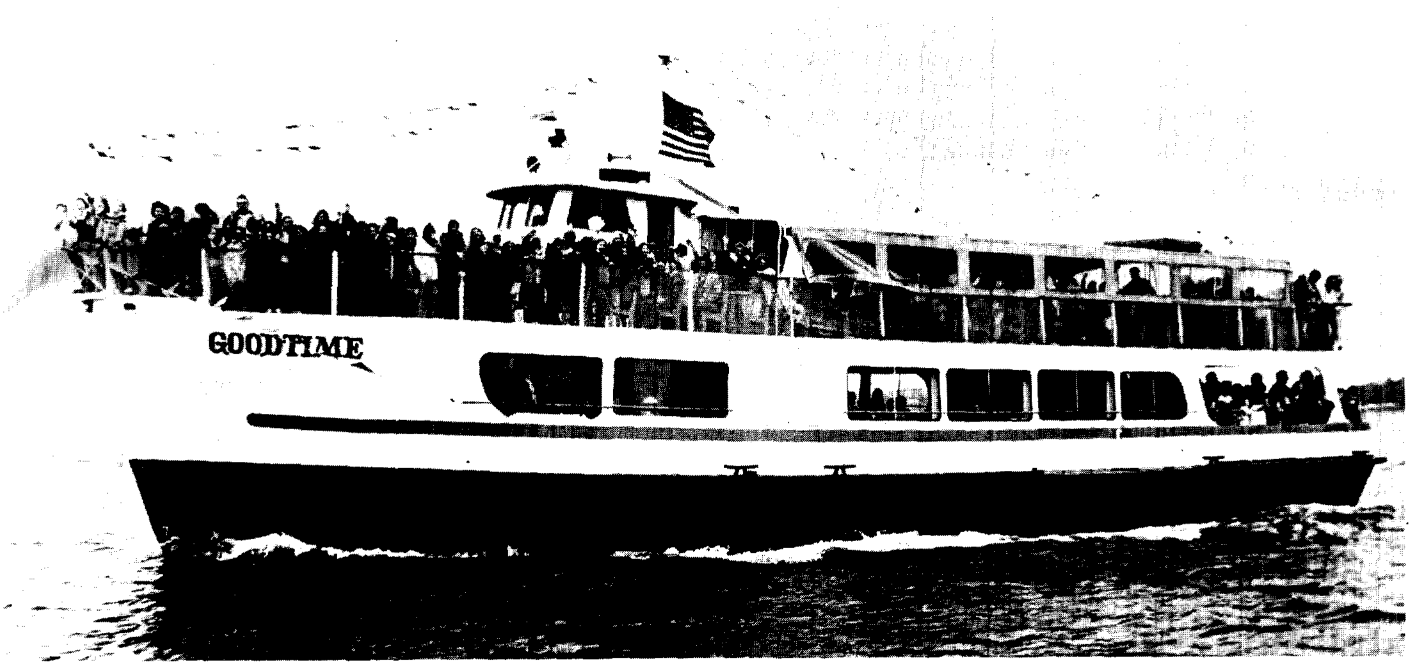
- "How can I help"
- "I can offer support services for the Speaker's Bureau"
- "Send more information"
- "Let me know what you need"

As expected a number of respondents had reservations about the chances of getting the idea to work. Major limiting concerns seemed to be lack of travel and expense money, unsure support of employers, and possible job conflicts. Significantly, the single respondent to Category 4 expressed concern that "the Institute may become the captive of the employers of its personnel." Two ex-chairmen of the Institute reminded us that previous attempts of establishing a Speaker's Bureau had met with failure. Finally, one European member made his observation "that the U.S. controversy in this field (safeguards) is homemade and not necessarily an export article"!

Notwithstanding the seen and unseen difficulties, the survey results show strong support for the Institute to "do something." In view of this interest and need, the Executive Committee has authorized the formation of a new Public Information Committee, separate from the current Safeguards Committee. This new Committee will spend full effort on public information activities previously initiated by the Safeguards Committee. Such a concentration of effort is expected to enable faster implementation of a Speaker's Bureau, coordination of news articles, and preparation of other public information media. The success of the new PIC should be a direct indication of the vitality of the Institute. We urge all members to support this new Committee in their efforts.

Almost anticlimatically, we can report that the Safeguards Committee will not dissolve with the passing of PI responsibility. On the contrary, efforts are now being focused in other areas. In November, the Executive Committee commissioned the Safeguards Committee to take a look at safeguards and low enriched uranium. Recent major safeguards emphasis has been on safeguards for strategic materials, and many individuals believe that significant differences should exist between these and non-strategic materials. Regulations recognizing such differences do not currently exist except for physical protection. The Committee's task will be to analyze this situation and develop specific recommendations. The task is formidable—especially for a part-time and volunteer effort. We hope the results will be timely and useful.

The critical safeguards environment is moving rapidly and the Institute is attempting to move with it. We are pleased with the membership's current interest and plead for continued support and direction. We need your ideas and help. The work of today provides the atmosphere of tomorrow. Let us all be proud to belong to an Institute that responds!



The "GOODTIME" will take registrants at the 1976 annual INMM meeting to the Kiana Lodge in the Garden of the Gods on the beautiful Olympic Peninsula in the heart of the evergreen playground. After arriving, registrants at the meeting will be treated to a fantastic Puget Sound "salmon barbecue."

NUCLEAR REACTORS PUBLICATION

Springfield, Va.—"Nuclear Reactors Built, Being Built, or Planned in the United States as of June 30, 1975" is a timely and relevant publication of interest to readers of this journal.

This compilation contains current information about facilities built, being built, or planned in the United States for domestic use or export which are capable of sustaining a nuclear chain reaction. Civilian, production, and military reactors are listed, as are reactors for export and critical assembly facilities.

Revisions are published twice a year, and the information presented is current as of June 30 or December 31.

The publication (44 pages, 8 x 10 1/2, paperback) is available as TID-8200-R32 for $4.00 from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161.

New Book by Raymond Murray

"Nuclear Energy: An Introduction to the Concepts, Systems and Applications of Nuclear Processes." By Raymond I. Murray. Paperback, $9.00. Hardback, $14.50. Pergamon Press, Inc., Maxwell House, Fairview Park, Elmsford, N.Y. 10523.

The future of mankind is inextricable from nuclear energy. The ever-increasing demand for energy is severely taxing available fossil fuel resources. The wise use of nuclear energy, based on both the hazards and benefits of its use, will be required to meet the energy needs of the future.

As one of the world's leading nuclear engineers, Dr. Murray has provided a factual description of basic nuclear phenomena, describing the devices and processes that involve nuclear reactions, and calling attention to the problems and opportunities that are inherent in a nuclear age. Independent reviewers have called the book "well planned and very successful in describing and explaining complex subjects in brief, concise and clear fashion" as well as "a timely and valuable addition to the literature on the subject." The book is clearly written, and requires no extensive training in either physics or mathematics.

The sequence of presentation proceeds from fundamental facts and principles, through a variety of nuclear devices, to peaceful applications of nuclear energy. Emphasis is first placed on energy, atoms and nuclei, and nuclear reactions. The book then describes the operating principles of radiation equipment, nuclear reactors, and other systems involving nuclear processes, giving quantitative information wherever possible. Finally, attention is directed to the subjects of radiation protection, beneficial usage of radiation, and the connection between energy resources and human progress.

Students taking courses in health physics, physics, all branches of engineering, especially nuclear engineering, the biological sciences, and pre-medicine, will find *Nuclear Energy* valuable as a survey text. The book contains significant information for professionals such as doctors, lawyers, and engineers as well as all civic-minded persons everywhere who have a growing need to be informed and aware of the impact of nuclear energy on our society.

LETTER . . .

Jaech Points Out Error in Book

Editor:

"I would like to use this means to point out an error in my book, "Statistical Methods in Nuclear Materials Control," TID-26298. On page 102, in Step 8, the subscripts on M_1 and M_2 are reversed. The mistake is carried through in the example on page 103. Since M_1 and M_2 are nearly equal in the example, the solution for M_3 is very nearly correct. It should be 0.0001112 rather than 0.0001023. I am grateful to Roy Morgan of the NRC King of Prussia Office, who was the first one to call this to my attention.—**John L. Jaech,** Staff Consultant, Exxon Nuclear Company, Inc. Richland, Wash.

I.R.T. to DEVELOP SYSTEM FOR E.R.D.A.

San Diego, Calif.—IRT Corporation has been awarded a contract by the U.S. Energy Research and Development Administration (ERDA) to develop a measurement system to help speed up the search for uranium.

IRT's $320,000 project is part of a $1.7 million program this fiscal year to support ERDA's National Uranium Resource Evaluation effort.

IRT, headquartered in San Diego, has been chosen to design, fabricate, and test a prototype Californium-252-based borehole logging system which will be used in conjunction with standard uranium logging operations. It will provide greater sensitivity than existing methods, especially for very low grade ores.

"The eleven-month project will utilize state-of-the-art technology," said Dr. Joseph John, manager of IRT's Nondestructive Inspection Systems Department. "A small Californium-252 neutron source will be used in the system to detect uranium around the boreholes. The results will be analyzed in the field to immediately determine even the smallest trace of uranium" he added.

Most of the IRT program will be conducted at IRT's San Diego facilities. "At the program's conclusion," said Dr. Donald K. Steinman, project manager, "IRT will deliver a working system to ERDA's Grand Junction Operations Office in Colorado. This will be a logging system complete with its own truck and data handling equipment ready for service in the field."

"The device will speed up evaluation of uranium deposits needed to meet the increasing demand for nuclear fuel," Steinman said. "The uranium mining and exploration industries have a great need for such a system."

Instant detection and assay of uranium ore with the Cf-252-based system eliminates the long and tedious process required by existing mining and exploration methods, John said. Logging techniques commonly used today detect uranium around the borehole by inference from geologic features and secondary characteristics. The Cf-252-based system will detect uranium directly.

The current year's ERDA contracts for uranium resource evaluation more than triple the amount spent on this project over the two previous years combined.

IRT is a high technology research and development company that specializes in the application of advanced technology to solve practical problems. The company has been responsible for a number of projects from original concept to the production of operational hardware. Some recent developments include a high speed letterbomb detector, a narcotics detector for screening automobiles and security systems to guard against the theft of nuclear materials.

Dr. Zorger

Zorger Directs Training Programs For Johnson Associates

Vienna, Va.—E.R. Johnson Associates, Inc. has announced that Dr. **Paul H. Zorger** has joined the organization as Director of Quality and Reliability.

Dr. Zorger is responsible for the direction of training programs for providing quality and reliability technology to the nuclear power industry and other industrial and governmental programs.

Johnson Associates is a management and technical consulting firm to the domestic and foreign nuclear industries and, through its Nuclear Audit and Testing Company subsidiary, furnishes quality assurance, quality and reliability technology, nuclear materials management, surveillance, physical security, and safeguards services. Nuclear fuel leasing activities are provided through a joint venture company, Fuel Management Corporation.

(Continued on page 15)

SIX NEW MEMBERS

The following six individuals have been accepted for INMM membership as of December 11, 1975. To each, the INMM Executive Committee extends its congratulations.

New members not mentioned in this issue of the Journal will be listed in the Spring 1976 (Volume V, No. 1) issue to be sent out next April or May.

Mary K. Dean, 1778 Pleasant Valley Avenue, Oakland, California 94611.

Paul J. DeBievre, European Commission (EEC), Central Bureau for Nuclear Measurements, B-2440, GEEL, Belgium.

Paul Desneiges, Controleur des Matieres Nucleaires, Commissariat a l'Energie Atomique, 29-33 Rue de la Federation, Paris-15, France.

Howard A. Hughes, Manager, Technical and Political Services, British Nuclear Fuels, Ltd., Risley, Womington, WA3 6AS, England.

John W. Leake, Principal Scientific Officer, United Kingdom Atomic Energy Authority, Building 154 Harwell, Didcot, Oxon OX11 ORA, United Kingdom.

Dayton D. Wittke, Nuclear Engineering Specialist, Omaha Public Power District, 1623 Harney Street, Omaha, Nebraska 68102.

The following change of address has been the only one received since the last issue of this Journal by the INMM Publications Office at Kansas State University, Manhattan.

Emmanuel R. Morgan, U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, D.C. 20555.

INMM OFFICER NAMED LASL SAFEGUARD HEAD

Dr. **G. Robert Keepin** has been appointed Nuclear Safeguards Program Director at the Los Alamos (New Mex.) Scientific Laboratory. The appointment, effective December 1, was part of an organizational integration of nuclear safeguards, reactor safety and fission energy programs at Los Alamos.

Keepin's responsibilities include the direction and coordination of R&D in nondestructive assay technology as well as the implementation and practical demonstration of newly-developed NDA technology in representative major facilities such as the new plutonium process facility now under construction at Los Alamos.

Dr. Keepin (or "Bob" as he's known in INMM) is a member of the INMM Executive Committee and served as the Institute's Technical Program Chairman this past year and for the 1976 annual meeting June 22-24 in Seattle.

The two newest members of the INMM Executive Committee are John L. Jaech (right) and Dr. G. Robert (Bob) Keepin. This photo was taken by James W. Lee, INMM membership chairman, at the September meeting of the Executive Committee. Mr. Jaech is N15 Standards Committee chairman of the Institute while Keepin is Technical Program Committee chairman. Mr. Jaech is a staff consultant with Exxon Nuclear Company, Inc., Richland, Wash. Dr. Keepin was appointed nuclear safeguards program director Dec. 1 at Los Alamos (New Mex.) Scientific Laboratory.

ZORGER DIRECTS PROGRAMS

(Continued from page 13)

Dr. Zorger brings to Johnson Associates and Nuclear Audit and Testing Company over twenty-five years of quality and reliability technology experience in the nuclear, electrical, and electronic industries and educational institutions. He has lectured thoughout the United States and Europe on the application of Quality and Reliability Technology, and has held positions as a design engineer, project engineer, director of engineering analysis, director of systems engineering and director of quality and reliability. He served as an adjunct professor in the graduate schools of Drexel Institute of Technology and American University, and has developed the Quality Technology Program and is currently serving as the program director at the University of Virginia.

Dr. Zorger holds a B.S. degree in Electrical Engineering, University of Minnesota, a B.S. in Industrial/Technical Education from State College, Millersville, Pennsylvania; an M.S. in Industrial Engineering and a Ph.D. in Economics both from the University of Pennsylvania. He is a senior member of IEEE and the American Society for Quality Control and is an ASQC Certified Quality Engineer, an ASQC Reliability Engineer and a Registered Professional Engineer, State of California, in Quality and Reliability Engineering. Dr. Zorger is an author of a chapter in the Reliability Handbook, is well known throughout the U.S. for his work in Reliability Technology and is listed in Who's Who in the South and Southwest.


Dr. Forscher

CERTIFICATION REPORT

Professional Competence Is Best Assurance

By Dr. Frederick Forscher, Chairman
INMM Certification Committee

Serious concern was expressed by several committee members, by members of the INMM, and by representatives of the NRC, regarding the need to establish qualification requirements for persons active in our profession in **some** areas as detailed in Section 5 of the standard, as contrasted with **all** areas required for full certification as a Nuclear Materials Manager.

Consequently, Section 1.0 Scope has been modified to read as follows:

> This standard defines the requirements for "Certification" as Nuclear Materials Manager. It sets forth the program scope in the fields of a) material control and accounting, and b) material and plant protection, in which a certified individual must demonstrate proficiency and competence.
>
> This standard also recognizes that an individual may not be qualified for full certification but may choose to be recognized as a qualified specialist in a specific field such as:
>
> Fuel Cycle Material Control and Accounting;
> Nuclear Reactor Material Control and Accounting; and
> Material and Plant Protection.
>
> The certification and qualification procedure shall be administered by a certification board that meets accreditation requirements.

Section 6.0 Acceptance Criteria and Administration has been modified accordingly.

> 6.2 A "Certified Nuclear Materials Manager" shall have demonstrated acceptable competence in the fields of a) material control and accounting, and b) material and plant protection.
>
> A "Qualified Nuclear Materials Specialist" shall have demonstrated acceptable competence in the selected field of specialization such as:
>
> Fuel Cycle Material Control and Accounting;
> Nuclear Reactor Material Control and Accounting;
> Material and Plant Protection.

A testing program is yet to be developed that will measure the respective competency of applicants for certification or qualification. This development program will take between 18 and 24 months to complete. It will be carried out by the Educational Testing Service (ETS) of Princeton, N.J. with the help, advice and consultation from many members of the profession and all members of the Certification Committee. Total cost of this test development program is estimated at about $65,000, based on firm proposals. We have applied to the NRC and to foundations for financial support of this important development. At the date of this report, we still have no firm financial support.

The test itself is **not** part of the standard N 15.28 Criteria for the Certification of Nuclear Materials Managers, that has been completed by your Certification Committee. However, it is a requirement of the standard that such a test shall be administered in the future by an accreditable certification board. Hence, it appears that no new certification (and qualification of specialists) will be issued till the test has been developed and a certification board has been established to administer the test and the other requirements of our criteria and standard N 15.28.

It must be recognized that the safeguards issues are currently in the public limelight, and that various, often competing, safeguards systems, both national and international are being developed through the political processes here and abroad. Regardless which system, or systems, will eventually be adopted, our membership can be sure that the professional competence of the people manning the system is the best assurance of its workability, and that such competence is reflected by our certification and qualification program.—**Frederick Forscher,** Chairman, INMM Certification Committee.

Meet at Columbus

DISCUSS REGULATIONS

A special meeting of concerned members was held at the Battelle Columbus Laboratories, Columbus, Ohio, Nov. 20 to consider the sponsorship of an INMM topical meeting to review and evaluate the NRC/ERDA regulations. Consensus of their opinion was that this review should not be limited to a special meeting but rather the concern should be a function of the INMM Safeguards Committee. A plan was drafted which included objectives, scope, resources, alternatives, and estimated cost.

The attendees further proposed that the activity should consist of a writing group of three to five members (who would isolate themselves to complete the task) and a review group. The review group will be contacted as the need for them arises.

Dennis W. Wilson, General Electric, San Jose, Calif., and Chairman of INMM Safeguards Committee, expressed a willingness to direct the activity and accepted the responsibility of forming the groups and proceeding with the task. He anticipated that a draft might be available by the February meeting of the INMM Executive Committee (a target date for completion) prior to our June 1976 annual meeting.

INMM Executive Committee members in attendance indicated that a request will be presented at their meeting Feb. 26-27 in Seattle, Wash., to allocate supplemental funds for this endeavor.

General Crowson, INMM Booster

Del Crowson

New Orleans, La., Nov. 19—Funeral services for Brigadier General **Delmar L. Crowson,** U.S. Air Force (Ret.), manager of the environmental section in Middle South Services' engineering department, were conducted at Arlington National Cemetery, Washington, D.C., on Friday, November 21. General Crowson was a native of Bell View, Ill., and a resident of Metairie for the past two-and-a-half years.

General Crowson joined Middle South Services August 1, 1973. Prior to joining the service company, he served, from 1967, as director of the Atomic Energy Commission's Division of Nuclear Fuel Activity.

In the 1946-1954 period, General Crowson was actively engaged in research and development programs exploring various applications of nuclear energy to meteorology. He was acknowledged as the author of the first publication (1949) in which the use of rockets and satellites for meteorological purposes was proposed.

General Crowson was decorated with the Legion of Merit, Commendation Medal, Air Force Distinguished Service Medal, and the AEC Distinguished Medal.

General Crowson served as local arrangements chairman for the 1975 INMM annual meeting held last June. He was held in esteem by many members of the Institute.

He is survived by his widow, the former Betty Parker, and four children: Stanley, Mrs. Margaret Anne Brooks, Mrs. Louise Campbell, and Andrew.

PORTAL RADIATION MONITOR

Oak Ridge, Tenn.—A portal radiation monitor to help prevent the theft of nuclear materials is now available to nuclear installations.

The IRT Corporation of San Diego, Calif., designer and manufacturer of the Portal Radiation Monitor (PRM-110) system has signed an agreement for ORTEC, Inc., of Oak Ridge (an EG&G subsidiary), to sell the PRM-110 system in the U.S., Canada, and Mexico. The PRM-110 provides the most advanced method available for automatic monitoring of entrances and exits of facilities where uranium and plutonium are present. The announcement was made jointly by Dr. **Charles A. Preskitt,** IRT Vice President, and **Alan L. Hofstein,** ORTEC Vice President and General Manager of research instrument sales.

Following the joint agreement, Hofstein said the technology of IRT and the international sales force of ORTEC, Inc.,"are both highly regarded and well known in the nuclear instrumentation field. ORTEC's association with IRT will allow our highly trained sales force to offer ERDA (U.S. Energy Research and Development Administration)-approved portal radiation monitors to nuclear installations throughout North America."

Preskitt said IRT early recognized the need for a radiation monitor and started development in 1972. "Now," he said, "we are able to offer the PRM-110, a system which has been fully tested and approved by ERDA. The PRM-110 is one of a complete line of modern IRT equipment designed for nuclear fuel safeguards and quality control," Preskitt added.

Recent changes in ERDA regulations specify that ERDA facilities and prime contractors use portal radiation monitors to assure control of special nuclear materials.

Technical concepts used in the PRM-110 include a digital electronics system which tracks not only the background, but also the variations in the background. Any abnormal detector outputs due to high or low background radiation levels or instrumentation failures are detected and indicated. Use of a microprocessor to perform arithmetic and logical operations on the data also reduces the number of electronic parts, thereby increasing system reliability and flexibility.

(Continued on page 37)

CITES RISING ORE PRICES, DELAYS IN PLUTONIUM RECYCLE

A new U.S. ERDA operating plan will hasten enrichment timing scenario, according to a study by Uranium Enrichment Associates, San Francisco. Included in the UEA plan:

- A full 9 million SWU of new enrichment capacity to satisfy the needs of the domestic U.S. market can be justified economically in early 1985, assuming a U.S. nuclear growth at ERDA's most recently forecasted moderate low rate.
- Assuming a moderate high rate of U.S. nuclear power growth, which is felt to be prudent for planning purposes, 9 million SWU of new capacity for the domestic market alone could be justified as early as early 1984.
- If the entire noncommunist world market including the U.S. is considered, then the next 9 million SWU of enrichment capacity is economically justified by mid-1983. An additional 9 million SWU plant in full commercial operation is needed by late 1984.

The above findings are among several major conclusions of a recent UEA study which finds that rising ore prices and delays in plutonium recycle are leading to a situation where utilities may be paying substantial and unnecessary penalties for their nuclear fuel as early as 1981, because of projected non-optimum high ERDA tails assay.

The study shows that adding new enrichment capacity and maintaining a low tails assay could save domestic utilities alone as much as $3 billion by 1984, assuming U.S. nuclear capacity grows according to the ERDA moderate low forecast. If U.S. nuclear growth goes to the ERDA moderate high case, this figure becomes $7 billion by 1984.

The UEA study focuses on the fact that, in the continued absence of recycle, and in the face of previously unanticipated rising ore prices, ERDA plants—which are presently over-contracted by a significant margin—will be compelled to operate at a higher and higher tails assay to meet their contractual obligations with both U.S. and non-U.S. utilities.

As a result of these anticipated changes in the operating plan of the ERDA plants, all utilities which have contracts with ERDA for their enrichment services will find it necessary to supply the ERDA plants with significantly increasing amounts of feed in order to receive their contracted amount of uranium fuel. This additional feed cost will be borne by the utility and not by ERDA.

One consequence of the above situation is that a significant burden will be placed on the U.S. raw materials supply industry, which is currently ill-prepared to meet this unexpected surge in demand. But perhaps even more significant will be the impact on U.S. utilities which already find themselves in weakened financial condition. These utilities, in the absence of additional enrichment capacity, will find it necessary to (1) seek additional sources of uranium supply at potentially higher price and (2) provide at their own cost amounts of feed substantially in excess of their previously anticipated requirements.

Assuming an ore price of $40/lb and an enrichment cost of $100/SWU in 1975 dollars, and an ERDA tails assay of 0.36 tails, the annual increment in cost over what would be incurred if the enrichment were performed at 0.2 tails would be $2.6 million annually for a typical 100 megawatt reactor. ERDA has stated that its plants will have to operate at 0.36 tails to satisfy its contractual obligations, in the absence of plutonium recycle.

According to the UEA study, a new 9 million SWU plant in 1984 could service a portion of the reactor contracts currently committed to ERDA. It is not necessary, in economically justifying the next unit of 9 million SWU, to consider the enrichment needs of reactors other than those currently committed and having enrichment contracts with ERDA.

As a final note of interest, it is worthwhile to point out that the U.S. uranium ore suppliers are faced with a quandary concerning the amount of additional uranium required. In the short to medium term, market studies have shown that uranium suppliers will have difficulty meeting demand. Significant price elasticity can be expected as the ore companies are asked to increase their output on short notice. As uranium ore prices rise, the above cost penalties can be expected to increase.

SAN DIEGO FIRM NAMES TWO NEW VICE PRESIDENTS

San Diego, Calif.—IRT Corporation has named two new vice presidents to head the company's Physics and System Effects Divisions, it was announced by Dr. Robert L. Mertz, IRT President.

Dr. **James A. Naber** is the new Vice President in charge of IRT's Physics Division. Naber has been manager of the department since joining IRT in 1965. He heads a staff of scientists involved in research activities.

Dr. **Eric P. Wenaas** will head IRT's System Effects Division. Wenaas joined IRT in 1969 and was promoted from the position of manager of the company's Electromagnetic Effects Branch. His work has involved research, phenomenology development, and applications of electromagnetic effects to systems.

IRT is a high technology research and development company that specializes in the application of advanced technology to solve practical problems.

Naber is developing programs in radiation sterilization and processing and in radiation qualification of nuclear reactor components. While at Purdue University, from 1959 to 1965, as a research and testing assistant in the Physics Department Radiation Damage Group, Naber did extensive work in radiation effects.

Before joining IRT, Wenaas was employed by Bell Aerosystems, where he was engaged in theoretical studies involving rarefied gas dynamics and particle-surface interactions. In addition, he worked on problems related to rocket engine instabilities. Prior to graduation from the State University of New York at Buffalo, he was a part-time instructor teaching dynamics, electromagnetic theory and circuit theory.

NUSAC APPOINTS BUSH SENIOR TECHNICAL ASSOCIATE

Falls Church, Va.—Dr. **Ralph F. Lumb,** President of NUSAC, Inc., has announced that Lt. Col. **Loren L. Bush, Jr.** (ret.) has joined the company as a Senior Technical Associate with the Security Programs Division.

Col. Bush comes to NUSAC from the Defense Nuclear Agency where he served as Chief of the Nuclear Security Division for the past five years.

NUSAC's Security Programs Division provides security consulting services to utilities, fuel fabricators, and fuel reprocessors in the nuclear field. These services include all facets of security program development from the design stage through operations.

NUSAC also provides consulting services in fuel quality assurance and nuclear materials licensing and safeguards, and provides for the confirmation of UF-6 delivered to fuel fabricators.

WILL WE IMPORT ENRICHMENT SERVICES?

An overflow audience at the recent 1975 Atomic Industrial Forum Conference in San Francisco heard **Jerome W. Komes** of Uranium Enrichment Associates warn that "if we continue to fumble around, we will soon be importing enrichment services for our own reactors."

In a major address to the Conference, Komes told conferees that "while we, in the United States, maunder about, worrying over . . . textbook concerns, we are losing the enrichment game in the real world."

Komes, who is chairman of the Bechtel-Goodyear-Williams Companies consortium that is aiming to build the nation's first privately-owned and operated enrichment facility, continued:

"It is incredible that the U.S.' reputed ability to take and carry out a practical commercial view seems to be lost while our friends in France, Germany, South Africa, Brazil, England, Holland and elsewhere are able to make decisions and position themselves in the uranium enrichment business."

The main gist of the Komes remarks, delivered at a meeting headlined by ERDA Administrator **Robert C. Seamans,** was that responsible people in the nuclear industry should stop sitting on their hands and become aware of what is at stake in privatizing enrichment. "One is either involved and a militant advocate or one is nothing," Komes stated.

Echoing earlier comments made at the Conference by FEA's **John Hill** that diverse segments of the nuclear industry "get together and make some hard choices about your . . . priorities," the UEA Chairman stated his own strong conviction that the federal budget was not sufficiently expansive to allow for both a government uranium enrichment project and government attention to the balance of the nuclear fuel cycle, if privatization failed to get Congressional backing.

Noting that the UEA bid to build the fourth U.S. enrichment plant would return $3 to $4 billion in taxes and royalties to the government, and provide favorable U.S. trade balances of an additional $8 to $10 billion over the normal operating life of the plant, Komes emphasized that UEA would make no request for any government money, subsidy, tax breaks, or hidden support, and further, that UEA participants were willing to place their full equity at risk.

While noting that many in Congress and in the Executive Branch of the federal government were aware of the critical nature of enrichment timing, and were working diligently to resolve the situation, the UEA Chairman also referred to "some in Washington who feel our proposal is less than the classic risk-taking of the corner grocery store."

Dr. Kanter

GUARD FORCES COURSE SOURCE FOR PRIDE

By Dr. Manuel A. Kanter
INMM Education Chairman

Forty-six persons from throughout the industry attended one or more of the three Institute-sponsored courses in Safeguards and Nuclear Material Control presented at Argonne National Laboratory in November, 1975. This was the second series of courses INMM sponsored at the Argonne Center, the first being a series of two courses given in November, 1974.

Nineteen of the attendees represented NRC licensees including nine from utilities. Fourteen came from ERDA contractors, six from USNRC, one from ERDA, four from abroad, and two from the National Bureau of Standards. Thus the November, 1975 course continued a shift from an ERDA orientation to an NRC orientation.

The first of the courses, "Introductory Statistics With Application to Measurement Quality Control" was a one-week presentation led by Richard J. Brouns of Battelle's Pacific Northwest Laboratory. He was assisted by Manuel A. Kanter who taught the first few days of the course and by Charles Petri and Jere Bracey of ERDA's New Brunswick Laboratory who made a half-day presentation of methods for the implementation of a measurement quality control program. The thirteen attendees found the course to be suited to their need indicating that there is merit in being able to offer statistical methods on more than one level.

Twenty-one attended James E. Lovett's course, "Fundamentals in Nuclear Material Control" given the week of November 10-14, 1975. Jim came over from Vienna especially to lead the course and the results warranted the effort. His perspective was even more ranging than his book on the subject as a result of his service with IAEA. Lawrence F. Wirfs, USNRC, made an informative presentation on the implementation of Sec. 70.58, Part 70 and Joseph Shaver, General Electric Company, did an excellent job outlining his company's application of automation.

In my opinion, the third of the courses, "The Role of Guard Forces in Materials and Plant Protection" was a presentation in which the Institute and the Argonne Center can take real pride. Dr. Joseph P. Indusi, TSO, Brookhaven, did an outstanding job in assembling a faculty for the four-day course. The eighteen participants were particularly impressed with the legal presentations which gave information that was new to most of them.

Although I took a major role in organization of the courses, I was ably assisted by Dr. William H. Sawyer and Ms. Nancy A. Cern who were really responsible for the day-to-day operation. We are all looking forward to a new series in the Spring.

Although plans for additional courses are not firm, it appears that there will be a course in Chemical Measurements, April 26-30, 1976, in Statistical Applications in Material Accounting, May 3-7, 1976, and in Advanced Concepts in Material Control, May 10-14, 1976. Definite information will be available next February.

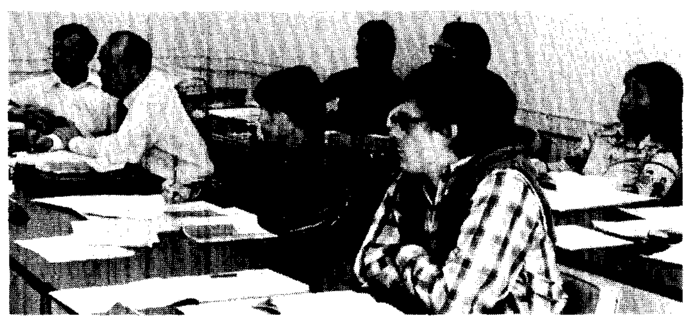
INMM FALL COURSES AT ARGONNE

INMM's Education Chairman, Dr. Manuel Kanter, learns about the role of guard forces.

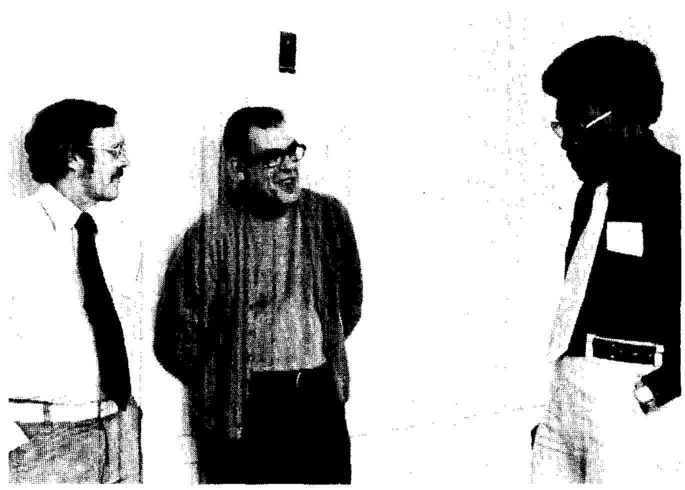
Richard J. Brouns, Battelle Northwest, course leader in "Statistics," and Fred Sherman, Texas Instruments.

William Costello, Suffolk County N.Y. Policy-Lecturer on emergency planning . . .

James E. Lovett, IAEA, course leader in Fundamentals of NMC.



Michael Roberts, Union Carbide, William Quinlan, United Nuclear, Sheila Patinkin, USERDA, Gaston Landresse, EURATOM, Roberto Albani, EURATOM, Roger Anderson, G.E., Jinny Dong, Atomics International, in course in statistical methods.



Raymond Jackson, USNRC, William Donovan, USERDA, Robert Shepard, USNRC, all talking statistics?

MORE INMM FALL COURSE PHOTO HIGHLIGHTS

Cesar Sastre of Brookhaven talking on the philosophy of physical protection.

Masayuki Iwanaga, PNC, Japan, takes statistical methods seriously.

High speed letterbomb detector, developed by IRT Corporation of San Diego, processes test run of mail as R.J. Michaels, IRT engineer, feeds stacks of sample letters to the system. The detector has been delivered to Washington, D.C., to serve a federal agency.

John L. Jaech (left) and Richard A. (Dick) Alto serve as chairman and secretary respectively of the INMM sponsored N15 Standards Committee. Jaech and Alto were photographed during the September INMM Executive Committee meeting in Colorado Springs, Colo.

INMM Section Of N.S.M.B. Annual Report

By John L. Jaech, Chairman
INMM N15 Standards Committee

Editor's Note—Each year the ANSI nuclear standards program issues an annual report emphasizing different aspects of the program as well as providing an informative picture of its present and future plans. This is called the NSMB (Nuclear Standards Management Board) Progress Report. In recognition of the contributions of the technical and professional societies engaged in the development of nuclear standards, the 1975 report will highlight the societies and their accomplishments in producing high quality nuclear standards. The INMM was asked to prepare a report on their activities for this reason, and the following report was prepared by the N15 chairman.

The Institute of Nuclear Materials Management (INMM) is an organization of some 400 members whose purpose is given in Article II, Section 1, of the INMM constitution, quoted as follows:

"In consideration of the high monetary value of nuclear materials and the necessity which this high value imposes for efficient management of such materials, this Institute is formed to encourage, in the broadest manner:

a. The advancement of nuclear materials management in all its aspects which involve, but are not limited to, the application of principles of chemistry, chemical engineering, nuclear physics, accounting, auditing, and statistics to the management of nuclear materials.

b. The promotion of research in the field of nuclear materials management.

c. The establishment of standards, consistent with existing professional and regulatory standards, for use in nuclear materials management. Such standards include, among others, material standards, accounting standards, units of measurement, and container standards with due attention to health, safety, and criticality considerations.

d. The improvement of the qualifications and usefulness of those engaged in nuclear materials management through high standards of professional ethics, education, and attainments and the recognition of those who meet such standards.

e. The increase and dissemination of nuclear materials management knowledge through meetings, professional contacts, reports, papers, discussions, and publications."

In connection with paragraph c, the INMM, in response to an invitation from ANSI, agreed to sponsor a newly-created Standards Committee in 1966. This new Committee was designated N15, "Methods of Nuclear Materials Control," and has the following scope:

"(To develop) Standards for the protection, control, and accounting of special materials in all phases of the nuclear fuel cycle, including analytical procedures where necessary and special to this purpose, except that physical protection of special nuclear material within a nuclear power plant is not included."

Thus far, 19 INMM sponsored standards have been approved by ANSI, with 13 of these approved through 1974, and 6 additional ones approved in 1975. Work is underway on some 18 additional standards. To date, 8 of the approved standards have been referenced in NRC regulatory guides.

Since the initial formation of the subcommittees and writing groups, some changes in emphasis have led to the deletion of one subcommittee and to the formation of several new subcommittees. After issuing two standards, the subcommittee on Measurements was dropped because its activities were found to parallel those of an ASTM sponsored Committee. Four new subcommittees have been formed: Calibration Techniques, Nondestructive Assay, Physical Protection in Plant, and Certification. The present makeup of N15 is as follows: N15 Chairman, J.L. Jaech; N15 Vice Chairman, L.K. Hurst; and N15 Secretary, R.A. Alto.

Subcommittee	Title	Chairman
INMM-1	Methods of Nuclear Materials Control	E.J. Miles
-3	Statistics	L.T. Hagie
-4	Records	S. Kops
-6	Inventory Techniques	R.A. Schneider
-7	Audit Techniques	R.J. Sorenson
-8	Calibration Techniques	L.W. Doher
-9	Non-destructive Assay	D.M. Bishop
-10	Physical Protection in Plant	W.J. Shelley
-11	Certification	F. Forscher

With respect to future plans in the standards writing activities, the aim is to concentrate on those areas that will play major roles in future programs developed to manage and control special nuclear materials. The following areas of emphasis are identified, not in any order of priority.

A. **Physical Security**

A five-year program has been developed to identify standards that will, hopefully, be written in the area of physical security. The listing, developed to integrate standards with proposed regulations and regulatory guides, is an ambitious one; and priorities will have to be established to reduce the list to one of manageable size.

B. **NDA Measurements**

Work is progressing on five standards in the non-destructive assay area. Five writing groups have been formed to address the problems of categorization of SNM for NDA, standardizing containers, defining physical standards, controlling and assuring measurement quality, and automating NDA data acquisition and analysis.

C. **Statistics**

Because of the important role that statistical techniques plays in the accountability of SNM, attention continues to be focused on developing additional standards on statistics. Projects currently underway include one relating to bias corrections, another to sample size considerations when estimating variance components, and another to combining sets of data. In addition, plans are to review and revise as needed those standards on statistics already issued.

D. **Inventory Techniques**

The emphasis on future control systems will be a real time accounting for SNM. Standards are needed to offer guidance on such systems. This aspect of inventory techniques will receive special consideration by the Subcommittee on Inventory Techniques.

E. **Certification**

In any control system, the success of the system ultimately depends on the qualifications and capabilities of the individuals responsible for system operation. In recognition of this, the INMM is currently reviewing its program for the certification of Nuclear Materials Managers. The mechanism for accomplishing this is the issuance of a standard on certification.

The above list of future activities does not mean to imply that work will not proceed on developing new standards in the remaining subcommittees. However, in some instances, for example in the area of calibration techniques, several standards have already been issued, which, for the moment, cover the range of needed standards in those areas. As new needs are identified, writing groups will again be formed to meet those needs.


Mr. Lovett

Report on October 1975 I.A.E.A. Safeguards Conference

By James E. Lovett
INMM Past Chairman

Editor's Note: The following article appeared in the January issue of Atomic Energy Review which is published by the International Atomic Energy Agency, Vienna, Austria. It is reprinted here in its entirety by permission.

INTRODUCTION

The international safeguarding of nuclear material against unauthorized use is one of the primary missions of the IAEA. In the early years only relatively small quantities were so protected, but with the coming into force of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in March 1970 international safeguards received a strong new emphasis. Since that date the number of States parties to NPT has steadily grown, and as this is being written 97 States have signed and ratified NPT. Safeguards agreements have been negotiated and are in force in 43 of these States. Also, much of the nuclear material in the remaining non-nuclear-weapon States is still safeguarded under various other agreements. The total number of States in which some form of safeguards agreement is in force is 63; the total number of facilities being safeguarded is close to 200.

Many authors have suggested various restrictions which they feel should be placed on IAEA safeguards activities. Among these, several which either are specifically mentioned in agreements or are generally accepted include:

Minimum interference with normal plant operations
Protection of commercially sensitive plant data
Maximum cost effectiveness
Primary reliance on materials accountancy
Secondary reliance on containment and surveillance techniques
Quantitative presentation of conclusions

In seeking to develop a practical and effective safeguards system within agreed restrictions and constraints, the IAEA has convened numerous panel, consultants, or working group meetings. There have also been three international symposia: in Vienna in 1965, published under the title "Nuclear Materials Management"; in Karlsruhe, FRG, in 1970, published under the title "Safeguards Techniques"; and in Vienna in 1975, to be published under the title "International Safeguarding of Nuclear Material." The purpose of this article is to review this third symposium.

The Symposium took place from 20 to 24 October, 1975 and was attended by 219 participants representing 34 countries and three international organizations. Papers were invited and received on essentially the complete range of topics related to safeguards. In all 95 papers were presented, 49 by the authors and 46 by a series of nine rapporteurs who summarized groups of closely related papers. It has not proved possible in this review article to include specific mention of all papers. With apologies to the authors not mentioned, a selection of some of the most interesting papers is described. The reader with a serious interest in the field of international safeguards is encouraged to obtain the Proceedings when published early in 1976.

It is significant to note that, in contrast to the many theoretical papers presented in 1970, most of the papers presented at the Symposium concerned actual practical experience. It cannot be claimed that all of the problems of international safeguards have been solved. On the other hand, as was clearly demonstrated at the meeting, many of the non-destructive measurement devices, the seals, surveillance cameras, and other containment/surveillance devices which are essential to effective safeguards do exist and are being refined. The active interest of the participants throughout the week-long meeting also clearly demonstrates the attention being given to the remaining problems throughout the world, and augurs well for their eventual solution.

IAEA SAFEGUARDS

In the opening paper Rometsch et al. (IAEA-SM-201/103) reviewed the current and projected status of the world nuclear industry in the decade 1975-1985. They presented a table showing the present estimated ability of the nuclear industry to determine whether any material may be unaccountably missing. Expressed as one standard deviation and including all sources of random and systematic error, the expected uncertainties given ranged from ± 0.2% for uranium isotopic enrichment facilities to ± 1.0% for plutonium in reprocessing facilities. Since the Agency's inspectors, in verifying this material balance, must necessarily introduce some additional uncertainty, Rometsch argued that, considering only nuclear materials accountancy, the ability of the Agency to conclude quantitatively that no diversion had occurred was never smaller than about 0.8% of a given facility's throughput, and may for some facilities be as high as 4.0% or more.

In order that future safeguards costs may be kept reasonable, Rometsch proposed that these limiting values be accepted as the significant quantities to be detected. He also suggested that safeguards be graded according to the usability of a given material for direct weapons manufacture and according to the ability of the possessing State to convert its material to more usable form. Thus, for example, less stringent safeguards would be applied to plutonium in spent fuel elements if the possessing State did not have the capability to recover that plutonium. Rometsch also suggested, as did Lopez-Menchero (IAEA-SM-201/104), that credit should be given where States institute their own domestic system of material control and include therein verification of material quantities. Neither author suggested any quantifiable relationship between a State's effort and the Agency effort. Both made it clear that in all cases the Agency should maintain some level of independent verification.

Nakicenovic (IAEA-SM-201/105) reviewed the current status of Agency safeguards from the practical or operational viewpoint. For each facility the IAEA prepares a document termed the "safeguards implementation practices" (SIP), which provides ". . . an in-depth analysis for a specific facility of the existing conditions as they affect the task of the inspectorate." Among other things, the SIP presents an analysis of the specific diversion hazards at the facility, the adopted safeguards approach, and the limitations which may be inherent in that approach. Nakicenovic described limitations in a number of categories, such as reluctance of a facility operator to move material (often understandable, as with fuel assemblies which are easily damaged, but nonetheless restricting to the Agency's activities), inability to perform needed non-destructive verifications (for example, of completed fuel assemblies) with portable instrumentation, technical problems of independent instrument calibration, delays both in the transmission of analytical samples and accounting data, and the human problems associated with sending inspectors on long trips to areas with different customs and languages. Most of these problems are well known, of course, and many of the papers presented later in the week dealt with potential solutions to some of them.

Nakicenovic also noted that the IAEA has the only global safeguards system, and that it must be and is ". . . designed to exist in harmony with promotional activity in the field of peaceful uses of nuclear energy." This, the author maintained, it is doing.

STATE SYSTEMS

Several authors described the activities in their countries directed toward a State system of material control. Page (IAEA-SM-201/52) reviewed in detail the system of the U.S. Nuclear Regulatory Commission (NRC). The NRC system, in the words of a participant from the United Kingdom, ". . . is undoubtedly . . . the most comprehensive domestic safeguards system which exists anywhere in the world." The system is applicable to 561 licensees, authorized to possess 616000 kg of fissile isotopes. Of these, 16 are considered as being authorized to possess large quantities of material of high strategic importance, defined as plutonium, or uranium enriched to at least 20% ^{235}U. These 16 in fact are authorized to possess 282000 kg of fissile isotopes, or almost 50% of the total material authorized by NRC.

The NRC system is intended, "to protect against, deter, and detect the theft or diversion of nuclear materials, and to protect nuclear facilities against industrial sabotage." As pointed out in the paper, these objectives are considerably broader than the mission assigned to the IAEA. In addition to materials accountancy, the NRC system also includes an extensive system of physical security designed to protect against theft or industrial sabotage.

The NRC system also differs from that of the IAEA in that the total burden of proof is placed on the individual facility operator. Inspections are conducted, indeed the NRC system includes a comprehensive inspection programme, but the purpose of inspection is ". . . to assure that persons who possess nuclear material are complying with applicable NRC requirements." According to the paper, a typical inventory verification inspection of a large uranium convertor/fabricator may require 130 man-days, of which about 50 man-days would be spent at the facility. Since the purpose of inspection is to verify compliance with regulations, however, such comprehensive inventory verifications normally are performed only once every two years.

U.S. licensees, according to Page, are required to determine by measurement the nuclear material content of all receipts, shipments, discards, and material on inventory. They are also required to maintain a measurement control programme, and to demonstrate the uncertainty of their material balance is below specified limits, ranging from ± 0.5 % for low enriched uranium to ± 1.0% for plutonium in a fuel reprocessing facility (all values at the 95% confidence level).[1] The primary requirement on material unaccounted for is that it may not exceed the calculated uncertainty.

Schleicher et al. (IAEA-SM-201/68) described experience in the implementation of the Euratom safeguards system. The Euratom system has many elements in common with the U.S. system described by Page, except that it does not include physical security measures. Also, the primary responsibility for the verification of material quantities is placed on the Euratom inspectorate rather than on the facility operators. Operators are required to measure nuclear material quantities, but not to determine the uncertainty of those measurements. Inspectors make frequent visits to facilities, extending even to "continuous physical presence," but in general do not undertake the extensive physical inventory verification inspections described by Page.

Fredericksen (IAEA-SM-201/76), Rohnsch and Gegusch (IAEA-SM-201/79), and Bardone et al. (IAEA-SM-201/102) described aspects of the State material control systems in their respective states. For the most part these systems are administrative in nature, designed to provide accountancy and other data needed by Euratom or IAEA safeguards. Bardone also described a number of measurement techniques in use or under development in Italy; these are referred to later.

PHYSICAL PROTECTION

With the general increase in terrorism and political unrest in the world during recent years, the physical protection of nuclear material against theft, either by employees or outsiders, has received increasing attention. This fact was emphasized by a number of authors, notably from the United States of America. Bennett (IAEA-SM-201/38), and Bahm and Nagele (IAEA-SM-201/49), presented mathematical models for analysing the risks to society from such attempts. Without giving any quantitative values, and indeed with a frank admission that quantitative values were not likely to be easily calculated, both papers showed that the societal risk can be viewed as the product of a series of probability factors. As examples can be mentioned the following: the probability that a group of terrorists would wish to accomplish an act of terrorism, the probability that they would choose a nuclear device as the means of achieving that goal, the probability that they would select a given plant from which to steal material, the probability that their attempt would or would not be detected at the perimeter fence, the probability that once detected the attempt would be defeated, etc. The authors suggest that qualitatively if not quantitatively, an analysis of such factors should help to focus attention on areas in which the physical security system is weakest, and away from areas in which the probabilities are already negligibly small.

Jones (IAEA-SM-201/35) described a computer simulation model for the assessment of the relative effectiveness of physical protection measures. Times required to cross barriers, response time of guard forces, characteristics of the attacking group, and other data are prescribed, usually in terms of probability distributions. The effectiveness of the protection system is then evaluated by repeated simulation of attacks, measuring the frequency with which the simulated attacks are successful.

Approaching the analysis of physical protection systems from a somewhat different direction, Schleter (IAEA-SM-201/36) discussed a decision structure for physical protection. He outlined a Safeguards Information System, intended to be both general and facility specific, as a basis for defining safeguards tasks, information flows and decision levels.

Chambers and Ney (IAEA-SM-201/12) discussed hardware aspects of physical protection, describing a doorway monitor that combined radiation and motion detectors with a photographic camera. The camera was activated only when triggered in coincidence by both the radiation and the motion detectors. The system thus allows unlimited passage of personnel so long as they do not carry nuclear material with them. It also allows the radiation detector to be set at a low level, one that might (and does) respond to occasional high background levels. Encasing the system in a tamper-indicating enclosure allows it to operate for long periods unattended, as it would when used by the IAEA as a surveillance device.

In another paper (IAEA-SM-201/66) Chambers described the development of a continuous inventory system for vault storage. Simple radiation detectors at each vault storage position, coupled with automatic verification of weight and radiation characteristics of containers entering and leaving the vault, are provided. A small dedicated computer maintains a continuing record of containers in the vault, compares observed weights and radiations with expected values derived from data provided by the operator, and adjusts radiation data for time dependence.

REAL-TIME MATERIAL CONTROL

The basic concept of nuclear materials accountancy safeguards is the preparation of a closed material balance. The measured beginning inventory at the start of an accounting period is adjusted by the addition of all measured inputs and by the subtraction of all measured outputs and the measured physical inventory at the end of the accounting period, yielding a quantity termed material unaccounted for, or MUF. If all inputs, outputs and inventory quantities are properly measured and recorded, then the expected value of MUF is zero, deviations from zero being caused by measurement

1. As pointed out in the paper, NRC will negotiate larger limits for facilities that can demonstrate that the specified limit is unattainable, or that it can be attained only after changes which will require a significant time delay. It is also true that, within the additional constraint that observed MUFs must be within the calculated uncertainty of the material balance, U.S. facilities may sometimes take a more relaxed attitude toward systematic error uncertainties.

errors or by unknown (and therefore unrecorded) material quantities. If the MUF is small, that is, if it can be explained by the known uncertainties of measurement, then diversion can be considered unlikely. If the observed MUF is larger than can be explained by the uncertainties of measurement and if it is not resolved by a consideration of possible unrecorded inventory quantities, then the unauthorized removal of material from the material balance becomes a possibility requiring further investigation.

The preparation of a closed material balance, the calculation of its probable uncertainty, and the safeguards verification of the quantities recorded in it are problems that are well understood. At least two-thirds of the papers presented dealt with some aspect of the closed material balance and most of the remainder of this article reviews those papers. In recent years, however, another difficulty has become of concern, that of timeliness. If physical inventories are taken at relatively infrequent intervals, say once or twice per year, and if a further delay of some weeks occurs before all samples are analysed, all results are compiled and all aspects are prepared and evaluated, then a diversion could go undetected for some months.

Several authors accordingly described efforts to reduce these delays through the use of computers, with information being supplied to the computer usually directly from the process area. Most of the work has concerned plutonium-uranium mixed-oxide fabrication facilities. These areas have both the greatest need, because of the high diversion potential of plutonium, and the greatest possibilities, because of the total glove-box containment which must be maintained at all times, coupled with the relatively low processing rates.

In true real-time material control nuclear material quantities cannot move from one part of the process to another without passing a computer-controlled measurement station where the quantity is measured and recorded. Most systems only approach this goal, since the computer usually is dependent on administrative controls to ensure that the operator does not bypass the measurement device. Keepin and Maraman (IAEA-SM-201/32), however, described DYMAC, a dynamic material control system being installed in a new plutonium facility under construction at the Los Alamos Scientific Laboratory. The DYMAC system provides no routine access between glove boxes except through or past the automated non-destructive measurement devices. It also provides physical security and surveillance devices to protect against more difficult means of bypassing the system. The computer is dependent on the operators only for batch identity data.

PROBABILITY AND SAFEGUARDS

Papers discussing statistical aspects of safeguards were few in number but excellent in content. Walker et al. (IAEA-SM-201/29) described the verification of plutonium inventories at the U.S. Energy Research and Development Administration's Hanford facilities. The basic approach involves:

Witnessing all in-process inventories

Obtaining independent destructive analyses on all in-process samples

Witnessing and confirming the presence of all inventory items

Performing NDA measurement verifications on randomly selected inventory items.

The statistical sampling plan and the choice of non-destructive instruments are based on three assumed possibilities, namely, complete removal of items, partial removal of items, or the biasing of measurement values. The non-destructive instruments used were also described.

Hough and Beetle (IAEA-SM-201/99) described the application of the same philosophy to the design of statistical sampling plans for IAEA safeguards inspection. In an extension of the work described by Walker and his co-workers, Hough and Beetle considered the calculation of the overall probability of detection for such a combined sampling plan, assuming that the would-be divertor followed an optimum strategy.

Jaech (IAEA-SM-201/14) considered two examples of the estimation of measurement uncertainties based on actual data, one involving shipper-receiver differences on low enriched UF_6, the other involving non-destructive measurements on barrels of plutonium waste. He also presented an iterative process for combining the results of a number of experiments into properly weighted estimates of measurement parameters.

INSTRUMENTATION AND MEASUREMENT METHODS

Almost two full days of the Symposium were devoted to what might be termed the hardware aspects of safeguards. In fact, the number of papers included was even greater since extensive use was made of 'rapporteurs', who summarized the work of a number of authors. Rapporteur summaries were included on destructive analytical techniques and the operation of analytical laboratories, the use of gamma-spectrometric techniques in safeguards, isotope-correlation techniques, material control and safeguards in reprocessing facilities, material control in the high-temperature gas-cooled reactor fuel cycle, material control in mixed-oxide fuel fabrication facilities, and safeguards measurements of spent reactor fuel.

Often referred to during the discussions but seldom specifically mentioned in formal papers was the problem of calibration standards for non-destructive measurements methods. A paper by Smith (IAEA-SM-201/19), accordingly, was noteworthy in that it was addressed directly to the problems of physical standards and valid calibrations. As noted by the author, "The calibration of an NDA instrument is strictly valid only for the assay of inventory items which do not differ from the physical standards used for the calibration with respect to any property to which the instrument is sensitive." The calibration of three instruments was specifically discussed; the Los Alamos Small Sample Analysis System (an active assay system based on the counting of delayed fission neutrons created by bombardment of samples by neutrons from a Van de Graaff generator), the Random Driver (a somewhat similar system, but using an AmLi neutron source and having the capability of handling containers up to 20 litres in volume), and the Segmented Gamma Scan (essentially a passive gamma spectrometer, but with the capability not only to rotate samples, but also to measure selected "segments" in the vertical axis). In each case the author discussed how the design of the system was carefully constructed to minimize biases, and the remaining biases which were identified and eliminated.

The operation of analytical laboratories in support of material control or safeguards operations was discussed by a number of authors. Lopez-Menchero et al. (IAEA-SM-201/98) reviewed steps the IAEA is taking toward the organization of a network of analytical laboratories in support of IAEA safeguards, and described the results of two plutonium analytical field experiments in which pure plutonium nitrate or oxide (PAFEX I) or reprocessing plant input solution (PAFEX II) samples were analysed by a number of participating laboratories. As might be expected, and indeed as was reported and discussed by other authors as well, the agreement between laboratories was not as good as agreement within any given laboratory. Although problems of standardization and calibration are presumed to lie at the root of this problem, no clearly identifiable differences in calibration procedures were reported.

Christensen and Schneider (IAEA-SM-201/10) reported on their experience in applying isotope correlation techniques to some thirty-three reactors of four different types, with the fuel having been processed in three different facilities. A total of 154 variables (ratios) were studied with the object of identifying those which were the most nearly linear over the widest possible range. Seven ratios were identified as meeting the defined requirements and were studied extensively. These seven provide a considerable measure of redundancy; in most cases only one or two ratios would be adequate to detect discrepancies in the declared data.

CONTAINMENT AND SURVEILLANCE

A tamper-indicating radiation surveillance instrument involving both motion and radiation detectors has already been described earlier in this report (Chambers and Ney, IAEA-SM-201/12). The general development programme for containment/surveillance systems, of which that paper was a part, was described by Hammond and Stieff (IAEA-SM-201/11). Although the systems developed have fairly wide applicability, the study was undertaken largely to meet anticipated needs in the safeguarding of enrichment facilities where inspector access to some parts of the facility might be denied.

Several papers discussed the possibility of applying seals to reactors or reactor fuel. Crutzen et al. (IAEA-SM-201/5) reported on the use of seals on MTR-type fuel in Euratom facilities and on development efforts to allow the application of seals to other types of reactor fuel. The most promising development is the ultrasonic seal, in which natural or artificial markings are introduced into the piece to be identified. Identification is by ultrasonic interrogation, and the results to date indicate that the irradiated fuel can be ultrasonically identified in the spent fuel pond. The general consensus of authors discussing physical seals was that too little was known about the possibility of the seal dislodging during reactor operation. Even if dislodgement is discounted, moreover, the prospects for post-irradiation verification of physical seals do not appear good.

Sinden et al. (IAEA-SM-201/67) reported on their studies related to the surveillance of fuel flow and reactor power at 'on-power' fuelled reactors of the CANDU type. When fission occurs in a thin layer of fissile material, some of the fission fragments have sufficient kinetic energy to escape from the material. To monitor reactor power, accordingly, the authors have studied the use of a track-etch monitor. Neutrons from the reactor cause fission in a small thin-layer fission source placed close to a slowly moving polyester film. The resulting track density (from fission fragments) is proportional to the incident neutrons, and therefore to the reactor power.

The complete Proceedings of the Symposium will be published shortly by the IAEA in Vienna.—**J.E. Lovett,** Division of Safeguards Development, International Atomic Energy Agency.

NUCLEAR MATERIALS INFORMATION SYSTEM

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INTRODUCTION

The Nuclear Materials Information System (NMIS) as it is presently constituted is the result of a long and rocky development. It was first visualized as an automation and computerization of the hand-kept records used for the Safeguards Control and Materials Management of the Atomic Energy Commission's nuclear material holdings.

The automated system was started in 1965. Since that time it has been broadened to serve all of the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC) users of nuclear materials data. In particular, the interfacing of transaction and inventory data with its unit costs; the development of a sealed source module; the building of safeguards and security inspection packages; and the analysis of nuclear materials data for safeguards, materials management and financial purposes to name a few.

Details of the system, its shortcomings and strengths and answers to its many critics is the thrust of this report.

DESCRIPTION

The Nuclear Materials Information System (NMIS) is a computerized system for receiving, storing, analyzing and reporting information on specified nuclear materials. At the present time, 19 separate nuclear materials are contained in the System.

The System, while generally spoken of and visualized as the NMIS Central Data Base at Union Carbide's Computer Science Division, Oak Ridge, Tennessee, must in fact be viewed as encompassing the field computers at the Operations Offices, the Government contractors and the licensees since they receive detailed transaction, inventory and analytical data, process that data and prepare it for transmission to the central data base at Oak Ridge. In addition, the NMIS must include the transmission facilities which connect the central data base with the field and the field computers. The description which follows is primarily of the Central Data Base operation at Oak Ridge, Tennessee.

The System processes information on nuclear materials owned and used by the U.S. Government, leased to or owned by private companies within the U.S., and leased or sold to foreign governments. At the present time, approximately 130 contractors, 1,100 licensees, 45 burial sites and 75 foreign nations or organizations are reporting to or receiving data from the System.

Data is reported to the System under contractual requirements, governmental rules and regulations and international agreements. It is processed, analyzed and reported for the coordinated support of safeguards, programmatic, administrative and financial management functions.

The Central Data Base has four major data systems: Inventories, Transactions (Inventory Changes), Material Balances and Forecasts. These primary systems are supported by auxiliary bases of reference information which results in a system of extreme flexibility that makes possible the rapid retrieval and interaction of pertinent data. Examples of these support bases are inventory composition profiles, unit cost data, current and historical transaction records, international contracts data, unirradiated scrap data, waste burial quantities and locations, material balance data (transactions, losses, MUF's, etc.), modes of transportation, authorized possession and contractual limits, etc. Other categories are added as needed without disturbing the existing data files. New and additional categories are expected in the near future in the development of the transportation module, the IAEA safeguards reporting requirements, and additional safeguards data fields.

The Central Data Base is maintained and operated on an intercoupled IBM 370/155-360/195 computer system. Each of the main processors has over one million bytes of core memory, and the system is equipped with many disk, data cell, and magnetic tape processing devices. The design of the computer system assures that operational support is maintained if one processor is temporarily out of service.

The NMIS data base contains approximately 152,000,000 characters of information stored in 1,700,000 computer retrievable records. The annual growth rate is about 55,000,000 characters of information.

All major components of the NMIS data base are maintained in disk and data cell direct-access storage that is on-line with the computer system for continuous availability of the information. Other information is stored in disk and magnetic tape units that are mounted and processed as needed.

A library of 215 computer programs performs the input processing, data base support, data retrieval, computational, analytical, and report-generating functions. Programming languages are COBOL, FORTRAN, and Assembler Language, with COBOL being the primary language.

The NMIS data control operation works on a schedule of 7:45 a.m. to 10:00 p.m., Monday through Friday, with this schedule being extended when needed. The Data Control Unit receives incoming data, schedules the required processing services, performs the error correction functions, and distributes the reports produced by the System.

Information on shipments of nuclear materials and other types of inventory changes is processed daily. The inventory cycle is closed monthly for the Government's production installations and quarterly for all nuclear facilities. Material balances are processed monthly, and a new twelve-year forecast is processed annually.

Reports generated and distributed by the NMIS include exception and on-demand reports, as well as the regularly scheduled reports for daily, weekly, monthly, quarterly, semiannual, and annual cycles as requested by the System's users.

AREAS OF SAFEGUARDS CONCERN

Seven broad areas of safeguards concern are identified below in which the NMIS must be responsive if it is to serve the safeguards needs. Each of these broad areas is made up of more detailed requirements and is discussed in the following paragraphs.

1. Material Status (Balance) Report Information

This area encompasses most of the safeguards information which is characterized as accountability data. That is, transfers (receipts and removals), operating losses (normal operating and accidental), production, burnup, material unaccounted for, etc.

In each of these areas the need for reliable and timely data is of extreme importance from a safeguards standpoint. Further, with regard to most of these items the need for reproducible "historical" information is also important.

Speaking to the transfer portion, it is important to record certain of the transfer information such as the date of shipment, weights of contents, isotopic composition when appropriate, material form, ownership, limits of error and measurement data, as well as the time of receipt, etc. These data are presently flowing into the NMIS. The greatest criticism seems to be that it is not flowing fast enough and not in enough detail. With regard to the problem of more timely flow, the NMIS can and does accept all pertinent data at any and all times it is submitted. The instructions provided to the field are that all data that is ready to be sent to the NMIS should be sent as soon as it is ready and in **no event later** than one week after it is prepared. We find that while some offices and contractors submit data daily or more often, many others continue to accumulate data for an entire week and some for even longer periods before submitting it. There is, of course, an optimum which has to be observed in the routine situation, which is the practicality of the cost of sending data as well as the nature of the data itself and the pressing need for the transmission.

There is also the question of whether enough detail of the transactions, etc. is included in the NMIS central data base. When one visualizes the NMIS as encompassing the computers at the field offices, contractors and licensees one can determine on a rational basis the data that should be handled, analyzed and retained at each location. In conjunction with this, the level at which action is to be taken on safeguards problems must be defined and the data to support such action be available at that location where the action is to originate.

As a matter of operating possibility, the NMIS central data base equipment and the organization of the data is such that any amount of detail could be included in the data bank, and further the analytical capability of the equipment is more than adequate to handle any review or analysis of the data that may be desired.

The question of access to the contained data and preparation of alert type reports needs to be considered. Once again the system can provide this type of response on most any schedule desired. Only the need for and description of the response must be established.

2. Inventories

Knowing the location of all pertinent nuclear materials is the heart of any safeguards system. That is whether such is in static storage, an operating process, or in transport. Further, with the exception of an observation (in one form or another) of an actual theft or diversion of material, it is only by taking a physical inventory that the presence or absence of material can be established. It is a further fact that only by having a balance around specific operations (storage, operation, etc.) that a material unaccounted for (MUF) can be established. Inventories therefore take on increased importance, and depending on the action or alarm level that one wants to establish will rest the size of the area or operation one wishes to draw the balance around and the frequency with which a physical inventory is to be taken.

For example: In a processing or production area, one could want an inventory on an hourly or daily or more or less frequent basis. The results of such an inventory may very well go no further than the operating foreman or possibly into a local operating computer or the plant central computer. In this kind of setup in the event of a discrepancy action would be taken immediately and one course may be taking an inventory of larger encompassing and adjacent areas to help locate the discrepancy.

Whether management wants this type of information flowing to or be included in the NMIS central data base is a decision which must be made. The equipment can handle it, but under most circumstances a more practical approach would appear to coordinate the use of the field computers more closely with the central base.

Another important aspect of an inventory is its makeup or composition. The coding of the composition of ending inventory (COEI) has been worked out and while it undergoes revision and change it is used by the central NMIS and in the most part by the operations offices and contractors. This coding is necessary to meet the needs of the users of the System. The present requirement for reporting inventories into the NMIS is that they be submitted by the 15th day of the month following the end of the month in which the inventory is taken. Once again, the System can accept the data at any time it is submitted. In addition, there is a requirement that a COEI be submitted on a quarterly basis (recognizing that in most cases this will be a "book" COEI).

Some confusion exists in this area in that the Manual requires a physical inventory **no less** frequently than once a year, with the option being available that more frequent inventories may be taken if the Field Office Manager deems it desirable to meet his managerial, financial and contractual needs. As a matter of fact, almost all of the large contractors take a monthly physical inventory and submit that data to the NMIS central data base.

With regard to inventory data from commercial licensees, the Code of Federal Regulations has for many years required that an annual inventory be taken (when the authorized possession limit is above certain levels), but has not required that the inventory data be submitted to the central data base. The NMIS is prepared to accept such inventories when they are reported, and in the meantime, prepares, for NRC use as needed, book inventories at various licensees.

3. **Exception Reporting**

In both the major areas of Material Status Report Information and Inventories, certain aspects of safeguards concern lend themselves to an "Exception Reporting" type of operation. This is true at every action or alarm level that is established, whether it be at the internal plant operating level, or at the Commission or Administrator's level.

This "Exception Reporting" has been instituted in the central data base to a limited extent for NRC (Safeguards Alarm Module). It functions on the basis of limits being identified for any data element of concern. For example, possession limits for special nuclear material. These limits are put in the NMIS and the computer programmed to query that limit whenever an inventory is reported and whenever a transaction of that material at the designated location takes place. If the limit is exceeded that fact is reported by the machine. The frequency of such alarm reporting, the elements to be reported and the alarm limits must all be established by the user of the information.

There is no practical ceiling to the number of items of data that could be included in this type of reporting for safeguards purposes nor is there any real practical limit as to the frequency with which such reports can be rendered. There is, however, the need for it to be instituted on a broader basis and for review of the reported data by the interested users and for action to be taken when exceptions are considered significant.

4. **Inspections**

A great deal of data and information is needed by safeguards inspectors when surveying, auditing and reviewing the safeguards aspects of an operation. In the past, manual preparation of the working papers, covering a year's activity or more, was a very time-consuming task.

An inspection package has been developed that is prepared from the NMIS central data base. There has been some criticism that the data thus obtained from the NMIS is not all that is needed by the inspectors, and that it is not completely current. Two practical answers must be made to these points. First, the survey package is built with a maximum amount of flexibility so that each package is produced essentially according to the specifications of the requestor. Where the package does not meet those specifications the program is changed in order to be able to provide the data when next requested. Second, the survey packages are prepared to cover the time period specified by the requestor at the latest date possible and still get the package to him on the date he has specified. This requires mailing in some instances and results in a time delay. The changes being made in the SACNET system and in our capability to send data from the central base out to the field over the SACNET as well as the unclassified terminal (PDP-10) are relieving this time lag to a great extent. The biggest problem in this area, however, is the lack of current input to the system, and the consequential limitations which cannot be overcome without changing the input. In addition, there is no practical way of avoiding some reconciliation by the auditors in order to bring the survey package "book" data into agreement with the data at the site being inspected.

In an effort to be more responsive to the needs of the inspectors in the NRC a new inspection package has just been developed which meets their special requirements as they have been communicated to this office.

5. **Transportation**

Every movement of special nuclear material (one gram or more for licensees) must be documented and the data transmitted into the System's data base. Both NRC and ERDA requirements call for the preparation and distribution of the transaction documents at the time of the shipment. The System maintains its capability to accept transportation data in an on-line mode and accordingly, can process the data as often as it is submitted. Present procedures call for submissions at least weekly to the NMIS.

Some of the key Safeguards transportation data elements are:

a. Identity of the shipper and receiver.

b. Dates shipped and received.

c. Forms of material and its weight and enrichment.

d. Limits of error for both shipper's and receiver's weights.

e. Primary mode of transportation used.

The System has recognized the need for further Safeguards transportation data and it is planned that action be taken to capture at least the following features:

a. Physical protection given the shipment.

b. Communications protection given the shipment.

c. Gross weights for all transfers (now obtained only for waste shipments).

d. Individual container or batch data as warranted.

e. Measurement methods applied to material being shipped.

f. Improved limits of error.

In order to assure that the transportation data in the NMIS is complete and contains all of the data elements needed by the different users, a meeting of all groups with such an interest was held in August 1975, to identify all needed elements of data, identify the means of having the data flow to the NMIS, identify responsibility for preparing directives (rules, regulations, orders or contract provisions), to start the data flowing and assure its accuracy and timeliness, to being to define the output wanted from the NMIS and to identify the organizations and individuals who will receive the output and establish its frequency.

At present, acknowledgement of receipt of the shipment must be given in ten days and measured in thirty days. Those requirements are often not observed. Without changing any of the input, the utility of the System for safeguards purposes would be significantly enhanced if both the shipper and receiver were required to measure and report its material movements more promptly. Transportation reports for NRC are now being prepared on an operational basis each quarter. Specific requests for many variations of such reports are being prepared once or twice a month. Plans exist for providing Albuquerque Operations much of the data it needs for trigger quantity shipments in conjunction with its management of the SST movement system.

6. **Interfaces with the International Atomic Energy Agency (IAEA) and Other Systems**

Interface programs have been developed to permit the direct transmission of data to the NMIS central data base from a number of contractors and at least one licensee system. Generally speaking, most domestic systems use the same coding structure and data sources as the NMIS; therefore, movement of data from one system to the other can be accomplished with little difficulty. It is expected that additional domestic interfacing will be worked out as transmission capabilities increase.

With regard to interfacing with the IAEA more serious problems exist. While most of the data elements that the IAEA has indicated they will want are the same as those flowing into the NMIS, additional elements and information will be required. As a result of earlier conversations with IAEA staff, extensive efforts have been made to prepare the NMIS to receive the additional data. Also, tentative plans have been made to have all data for the IAEA submitted to the NMIS central data base where it will be collected and, as agreed with the IAEA, placed on magnetic tape for transmission to Vienna in the format which will permit direct input into the IAEA system.

There is not much more that can be done with the NMIS to expedite this interface until definitive requirements are established with the Agency; the requirements for submission of the data to the NMIS are worked out; and the format for submission of the data to the Agency is known.

7. **Physical Security**

Historically the NMIS has had only limited usefulness as a management tool in this area. The Reporting Identification Symbol (RIS) Directory carries addresses for classified documents and nuclear materials as well as an appendix indicating the Field Office responsible for security of each RIS. No other data of a direct security nature has been included. The System is also designed to identify each report prepared and relates the designated classification accordingly.

Recently however, NRC safeguards staff has asked that we develop a physical security register for all licensees authorized to possess trigger quantities of SNM. The various characteristics regarding the security at each facility, as provided in their license application, would be put in the System in a manner that they could be drawn on for individual facility inspection and confirmation, or used for comparative purposes in a logical licensee group study.

This type of information together with other data relating to nuclear materials which have security implications can be included in the System upon the identification of the desired elements, arrangements for them to flow to the System and establishment of report format, frequencies and users.

RESPONSE CAPABILITIES

The response capabilities of the NMIS must be considered within the parameters of the following particular categories:

1. **Hardware**

The hardware within which the data base is contained is capable of responding to any query made for

NMIS data in a matter of seconds. All NMIS data including all programs which are frequently used (except for some historical files) are maintained on direct access storage disks or data cells.

The CSD computer system is operated on a "batch" mode and is used by the NMIS only a very small part of the time it is in operation. Usually a matter of minutes each day and a few hours at the close of a reporting period. Consequently, except when the computer is down or when other users exercising a higher priority are using the computer the hardware is **not** a source of delay. In an emergency, priority arrangement can be made to process NMIS requirements immediately.

2. Software

The software capabilities of the NMIS are increased as required to meet the needs of System users. As noted above, many programs are maintained in a direct access mode. One of the major problems in the software area is trying to keep up with the many variations in special requests from users. That is to say if there is a different way of asking for information someone will request it.

The software can be divided into four major categories.

a. Data Base Support Programs,
b. Retrieval Programs,
c. Computational and Analytical Programs, and
d. Report Generation Programs.

The software is developed on a modular basis with specific personnel assigned to each module. The interaction of the modules results in all personnel being familiar with each module and able to assist when additional help is needed.

The modular development provides for maximum flexibility and greatly increases the ease and speed by which data can be retrieved and interacted with other data. This is of particular importance in the development of the analytical needs of the safeguards program.

3. Communications

The communications network for the transmission of data to and from the NMIS central data base should be considered an integral part of the System.

The primary means of transmitting data is over the SACNET system which is a secure high speed system interconnecting all of the field offices and the major contractors through a "switch" computer located at Headquarters. Through continued development, the SACNET is now accepting, for direct transmission to the field, reports and data from the central data base. This development replaces the need to prepare "hard copy" for mailing thereby reducing the workload as well as providing reports on a more timely basis.

In an effort to meet the needs for the transmission of unclassified data, especially from the licensees, two computers at the Holifield National Laboratory have been set up to receive NMIS data using a telephone dial-up connection. The two computers are an IBM 360-75 and a PDP-10. The PDP-10 is tied into the central data base computer at the Computer Science Division for one-way transmission from the PDP-10. Transmission from CSD to the PDP-10 must have a manual break which is the preparation of a tape that is hand-carried to a PDP-11 at CSD which then transmits to the PDP-10 which in turn can transmit to a qualified terminal in the field either directly or through the IBM 360-75.

The two computers (PDP-10 and the 360-75) can receive from any of a large number of terminal devices set up in the field, all the way from an IBM Selectric Typewriter to any compatible computer.

Information to the central data base can be sent by the above means as well as by punched cards, paper tape, magnetic tape, or transcription sheet. This flexibility permits field users to utilize the most effective means at their disposal.

4. **Timeliness**

The timeliness of the data in the NMIS is a function of the programs with which it is submitted. There is no delay in getting the data into the data base once it is received at CSD. The use of SACNET and the unclassified computer setups (PDP-10 and 360-75) assure electronic communication with those groups that have terminals.

Retrieving data depends on whether the existing retrieval programs can be used or if they must use modified or new ones written. All variations of such programs are retained for future use as needed.

In general, the CSD personnel have been able to give a 2-hour turn-around on requests for information where no modification to programs is required. Where minor modifications are involved, 24-hour response is usually possible. Major changes take longer and of course other priority items can interfere in all instances.

5. **Report Distribution**

As a general principle, it has been felt that the computer can prepare a specific report for a user, more quickly and efficiently, than the user can work through and extract data from a large report. For that reason, NMIS reports have been tailored to meet individual requirements insofar as practical. This policy has of course increased the actual number of reports, but has increased the utility and usability of them.

A specific group of people dedicated to the exclusive use of the NMIS at CSD called the Data Control Unit has been established to do the "housekeeping" work of operating the System. This group handles the data input to the NMIS, takes action to correct or obtain correction of errors noted or identified by the Edit Programs, and prepares and transmits reports to the various users. The load on this group has been very great but is being moderated with the direct transmission of reports to the field via SACNET.

AREAS OF CRITICISM

The areas of general criticism of the NMIS have for the most part centered around what has been characterized as the inability of the System to meet specific needs of specific users, and in particular, the safeguards users. Certainly with this System, as with any and all systems, there are limitations, but with the computer equipment available (main frame, storage and other auxiliary devices) there is very little that the System cannot handle. Consequently, the general criticisms have to be looked at in the context of Policy Positions, Requirements for Data Flow, and the desire for detail in a central data base as distinct from detail in the field units.

The five areas where criticism is generally directed at the System are discussed below.

1. **Real Time Data**

From a Safeguards standpoint there are many who feel that data must be put in any data control system on a real time basis and that a continual analysis of the input should be made. This could be done in the central data base, but as discussed earlier for the most part it is more practical to handle as much detail as possible in the local computers, with periodic (daily or less) transmission of results to the central base for further analysis with respect to other facilities, and for central storage.

The availability of computer equipment, transmission facilities and the real need, from the safeguards control standpoint, are the only deterrents to such a system being implemented. Costs and operating personnel become great but are **not** impossible.

2. **Complete Detail Data Is Not Available**

Many of the arguments given above are applicable to the supposed lack of detail in the NMIS central data base.

There is no limitation on the amount of detail data that can be put in the System. In fact the level and amount of detail being included is constantly increasing as the users identify their needs and the flow can be established and reported. The real problem is in making a policy decision as to where detail is to be maintained and what would be best to keep in the central data base.

The practical limitation on the central data base is the available storage capacity and that is expandable without limit. Another practical problem is getting the data to flow as it is developed and on a timely basis (whatever the desired time limitation is established at). In this latter area transmission and computer capacities as well as personnel become important factors in the decision-making process.

3. **Analysis of Data**

The capability of the central computer to analyze the data contained in it is well established. Such analytical work has been done whenever requested by the Safeguards interests (for example, the NRC Safeguards Alarm Report). Other users of the NMIS make extensive use of the analytical capability of the central computer on a continuing basis.

It has long been the contention of the NMIS group that many of the safeguards problem areas should be considered for analytical probing by the central computer utilizing the data presently flowing to the System, and that much more could be done if other logical data elements were included in the base.

4. **Delay in Getting Reports**

The makeup of reports from the NMIS is limited only by the desires and needs of the users. The accuracy of the data, the timeliness of the data and the completeness of the data are a function of the flow of information to the computer. There is no question but what all of these can be improved with the proper pressure being applied in the right areas.

Likewise the type of reports, the frequency of the reports and the distribution of the reports is a function of the desires of the users and the accuracy and completeness of the specifications which are provided in requesting the reports.

5. **Safeguards Data Must Be Separate From Managerial Data**

With only minor exceptions in all fields of Safeguards and Management of nuclear materials, any movement, measurement, use, loss or characteristic of the nuclear material is of interest to both groups. That is to say whenever any measurement of the material is made (analytical or physical) safeguards people are interested in the quantity, the composition and the location. This interest also exists for plant management people, finance people and program people. This same thing is true with respect to movements (transfers, both intraplant and interplant), losses whether normal operating, accidental or other, and inventories, i.e., safeguards from the standpoint of control, finance because of dollar value and need to adjust books and assign costs, production and program from the standpoint of accomplishing their work and the efficiency of the operations.

The argument is put forth that the level of detail differs with the various groups. That is true but let's examine it a moment. If one group needs more detail than the other groups these other groups will in most instances be happy with the increased detail and if not, the detail can be summarized by the computer to meet the specific needs.

The timeliness of data is another area where separation is suggested as being warranted. The same arguments apply. All segments of finance, production, program control and safeguards prefer to work with current data. So while their ultimate actual needs may be different the group requiring the most prompt data sets the controls, and information is adjusted to meet the other's time schedules.

Regarding Physical Security, once again all groups have an interest in the protecting of their mutual assets. While finance, production and program people may not care to receive detailed security reports, the security of the materials and plants impacts on their work in the way of increasing or decreasing costs to their work and consequently the ultimate funding of their programs. Therefore the data can be included in the NMIS and be of benefit to all users.

Finally, it is recognized that the NMIS is not a panacea for all of the safeguards problems and needs, but at the same time its usefulness and capabilities are not understood and, therefore, are not utilized as they should be.

Establishment of separate systems would not only require the duplication of equipment and facilities, but would require duplication of the reporting of data including corrections and adjustments. This latter duplication would quickly result in discrepancies in data contained in the different systems, and could only lead to embarrassment and frustration when such discrepancies surface.

PORTAL RADIATION MONITOR

(Continued from page 17)

The PRM-110 will routinely detect, with 90 percent confidence in one second or less, radiation from 0.5 gram of plutonium that is shielded by 3 mm of brass.

Other high technology equipment developed by IRT provides quality control for the manufacture of nuclear fuel, neutron radiography systems for nondestructive inspection, assists in exploration for oil and uranium and screens vehicles for narcotics. Also, IRT has developed a high speed letter bomb detector capable of screening letters at a rate of 600 per minute and a borehole logging device to aid in the search for uranium.

IRT began in 1956 as a part of General Atomic Laboratories in La Jolla, California. The organization's nuclear research and development activities expanded and, with the sale of GA to Gulf Oil Corporation in 1967, this division became known as Gulf Radiation Technology. Later, this division was merged with Intelcom Industries, changing the name to Intelcom Rad Tech. Now the company name has been shortened to IRT Corporation.

ORTEC was founded in 1960 by a group of scientists from Oak Ridge National Laboratory for the purpose of developing and manufacturing nuclear physics instrumentation. In 1967, ORTEC merged with EG&G, Inc. and its sales have expanded worldwide. The firm now has subsidiary companies in Germany, France, England, Italy, and Brazil. ORTEC sales operations in the U.S. are through 18 direct sales engineers and in Canada, through Radionics Ltd. In Mexico, ORTEC is represented by Ing. Jacques Thions. ORTEC supplies a variety of research and materials analysis instrumentation for the physics, life sciences and materials analysis market.

ERRORS OF MEASUREMENT WITH MORE THAN TWO MEASUREMENT METHODS

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Introduction

In safeguards applications, it often happens that two measurement "methods" are used to make measurements of the same items. "Methods" is used in a general sense, and the problem includes such typical situations as occur when the shipper and receiver make measurements on the same items, when an inspector makes measurements on sampled items and compares his results with the operator's values for those items, and when an analytical laboratory wishes to compare two analytical techniques by measuring the same items by both techniques.

A problem of interest in this situation is to obtain estimates of the random errors of measurement for both methods, and to test various hypotheses about these parameters. The estimation problem was first considered by Grubbs [1]. His estimation method is presented by the author [2] in the context of safeguards applications, and procedures for testing various hypotheses, due to several authors, are also given. In this journal, the author has treated other aspects of the problem in two earlier papers [3] [4].

In some instances, there are more than two measurement methods whose precisions are to be estimated or for which certain hypotheses are to be tested. This occurs, for example, with shipper-receiver data if an inspector also measures a sample of items previously measured by both the shipper and the receiver. Another example occurs when the same items are measured in a number of laboratories, and/or by a number of measurement techniques.

Grubbs [1] also provides the estimates of the precisions in the case where there are more than two measurement methods. There are a large number of hypotheses that one might wish to test. The author recently developed a general large sample test procedure that may be applied to test a variety of hypotheses [5]. It is the purpose of this paper to give the estimating equations, describe the large sample test procedure in simple terms, and apply the methodology to an actual example.

Problem Setting and Notation

Let there be N measurement methods, and denote the number of items measured by each method by n. The total number of data points is therefore nN, there being N columns of data, each column having n observations corresponding to the n items measured.

The measurement on the j-th item made by method i is denoted by y_{ji}, with j=1,2,...,n and i=1,2,...,N. The assumed model is

$$y_{ji} = x_j + \epsilon_{ji} \qquad (1)$$

where x_j is the true value for item j, and ϵ_{ji} is the random error of measurement assumed to be selected at random from a normal population with zero mean and variance denoted by v_i. The problem is to obtain the estimates of v_i; i=1,2,...N, and make various tests of hypotheses concerning the v_i.

Before proceeding further, it is noted that the model (1) assumes that the N measurement methods are unbiased. This is not a necessary assumption, and the procedures to follow are valid if some or all of the N measurement methods are biased by constant amounts.

Estimation of Measurement Parameters

The parameter, v_i, is estimated by the following steps.

Step (1): Form the columns of differences of the data. There are $N(N-1)/2$ such columns, each with n data points.

Step (2): Calculate the sample variance for each column of differences. For the column of differences corresponding to methods i and k, denote the sample variance by V_{ik}. There are $N(N-1)/2$ such sample variances.

Step (3): Sum up all V values containing i as one subscript. There are $(N-1)$ such values.

Step (4): Sum up the remaining V values, those not containing i as one subscript. There are $(N-1)(N-2)/2$ such values.

Step (5): Divide the result of Step (4) by $(N-2)$, and subtract this quantity from the result of Step (3).

Step (6): Divide the result of Step (5) by $(N-1)$. This is the estimate of v_i.

Steps (3)-(6) are repeated for $i=1,2,\ldots,N$ to provide the estimates of the N precisions.

Hypothesis Testing

The kinds of hypotheses that one might want to test about the precisions of the measurement methods are potentially quite varied. If all measurements are made using the same analytical technique, it is reasonable to test the hypothesis that all methods have the same precision. If more than one analytical technique is used, the hypothesis might be that those measurement methods based on the same analytical technique have the same precisions while allowing for different precisions for the different analytical techniques. As another example, some or all of the measurement methods may have stated precisions associated with them, and the hypothesis might be that the precisions, singly or jointly, are as stated.

A general procedure is given for testing various hypotheses that might be proposed. This procedure requires making use of the following defining relationships.

$$v = v_1 \, v_2 \ldots v_N \qquad (2)$$

$$Q = v/v_1 + v/v_2 + \ldots + v/v_N \qquad (3)$$

$$W = v \, (V_{12}/v_1v_2 + V_{13}/v_1v_3 + \ldots V_{N-1,N}/v_{N-1}v_N) \qquad (4)$$

(There are $N(N-1)/2$ terms in this sum)

$$L = -0.5 \, n \, (\ln Q + W/Q) \qquad (5)$$

With these definitions in mind, follow the steps given below to test a specified hypothesis.

Step (1): Replace the v_i values in equations (2) - (5) by their estimates given in the preceding section. Denote the value for L thus calculated by L_1.

Step (2): Similarly, for a given hypothesis, replace the v_i values in equations (2) - (5) by those values specified by the hypothesis in question. Denote the value for L thus calculated by L_2.

Some common hypotheses and the corresponding values that should be used for the v_i quantities are:

a) If the hypothesis is that all precisions are equal, use the same value, $\bar{v}$, for all v_i quantities, where $\bar{v}$ is the average of all the estimates of the v_i's given in the preceding section.

b) If the hypothesis is that within certain subsets the precisions are equal, then calculate as many values for the v_i's as there are subsets. Each value is the average of the estimates of the v_i's comprising that subset.

c) If the hypothesis is that one or more of the precisions are equal to stated or hypothesized values, then use these hypothesized values in their stead. For the remaining v_i's, use the appropriate averages of their estimates as in (a) or (b).

d) For other specified hypotheses, the general approach of reference [5] may be applied.

Step (3): Calculate $\lambda = 2 \, (L_1 - L_2)$

Step (4): Reject the hypothesis in question at the α level of significance if λ exceeds $\lambda_{m,\alpha}$ tabulated in Table I. The quantity m is equal to N minus the number of different parameters estimated under the hypothesis.

Table I

$\lambda_{m,\alpha}$ = Critical Values for λ

m	α = 0.05	α = 0.01
1	3.84	6.63
2	5.99	9.21
3	7.81	11.34
4	9.49	13.28
5	11.07	15.09
6	12.59	16.81
7	14.07	18.48
8	15.51	20.09
9	16.92	21.67
10	18.31	23.21

Example

In auditing the performance of accountability scales, 15 items of varying weights were weighed on each of 6 scales. Here N=6 and n=15 so that nN, the total number of observations is 90. The data are given in Table II.

Table II

Weights of Items (kg)

Item	Scale 1	2	3	4	5	6
1	9.320	9.350	9.290	9.350	9.325	9.325
2	8.345	8.380	8.325	8.400	8.350	8.355
3	4.140	4.160	4.125	4.150	4.125	4.155
4	5.700	5.725	5.690	5.750	5.675	5.710
5	15.900	15.975	15.930	15.950	15.925	15.920
6	11.700	11.740	11.800	11.775	11.775	11.710
7	13.240	13.300	13.290	13.300	13.300	13.260
8	10.730	10.760	10.725	10.850	10.725	10.742
9	12.280	12.320	12.300	12.350	12.300	12.294
10	8.070	8.100	8.090	8.100	8.050	8.085
11	18.290	18.350	18.380	18.350	18.300	18.300
12	19.840	19.900	19.900	19.950	19.850	19.850
13	15.630	15.700	15.610	15.725	15.625	15.645
14	14.660	14.725	14.700	14.750	14.675	14.678
15	1.760	1.780	1.780	1.800	1.825	1.770

First, consider the estimation of the measurement parameters. The steps given in the section on Estimation are followed:

Step (1): The N(N-1)/2 or 15 columns of differences are formed. For example, in grams, the column of differences for scale 1 minus scale 2 is -30, -35, -20, ..., -20.

Step (2): The sample variances are computed. For a given column of differences, the variance is the sum of the squared values minus the square of the sum over n=15, this difference divided by n-1=14. The results are given in Table III.

Table III

Sample Variances in Example (g^2)

V_{12} = 361.43	V_{23} = 1349.29	V_{35} = 1099.52
V_{13} = 1620.71	V_{24} = 765.00	V_{36} = 1596.50
V_{14} = 952.86	V_{25} = 1095.95	V_{45} = 1738.10
V_{15} = 930.24	V_{26} = 293.35	V_{46} = 957.78
V_{16} = 18.21	V_{34} = 1936.44	V_{56} = 924.21

Step (3): To estimate v_1, the sum is

$$(V_{12}+V_{13}+V_{14}+V_{15}+V_{16}) = 3883.45$$

To estimate v_2, the sum is

$$(V_{12}+V_{23}+V_{24}+V_{25}+V_{26}) = 3865.02$$

To estimate v_3, the sum is

$$(V_{13}+V_{23}+V_{34}+V_{35}+V_{36}) = 7602.46$$

For v_4, the sum is 6350.18

For v_5, the sum is 5788.02

For v_6, the sum is 3790.05

Step (4): The sum of all 15 V_{ik} values is 15639.59. Therefore, to estimate v_1, the sum is 15639.59-3883.45= 11756.14

For v_2, it is 15639.59-3865.02= 11774.57

For v_3, it is 8037.13

For v_4, it is 9289.41

For v_5, it is 9851.57

For v_6, it is 11849.54

Step (5): To estimate v_1, 3883.45-(11756.14)/4= 944.415

To estimate v_2, 3865.02-(11774.57)/4= 921.3775

For v_3, 5593.1775

For v_4, 4027.8275

For v_5, 3325.1275

For v_6, 827.665

Step (6): $\hat{v}_1$ = 944.415/5=188.88

$\hat{v}_2$ = 184.28

$\hat{v}_3$ = 1118.64

$\hat{v}_4$ = 805.57

$\hat{v}_5$ = 665.03

$\hat{v}_6$ = 165.53

Having found the estimates of the precisions, test the hypothesis that all are equal. This is the situation (a) under Step (2) of the procedure to test hypotheses. The steps of that procedure are followed. In what follows, all the V_{ik} and v_i values are multiplied by 10^{-2} for convenience.

Step (1): From equations (2) - (5),

v = (1.8888)(1.8428)...(1.6553) = 3452.8345

Q = 1828.0572 + 1873.6892 + 308.6636 + ... + 2085.9267 = 7044.1566

W = 3452.8345 (1.0384 + 0.7671 + ... + 0.8396) = 32330.4902

L_1 = -7.5 (8.8600 + 4.5897) = -100.873

Step (2): The same value, $\bar{v}$, is used in equations (2) - (5). Thus, these equations simplify as follows:

$$v = (\bar{v})^N = (5.2132)^6 = 20074$$

$$Q = N(\bar{v})^{N-1} = 6\ (5.2132)^5 = 23103$$

$$W = (\bar{v})^{N-2}\ (V_{12}+V_{13}+\ldots+V_{N-1,N})$$
$$= N(N-1)(\bar{v})^{N-1}$$

$$W/Q = N-1 = 5$$

$$L = -7.5\ (10.0477 + 5) = -112.858$$

Step (3): $\lambda = 2\ (-100.873 + 112.858) = 23.97$

Step (4): At $\alpha = 0.05$, and at $m = 6-1 = 5$; $\lambda_{m,\alpha} = 11.07$ from Table I. Since $23.97 > 11.07$, reject the hypothesis that all precisions are equal.

In calculating m, the number of parameters estimated under the hypothesis is 1, the overall average precision.

Consider another hypothesis. Scales 1 and 6 are of one type, scale 2 is of a second type, and scales 3, 4, and 5 are of a third type. This suggests the hypothesis:

$v_1 = v_6 = s_1$, estimated by $(\hat{v}_1 + \hat{v}_6)/2 = 177.21$

$v_2 = s_2$, estimated by $\hat{v}_2 = 184.28$

$v_3 = v_4 = v_5 = s_3$, estimated by $(\hat{v}_3 + \hat{v}_4 + \hat{v}_5)/3 = 863.08$

Steps (1) - (4) are again followed. Step (1) is the same as in the previous example.

Step (2): The equations (2) - (5) simplify as follows:

$$v = s_1^2\ s_2\ s_3^3$$

$$Q = 2s_1s_2s_3^3 + 3s_1^2s_2s_3^2 + s_1^2s_3^3 = 7511.2414$$

$$W = s_1s_3^3\ (V_{12}+V_{26}) + s_1s_2s_3^2\ (V_{13}+V_{14}+V_{15}+V_{36}+V_{46}+V_{56}) + s_1^2s_3^2(V_{23}+V_{24}+V_{25}) + s_2s_3^3(V_{16}) + s_1^2s_2s_3(V_{34}+V_{35}+V_{45}) = 34554.8350$$

$$W/Q = 4.6004$$

$$L_2 = -7.5\ (8.9242 + 4.6004) = -101.435$$

Step (3): $\lambda = 2\ (-100.873 + 101.435) = 1.12$

Step (4): At $\alpha = 0.05$ and $m = 6-3 = 3$; $\lambda_{m,\alpha} = 7.81$ from Table I. Since $1.12 < 7.81$, do not reject the hypothesis that scales of a given type have the same precisions.

As a final hypothesis, suppose that an a priori precision value is hypothesized for the scales 3, 4, and 5. Based on the vendor's statement, suppose that the hypothesis is

$v_1 = v_6 = s_1$, estimated by 177.21 as in the prior example

$v_2 = s_2$, estimated by 184.28 as in the prior example

$v_3 = v_4 = v_5 = 500$

Steps (1) - (4) are again followed, where Step (1) is the same as in the previous examples. In step (2), replace s_3 in the previous example by its hypothesized value, 500 (or 5.00 since all numbers are divided by 100 for convenience).

Step (2): $v = s_1^2\ s_2\ (5.00)^3$

$$Q = 816.4065 + 434.0262 + 392.5423 = 1642.9750$$

$$W = 1450.4195 + 5700.3949 + 2520.3100 + 41.9467 + 1381.3780 = 11094.4491$$

$$W/Q = 6.7527$$

$$L_2 = -7.5\ (7.4043 + 6.7527) = -106.177$$

Step (3): $\lambda = 2\ (-100.873 + 106.177) = 10.61$

Step (4): At $\alpha = 0.05$, and $m = 6-2 = 4$; $\lambda_{m,\alpha} = 9.49$ from Table I. Since $10.61 > 9.49$, reject the hypothesis.

Having already concluded when testing the second hypothesis that $v_1 = v_6$, it follows that this third hypothesis is rejected because the stated value of 500 for v_3, v_4, and v_5 is incorrect. The precision for this type scale is different from that stated.

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A SYSTEM OF ACCOUNTABILITY AND QUALITY FUEL ROD SCANNING IN A FUEL FABRICATION FACILITY

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I. INTRODUCTION

Fuel rod scanning at General Electric's Nuclear Fuel Fabrication Facility was initiated in 1969 by the installation of a passive rod scanning operation. This operation eventually employed 42 passive rod scanners scanning the entire UO_2 rod output of the Wilmington facility. In early 1970, the Los Alamos Scientific Laboratory (LASL) fuel rod scanner was introduced into the Wilmington facility as a joint effort of the then USAEC and the General Electric Company. The LASL scanner was designed to assay the fissile content of fuel rods in contrast to the passive scanners which measured the variation of fissile content per unit length of fuel rod. This joint effort demonstrated the feasibility of scanning fuel rods for fissile content within the tolerances required for accountability purposes. Concurrent with the joint effort on the LASL scanner, the General Electric Company developed and built at the Vallecitos Nuclear Center, and installed in the Wilmington facility in 1971, a neutron-activated fuel rod scanning system. Initial operation of the system began in 1972 with the scanner being operated manually. That is, chart recording of fuel rod enrichment and density traces were evaluated manually by scanner operations personnel. Subsequent operation of the scanner has utilized a dedicated on-line computer for data retrieval and processing.

II. Cf-252 FUEL ROD SCANNING SYSTEM

Experimental data obtained in 1971-72 were used to develop the Cf-252 fuel rod scanning system[1] at the Vallecitos Nuclear Center (VNC). It was demonstrated that sufficient counting rates could be obtained from the thermal flux irradiation of a BWR-type fuel rod and subsequent counting of the U-235 fission product activity to perform measurements of enrichment and U-235 content for quality assurance and accountability purposes. With the feasibility of the technique demonstrated, a scanning system was devised, with Cf-252 as a source of neutrons, which fulfilled the following requirements: (a) thermal neutron flux in the vicinity of 5×10^6 n-cm^{-2}-sec^{-1} with a U-235:U-238 fission ratio of at least 10^4; (b) minimum source-to-detector spacing was required to optimize the signal, but yet sufficient to give an acceptably low background count rate from the Cf-252 source; (c) provision for adequate shielding of personnel; and (d) multiple irradiation channels for production fuel scanning flexibility and optimum source utilization, but with spacing adequate to prevent excessive adjacent channel interaction and to accommodate a fuel rod handling system.

1. System Design and Operation

Based on the above studies, the irradiator was designed and built at VNC (Figure 1). The 9-ton irradiator cask is cylindrical (4-1/2 long by 5 feet in diameter) and can accommodate six fuel rods simultaneously in holes or channels located symmetrically about the long axis of the cylinder on a 1-foot diameter circle. Approximately 3 milligrams of Cf-252, contained in a standard SR-CF-100 capsule, is located in the radial center of the irradiator, but offset axially to minimize source-to-detector effects. Source transfer is made in a completely shielded system from a specially designed shipping cask made to be compatible with the irradiator cask. Neutron moderation and shielding are provided by water-extended-polyester (WEP-65). Lead and boron were added to the outer region of the shielding to minimize the capture gamma ray component. Polyethylene was placed in the region between the source and detector to enhance neutron shielding. Since the count rates from irradiated fuel rods are too high for NaI detectors, NE102 plastic hole-through scintillators and fast phototubes were used as detectors for the measurement of the induced fission product gamma activity. The detectors are embedded in a shield of lead and tungsten alloy (Figure 2). Since the gamma ray activity measured by the enrichment detectors is actually a function of the U-235 content per unit length, rather than enrichment, it is necessary to monitor the density of the fuel rod. Therefore, a Cs-137 source is located at the radial center within a shielding assembly at the entry of the irradiator. The 662-kev gamma ray beam from the Cs-137 is collimated to the center line position of each fuel rod, and the attenuation of the beam is used to monitor fuel column density and uniformity. A set of NE102 plastic detectors is used to monitor the collimated beam intensity. Preceding these detectors is a set of hole-through NaI(T1) detectors embedded in the Cs-137 source shielding assembly to monitor the U-238 daughter activity and any residual fission product activity which may be present when rescanning fuel rods.

In designing the counting system, consideration was given to minimizing the counting loss especially at the high enrich and high count rate end of the scale. Since count rates for irradiated fuel are in the range of 50 to 500 MHz, a 20-nsec paired pulse resolution is required to obtain a counting loss of less then one percent. For this reason, the system uses fast (100 MHz) discriminators to process these signals. Events are counted with 100 MHz CAMAC scalars which were chosen as the most straightforward means of interfacing the detectors to an on-line computer. These scalars make the interfacing quite simple and inexpensive to pre-CAMAC alternatives, which would have required that a special interface be designed and built. Strip chart recorders permitted the utilization of the system for production scanning while the computer software was being developed and debugged.

2. Data Retrieval and Processing

The computer utilized in the Cf-252 fuel rod scanning system is a Data General Corporation NOVA 800, which is plug compatible with the CAMAC controller (Figure 3). The NOVA 800 is a fast (800nsec cycle time) minicomputer and is enhanced greatly on this system by a cartridge disk operating system, a 9-track magnetic tape, and a high speed electrostatic printer/plotter. This combination of software and high speed peripheral equipment has made the system ideal from a software development standpoint. The rod scanning software uses assembly language and operates a modified version of Data General's Real Time Operating System (RTOS). RTOS is an all-core, multitask priority scheduling monitor that allows simultaneous but independent data gathering and processing from each of the six scanning channels. A real time clock controls the reading and resetting of the CAMAC scalar each 1/8-inch along the fuelrod. Rod data (e.g., rod number and design enrichment) are input by either the CRT consoles or the computer teletype. Raw data are stored on the disk until the rod traversal (approximately four minutes) is completed. Then, the raw data as well as rod identification, station number, date, and time are transferred to magnetic tape for permanent storage. The data are corrected for background, density, and channel cross-talk effects, and then digitally filtered to optimize the signal-to-noise ratio. The enrichment, density, and U-235 data are then checked for compliance to quality assurance and accountability limits. If these limits are exceeded, a blinking message is issued to the scanner operators on one of two CRT display consoles (Figure 4), and a plot of enrichment and density is produced on the electrostatic printer (Figure 5). A summary of these measurements is also printed on the plot and on the CRT console screen. Appropriate disposition of the fuel rod is then taken by scanner operating personnel. The plot plus measurement summary becomes the permanent record for each fuel rod.

3. Calibration

The Cf-252 fuel rod scanning system is calibrated with an automatic calibration software routine, codenamed "Autocal." This routine enables the computer to self-calibrate or "autocalibrate" the scanning system. When recalibration is required, the scanning system operator selects the appropriate fuel rod standard nearest to the production rod enrichment being scanned, places the standard on the load rack, and inputs the standard number to the computer by the CRT console. The operating system software routinely scans each rod serial number and compares these rod numbers to those listed in the standard rod library maintained in the computer memory. When a match is made between the rod serial number input and a standard rod number, the computer calls the Autocal software routine. The Standard Rod is then scanned and the measured values for enrichment, density, and U-235 compared via the Autocal software with the assigned values for enrichment, density, and U-235 in the standard rod library. The Autocal software then adjusts the constants in the enrichment, density, and U-235 models to calibrate the system. The measured values prior to calibration adjustment for enrichment, density, and U-235 are also printed on the electrostatic printer/plotter summary as a measure of system drift since the last calibration. The scanning system is calibrated every four hours of production operation and, additionally, between either enrichment or fuel design changes. The fuel rod standard nearest to the design enrichment of the rods to be scanned is used to calibrate the system. The Autocal summaries are collected, input to a time-share computer file, and system performance statistics derived for each channel on a weekly basis.

4. System Performance

The fuel rod U-235 assay performance of the Cf-252 fuel rod scanning system is maintained by a rigid system of measurement controls and is routinely overinspected to quantify actual measurement uncertainties. A committee consisting of representatives from operations, maintenance, quality, and engineering meets routinely to review scanning problems and to maintain a high level of measurement assurance. As a result of this measurement control program, the single measurement errors for the scanning system are 1.50 percent relative and 0.5 percent for precision and accuracy, respectively.

III. FUEL ROD STANDARDIZATION

Full-length fuel rod standards have been fabricated for use in the calibration and qualification of the Cf-252 fuel rod scanning system. The materials used in these standards were selected from production materials and processed on production line equipment under carefully controlled and auditied conditions. During the fabrication process, samples were taken for submittal to four independent analytical laboratories. The resultant analytical results were statistically tested and combined to characterize the fissile content and associated limit of error for each standard rod. This standards program has produced standards which are characterized in fissile content, uranium content, density, and enrichment. The fabrication and qualification process is described below.

1. Fabrication Process

The fabrication process for fuel rod standards is initiated by the issuance of and agreement to fabrication guidelines. These guidelines delineate the responsibilities, process guidelines, and sampling plans to be followed during the fabrication of the standards. The guidelines are then published for management/ technical review and concurrence. Following this process, UO_2 powder is selected from the in-process inventory, blended for enrichment homogeneity, and sampled for isotopic, %U, and metallic impurities. The analysis of these samples assures that the UO_2 powder selected, regardless of its origin, meets manufacturing and quality specifications. Each blending and sampling process is audited by quality assurance personnel. The powder is quarantined while in storage waiting processing.

Before pressing, each pellet press to be used is cleaned according to standard enrichment cleanout procedures. The cleanout is audited by quality personnel to ensure the integrity of the cleanout. Each powder lot is then pressed into green pellet boats. Each boat is further checked for enrichment to ensure avoidance of enrichment mixup errors. While waiting sintering, each pellet boat is clearly marked as standards material and quarantined. When the sintering process is complete, the pellets are ground to a diameter tolerance and stored waiting loading operations in special quarantine cabinets. Zirconium tubing, for use as standard rod tubeshell, is then selected from the inprocess stock and subjected to ultrasonic gaging to ensure uniformity of wall thickness relative to quality specifications. The tubeshell is then serialized utilizing numbers supplied by the materials control function and the tubing placed in the rod loading area to await loading.

Before the rod loading operation begins, each fuel stack weighing scale is carefully calibrated using a mass standard traceable to a NBS mass standard. During the rod loading process, the scale calibration is checked before, during, and after weighing of the fuel stacks of each enrichment lot to determine scale drift. Sufficient weighings of each fuel stack are performed to characterize the weight of each fuel stack. Also sufficient fuel stack length and diameter measurements, and samples for %Uranium, enrichment, and metallic impurities are taken to determine the density and U-235 content of each standard rod. Each rod is then loaded, outgassed according to current manufacturing specifications, and the final end plug welded in place. The finished fuel rod standards are then placed into rod storage cabinets under quarantine until the laboratory and weight data has been processed to assign a U-235 value to each standard. Each of the aforementioned process steps is audited by quality assurance personnel to ensure conformance to the process guidelines and the actual process steps documented.

2. Standard Rod Qualification Process

Samples taken during the standard rod loading process are submitted to four independent analytical laboratories for analysis of percent uranium, enrichment, and metallic impurities. The resultant analytical values are statistically tested and combined to characterize the uranium and U-235 values for each standard rod using the following method:

a. Cochran's test for equality of variances is used to test the relative significance of the sample variances. For example, the data from a particular laboratory would be excluded if its sample variance is significantly larger than the others.

b. A fixed-effects analysis of variance (ANOVA) was used to analyze the data not excluded by Cochran's test. If an F-test on the resultant among-laboratories and within-laboratories variances indicated no significant differences between these two variances, then all data points are regarded as being from the same population. The mean and its associated variance are then assigned to the standard as appropriate.

c. Duncan's Multiple Range Test is used if the F-test in b indicated that the among-laboratories variance was significantly greater than the within-laboratories variance. Duncan's Multiple Range Test is then used to see if this group of heterogeneous means could be separated into subgroups of nonheterogeneous means to give the best estimate of the overall mean. If no distinction can be made, values for the assigned mean and its associated variance are determined as if all data points are from the same population. If the mean of one laboratory is significantly different from the means of the other laboratories, then data from the significant laboratory is eliminated. The remaining data points are then treated as one sample to determine the mean and its associated variance to be assigned to the standards.

During the useful life of a fuel rod standard its fuel stack integrity, tubeshell uniformity, and fuel column design are routinely checked and the standard replaced if it ceases to adequately represent the production fuel rod being assayed and evaluated. Records are kept of the evaluation process during the life of the standard as part of the qualification.

IV. CONCLUSION

The Cf-252 fuel rod scanning system is used for the routine evaluation and assay of production fuel rods as part of the quality inspection process at the Wilmington facility. Routine scanning operations, standardization, and measurement control are subject to continual evaluation and are consistent with recent Nuclear Regulatory Commission Guides and relevant ANSI Standards.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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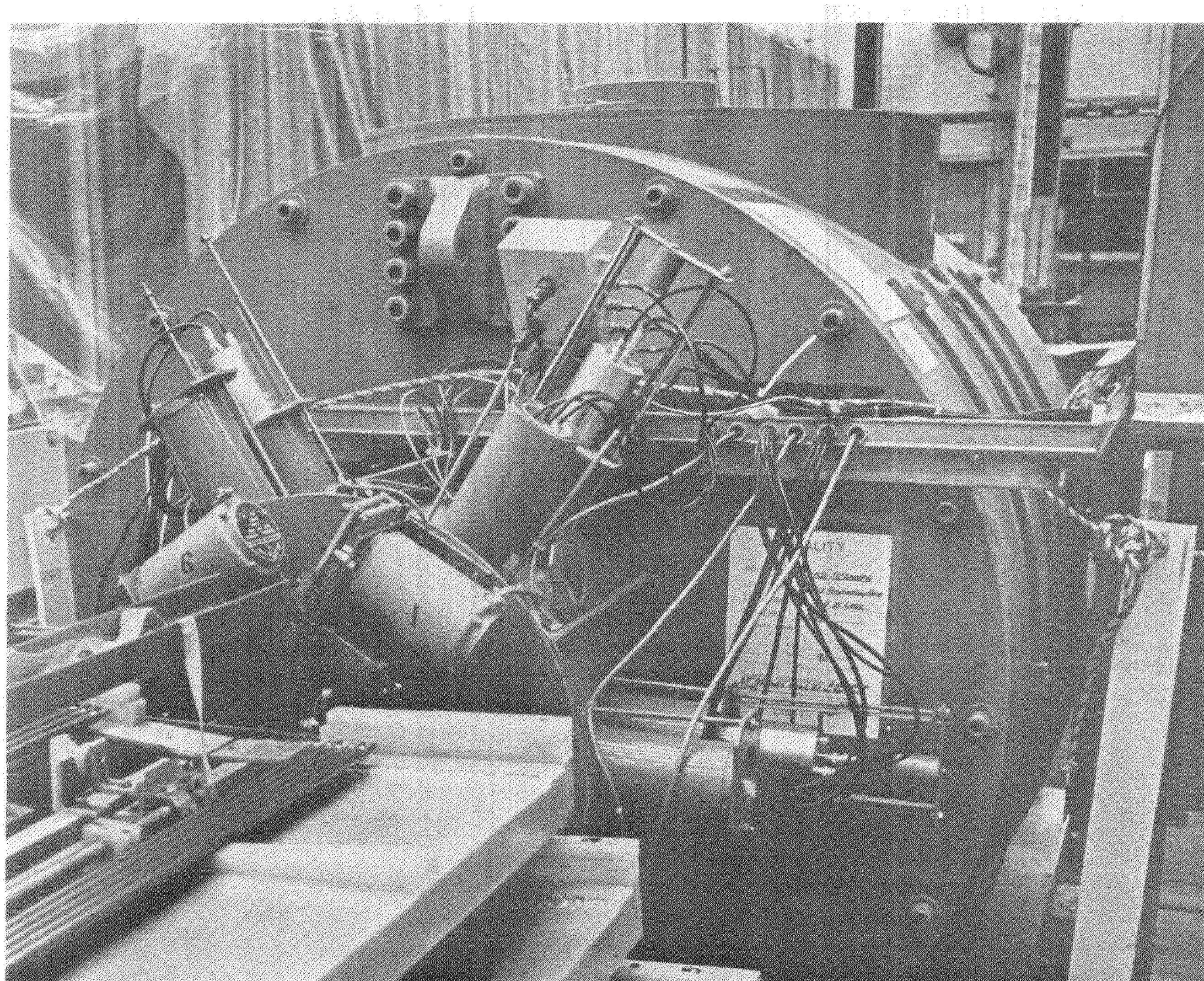

Figure 1
Cf-252 Irradiator

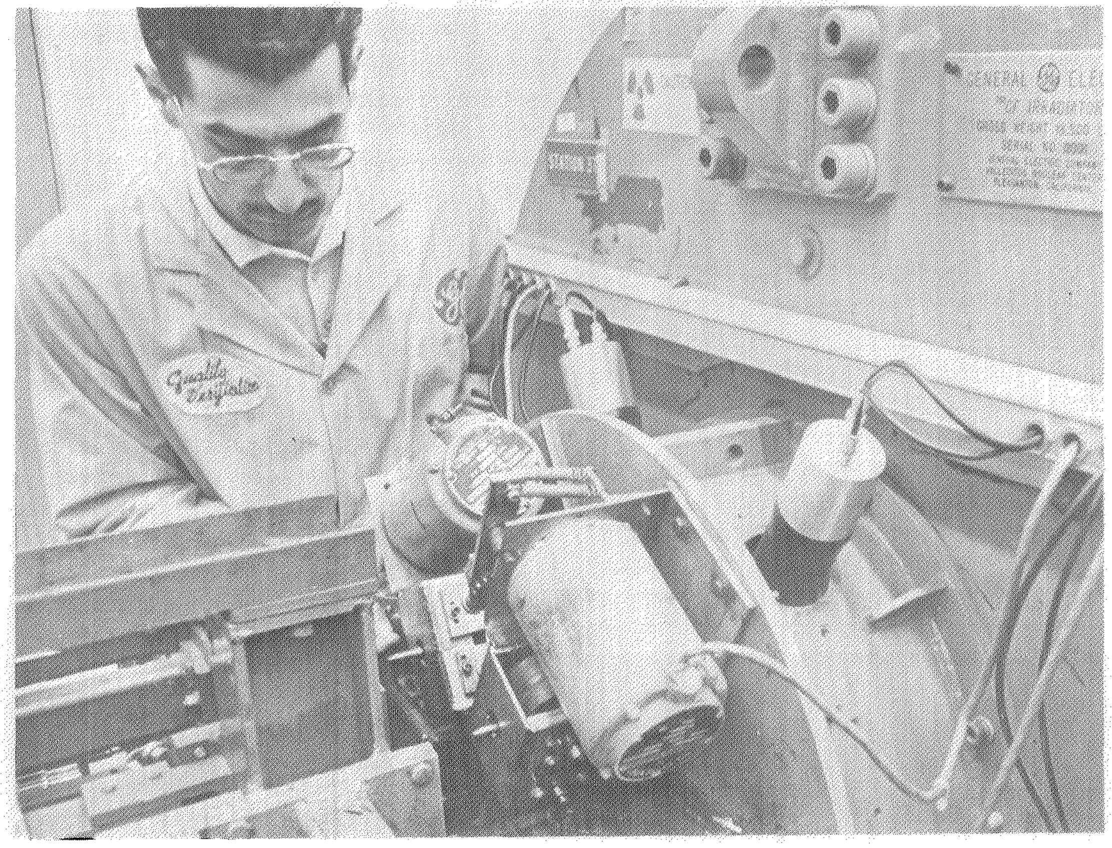

Figure 2
Enrichment Detector Array

Figure 3
Computer System

Figure 4
CRT Console and Display

Figure 5
Electrostatic Printer/Plotter

OPTIMIZING THE USE OF BIAS CORRECTIONS IN MINIMIZING THE VARIANCE OF MUF

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ABSTRACT

The variance of the error of bias corrections to measurement processes is part of the variance of MUF. This paper presents a method of minimizing this part of the MUF variance for a total cost constraint.

Introduction

The purpose of a bias correction is to adjust for a bias in a measurement process. The objective of this article is to develop a method for apportioning the effort used in making bias corrections to measurement processes. One of the components of the variance of MUF is the variance due to bias corrections. The purpose here is to determine the conditions under which this variance component is minimized where there is a fixed total cost and a certain cost structure which distinguishes between the different costs of the different measurement processes. Weighing, for example, would generally cost much less than chemical analysis for concentration. The article assumes a proportional bias and error model which is useful for simplifying the presentation of results. There would be no additional conceptual difficulties in using bias and error models which are independent of the magnitudes of the properties involved, or even in using a mix of the two types of bias and error models. For the instructional purpose of this paper, the proportional model was considered to be the easiest to follow.

When n statistically independent measurements of a standard are made and the bias estimate is not deemed to be statistically significant, there is some question as to how to proceed since the test may simply not have enough power to detect a bias of the size that exists in the particular case.[1] When bias corrections are always made to measurement processes, there is no problem in handling the variance problem since the variance of a bias correction arises from the average of the random errors of n measurements of the standard and the random error in the standard's uncertainty. Once a bias correction is determined by estimating the measurement process bias, the error in the bias correction which arises from random errors is propagated in MUF as a systematic error.

Even when the characteristics associated with bias corrections to an individual measurement process are known it is implicitly realized that:

a. different measurement processes have widely different effects on the variance of MUF,

b. the costs of making measurements vary greatly with the different processes,

c. in a statistic such as MUF some systematic errors can tend to cancel out because the same systematic errors occur in strata of comparable amounts but with different signs in the MUF formula, and

d. the inherent measurement precisions vary for the different measurement processes.

Suppose all the measurement processes in MUF which estimate amount values, or which enter into amount estimates are adjusted by bias corrections.

Write MUF as

$$MUF = \sum_{i=1}^{t} a_i \hat{X}_i$$

where $\hat{X}_i$ is an item amount estimate, and a_i is +1 or -1 according to whether the amount $\hat{X}_i$ enters the MUF equation as a positive or negative value.

Under the Proportion Error Model

A bias estimate for a measurement process is obtained by subtracting a standard's stated value for the average of n statistically independent measurements of the standard. The bias estimate is then subtracted from measurements made by the process. The ℓth weight bias correction, for example, has a proportional error of Δ_{W_ℓ} whose variance is $\sigma_\ell^2/n_\ell + \sigma_\ell'^2$ where σ_ℓ and σ_ℓ' are, respectively, the measurement precision standard deviations of process and the standard's stated value. The models for the measurements of the ith item's weight and concentration, corrected for bias, are

$$\hat{W}_i = W_i(1 + \Delta_{W_\ell} + \delta_{W_i}),$$

$$\hat{C}_i = C_i(1 + \Delta_{C_k} + \delta_{C_i})$$

where W_i and C_i are true values, δ_{C_i} and δ_{W_i} are proportional random errors, and Δ_{W_ℓ} and Δ_{C_k} are the proportional errors resulting from bias corrections.

It is easy to identify which systematic errors affect which items when the bias corrections eliminate the systematic errors induced by a bias and replace them with the systematic errors which remain after bias corrections are applied.

Then $\hat{X}_i$, the bias-adjusted estimate of the ith amount, has the model

$$\hat{X}_i = C_i W_i(1 + \Delta_{C_k} + \Delta_{W_\ell} + \delta_{C_i} + \delta_{W_i})$$

where higher-order cross product terms are dropped, and

$$MUF \approx \sum^{t} a_i X_i(1 + \Delta_{C_k} + \Delta_{W_\ell} + \delta_{C_i} + \delta_{W_i}).$$

Suppose there are random proportional systematic errors of concentration and weight respectively. MUF can be rewritten as

$$MUF = \sum^{t} a_i X_i + \sum_k^{n} \Delta_{C_k} \left\{ b_{k_1} X_{k_1} + \ldots + b_{k_{n_k}} X_{k_{n_k}} \right\}$$

$$+ \sum_\ell^{m} \Delta_{W_\ell} \left\{ d_{\ell_1} X_{\ell_1} + \ldots + d_{\ell_{m_\ell}} X_{\ell_{m_\ell}} \right\}$$

+ Random Error Terms

where $\sum^{t} a_i X_i$ is the true MUF value. The values b_{k_u}, $u = 1,2,\ldots, n_k$ and d_{ℓ_v}, $v = 1,2,\ldots m_\ell$ are just the a_i coefficients rearranged in an appropriate order. X_{k_u} is simply the value of the uth item which is affected by the kth proportional systematic error of concentration. Let

$$B_k = \sum_{u=1}^{n_k} b_{k_u} X_{k_u}, \quad D_\ell = \sum_{v=1}^{m_\ell} d_{\ell_v} X_{\ell_v}.$$

Then

$$MUF = \sum a_i X_i + \sum^{n} \Delta_{C_k} B_k + \sum^{m} \Delta_{W_\ell} D_\ell$$

+ Random Error Terms.

At this point the measurement processes are going to be resubscripted in order to avoid having to repeat the same type of results for weight and concentration. With j as a subscript the m weight bias corrections stay as they are but m is added to the concentration subscripts. Then

$$MUF = \sum a_i X_i + \sum^{m'=n+m} \Delta_j E_j + \text{other terms},$$

where $\Delta_j E_j = \Delta_{W_j} D_j$, $j = 1,2,\ldots,m$: $\Delta_{m+k} E_{m+k} = \Delta_{C_k} B_k$, $k=1,2,\ldots,n$, $m+n = m'$. The variance of MUF can be written as

$$\sigma^2_{MUF} = \sum_j^{m'} E_j^2 \sigma_j^2 / n_j + \text{other terms}.$$

The other terms include components due to random errors and to errors in the stated values of the standards. If it costs d_j dollars to make a measurement for the jth bias correction then it costs $D = \sum^{m'} n_j d_j$ dollars for all bias corrections. It is apparent that increasing n_j decreases only the variance component $E_j^2 \sigma_j^2 / n_j$. The problem is to minimize the variance of MUF for the dollar amount D. The usual approach for this type of minimization problem is to use Lagrangian multipliers.[3,4]

Write

$$G = \sum^{m'} E_j^2 \sigma_j^2 / n_j + \lambda (\sum d_j n_j - D).$$

It can be shown that G is minimized when

$$n_j = K \frac{|E_j| \sigma_j}{\sqrt{d_j}} \qquad (1)$$

where

$$K = \frac{D}{\sum^{m'} |E_j| \sigma_j \sqrt{d_j}}$$

and the resulting value of G is

$$\frac{\sum_j^{m'} E_j^2 \sigma_j^2}{n_j} = \frac{\left(\sum^{m'} |E_j| \sigma_j \sqrt{d_j} \right)^2}{D}. \qquad (2)$$

Thus for a total amount D, the smallest value that the variance component in MUF due to bias corrections can attain is

$$(\sum^{m'} |E_j| \sigma_j \sqrt{d_j})^2 / D.$$

Another approach is to fix the total variance to be induced by bias corrections, solve for the total cost required and then apportion the cost over the different bias corrections. Let S denote the desired variance. Then

$$D = \left(\frac{\sum^{m'} |E_j| \sigma_j \sqrt{d_j}}{S} \right)^2$$

is the cost and n_j is solved as before.

Conclusions

Formula 1 indicates that the number of measurements of the standard should be taken,

a. directly proportional to $|E_j|$,

b. directly proportional to σ_j, the precision proportional standard deviation of the jth measurement process, and

c. inversely proportional to the square root of d_j, the cost per measurement of the jth bias correction.

If, for example, the flow is constant, the receipts and products are all weighed on the same scale and the bias is proportional, the bias component essentially cancels out. If under these conditions the same proportional bias correction is made on all items the contribution of this variance component to σ^2_{MUF} is essentially zero since $|E_j| \approx 0$. If different scales are used for the receipts and for the product, there will be two separate bias corrections. Each of these bias corrections will be multiplied by a coefficient where all the terms in the coefficient are of the same sign and there will be no cancellation effects.

In small material balance areas where calorimeters, spectrometer values and scales are used to maintain a material balance of Pu isotopic amounts where the same instruments are used on receipts and shipments and where the systematic errors are proportional to the amounts, many of the $|E_j|$ values are essentially zero.

If the paper had started out initially assuming the bias and errors were independent of the magnitudes involved, the results regarding point c would have been the same, but points a and b would have been changed. Consider bias corrections made to the kth concentration measurement process for example. Then the measurements should be taken

a. directly proportional to $\left| \sum^{n_k} b_{k_u} W_{k_u} \right|$ where b_{k_u} is simply the sign of the uth of the n_k values affected by the kth bias correction, where W_{k_u} is its associated weight value, and

b. directly proportion to σ_k', the precision standard deviation of measurement of the kth concentration measurement process expressed in the appropriate units, e.g., g/g.

Example 1

Following is an example to illustrate the procedure and to serve as the basis for a few additional remarks. In this MUF there are only receipts and shipments, but no waste streams, beginning and ending inventories. Nominal values of weight and concentration values are perfectly adequate to plan the minimization study. The input nominal values are $W_i = 100$, $C_i = 0.7$, $i = 1,2,\ldots,8$; the output nominal values are $W_i = 67$, $C_i = 0.52$, $i = 9,10,\ldots,24$.

Perhaps the most difficult aspect is to indicate what bias correction affects which item value. This is done in the following table.

Item	a_i	W_i	C_i	X_i	ℓ	k
1	1	100	0.70	70	1	1
2	1	100	0.70	70	1	2
3	1	100	0.70	70	1	3
4	1	100	0.70	70	2	1
5	1	100	0.70	70	2	2
6	1	100	0.70	70	3	3
7	1	100	0.70	70	1	2
8	1	100	0.70	70	1	2
9	-1	67	0.52	34.84	3	3

Item	a_i	W_i	C_i	X_i	ℓ	k
10	-1	67	0.52	34.84	3	3
11	-1	67	0.52	34.84	2	3
12	-1	67	0.52	34.84	2	4
13	-1	67	0.52	34.84	2	4
14	-1	67	0.52	34.84	2	1
15	-1	67	0.52	34.84	3	3
16	-1	67	0.52	34.84	1	4
17	-1	67	0.52	34.84	1	4
18	-1	67	0.52	34.84	3	1
19	-1	67	0.52	34.84	3	3
20	-1	67	0.52	34.84	4	5
21	-1	67	0.52	34.84	4	5
22	-1	67	0.52	34.84	4	5
23	-1	67	0.52	34.84	4	5
24	-1	67	0.52	34.84	4	5

For example, item 8 is a receipt, has a nominal value of 70 and is affected by the first weighing bias correction and the second concentration bias correction.

Or if desired it may be put in the matrix-like form

	j	WEIGHT				CONCENTRATION				
	i	1	2	3	4	5	6	7	8	9
RECEIPT	1	1				1	1			
	2	1								
	3	1						1		
	4		1			1				
	5		1				1			
	6			1				1		
	7	1					1			
	8	1					1			
PRODUCT	9			-1				-1		
	10			-1				-1		
	11		-1					-1		
	12		-1						-1	
	13		-1						-1	
	14		-1			-1				
	15			-1				-1		
	16	-1							-1	
	17	-1							-1	
	18			-1		-1				
	19			-1				-1		
	20				-1					-1
	21				-1					-1
	22				-1					-1
	23				-1					-1
	24				-1					-1

The first column represents the items that are affected by the first weight bias correction and the way they are affected as regards the sign in MUF. The nominal amount of a receipt is 70.00, the nominal shipment amount is 34.84. Then

$E_1 = 70 + 70 + 70 + 70 + 70 - 34.84 - 34.84 = 280.32$

$E_2 = 2(70) - 4(34.84) \quad = \quad 0.64$

$E_3 = 70 - 5(34.84) \quad = -104.20$

$E_4 = -5(34.84) \quad = -174.20$

$E_5 = 2(70) - 2(34.84) \quad = \quad 70.32$

$E_6 = 4(70) \quad = 280.00$

$E_7 = 2(70) - 5(34.84) \quad = - 34.20$

$E_8 = -4(34.84) \quad = -139.36$

$E_9 = -5(34.84) \quad = -174.20$

If X denotes a column vector of the X_i values and B is a matrix as above, then $E = B'X$ is a column vector of the E_j values.

If D = 500, the total cost, the following are all that are needed for the minimization

ℓ	k	j	σ_j	$\lvert E_j \rvert$	d_j
1		1	0.005	280.32	1
2		2	0.003	0.64	1
3		3	0.007	104.20	2
4		4	0.001	174.20	2
	1	5	0.05	70.32	10
	2	6	0.02	280.00	15
	3	7	0.03	34.20	15
	4	8	0.01	139.36	20
	5	9	0.03	174.20	10

The following additional results are calculated

j	$\lvert E_j \rvert \sigma_j / \sqrt{d_j}$	$\lvert E_j \rvert \sigma_j \sqrt{d_j}$
1	1.40160	1.40160
2	0.00192	0.00192
3	0.51576	1.03152
4	0.12318	0.24635
5	1.11186	11.11857
6	1.44591	21.68870
7	0.26491	3.97368
8	0.31162	6.23237
9	1.65261	16.52606
	6.82937	62.22077

Then

$$\frac{1}{\sqrt{\lambda}} = \frac{D}{\sum \lvert E_j \rvert \sigma_j \sqrt{C_j}} = \frac{500}{62.2208} = 8.0359$$

and

$$n_j = 8.0359|E_j|\sigma_j/\sqrt{d_j}, \quad j = 1,2,\ldots,9$$

which are as follows

n_j = 11.26, 0.02, 4.14, 0.99, 8.93, 11.62, 2.13, 2.50, 13.282.

If one rounds and takes at least one observation per class the values are

n_j' = 11, 1, 4, 1, 9, 12, 2, 3, 13;

j = 1,2,...,9.

Here

$$\sum^{9} E_j^2\sigma_j^2/n_j = (\sum|E_j|\sigma_j\sqrt{d_j})^2/D = 7.74$$

and

$$\sum^{9} E_j^2\sigma_j^2/n_j' = 7.60.$$

Some decisions have to be made about how to handle the situation which occurs because these n_j numbers will not be integers. One can round as indicated. A more conservative approach would be to take the largest integer in $n_j + 1$. (Dynamic programming will solve the problem in integer values but this would not change the results very much.)

In the previous example using rounding the actual variance turns out to be 7.60 instead of 7.74, a very small difference.

The example shows that small sample sizes are required when the $|E_j|$ value is small, e.g., j = 2,7. It is useful to take quite a few samples even when the relative standard deviation is small if the cost is small enough and the standard deviation of the particular component $|E_j|\sigma_j$ is large enough, e.g., j = 1,3. Even though the costs of concentration methods are high it is generally worthwhile to make corrections here because the σ_j values, the relative standard deviations, are also high.

Perhaps the main conclusion is that minimizing the variance needs some study and design to come up with the appropriate numbers of measurements to take.

It is interesting to see what the advantages are over an approach allocating equal costs to each process. For the jth measurement process (500/9) dollars are spent obtaining $(500/9)/C_j$ measurements. The resulting variance component is then

$$\sum^{9} E_i^2\sigma_j^2 d_j/(500/9) = 16.65.$$

In this example the equal allocation of funds has an efficiency of E = (7.74/16.65) x 100% = 46%.

If the same numbers are to be taken from each measurement process then $n\sum^{9} d_j = n(76) = 500$, and n = 6.58. Then the resulting variance component is

$$\sum^{9} E_i^2\sigma_j^2/6.58 = 11.64$$

for an efficiency of E = 7.74/11.64 x 100% = 66%.

If one wishes to control the variance due to bias corrections to a fixed value

$$S = \sum^{m'} E_j^2\sigma_j^2/n_j$$

say, one simply solves

$$S = \left(\sum^{m'} |E_j|\sigma_j\sqrt{d_j}\right)^2/D$$

for D. The resulting D is the total amount to be spent and then the calculation of sample sizes proceeds as before. For example if the desired S value is 4 units,

$$\$(\sum^{m'} |E_j|\sigma_j\sqrt{d_j})^2/4 = \$62.22^2/4 = \$968$$

must be spent.

It is somewhat hard to come up with a compelling rationale for fixing the total number of observations to be taken. Suppose, nevertheless, that N = 120 measurements are to be taken. Then

$$n_i = H|E_j|\sigma_j/\sqrt{d_j}$$

where

$$H = N(\sum|E_j|\sigma_j/\sqrt{d_j})^{-1} = 17.57.$$

n_1 is, for example, equal to 17.57(1.4016) = 24.6. n_j = 0.03, 9.06, 2.16, 19.54, 25.41, 4.65, 5.48, 29.04; j = 2,...,9.

It is seen in the example that the efficiency is reduced considerably if the allocation is done in the context of faulty criteria. However, the number of measurements in the classes can be varied to some degree if they are all kept in the neighborhood of the optimum vector $(n_1\ n_2\ \ldots\ n_m)$. The reason for this is that the minimum occurs where the partials vanish, i.e., where the rate of change of the variance value is zero for the different variables. Thus, around this optimum vector the variance is changed very little with small changes in the n_j values.

Another way of reducing the component of the MUF variance which is due to bias corrections is also suggested by this study. If it is possible to use the same instruments with the same bias corrections on items which appear as both receipts and products, the biases and bias correction values will tend to cancel somewhat and in a constant flow facility will tend to drop out of the MUF equation.

Acknowledgement

The author would like to express appreciation to the referees who read the paper carefully and made some very helpful technical and editorial suggestions.

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BIAS BATTLE

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In the spring of 1974, the AEC issued a series of license conditions requiring certain special nuclear material licensees to adjust material accounting data for any measurement bias which exceeds 10% of its standard deviation. At the outset, this requirement appeared to be relatively unobtrusive in light of other license conditions because many people have the intuitive feel that a bias is some measure of the difference between a standard value and a measurement associated with the standard, and because measurement equipment standard deviations are relatively easy to calculate.

What was not apparent, however, were answers to questions such as "Should all bias corrections be made regardless of size?", "How meaningful is a .1σ bias correction?", and "What is an appropriate sample size?" The purpose of this paper is to shed some light on bias correction applications by attempting to answer such questions, based on empirical data obtained at a fuel fabrication facility.

What is a Bias?

Whereas bias is the difference between a measured value and the "true" value, the word "bias" is herein defined as an estimate of said difference and is obtained by averaging the difference between standard values and n independent measurements on the standards.

Control the Process

Implicit in the word "bias" is the assumption that the measurement process yielding control data is producing credible results. That is, data containing operator mistakes, calculational errors, and etc. are not used in the determination of bias. Additional error sources, such as standard instability, may be evaluated by F-tests and data therefrom either accepted or rejected prior to calculating bias.

When Should Corrections Be Made?

From a statistical standpoint, measurement data should be corrected for bias when sufficient data has been accumulated to discern real measurement system changes without responding to purely random events. Thus, corrections made after fabrication and based on standards data obtained prior to, concurrent with, and subsequent to material accounting data measurements are based on the most complete set of information and therefore this is the preferred method. However, if a facility processes SNM into ultimate sealed form, then adjusts measurement data for bias after more standards data has accumulated, a host of problems may ensue. Adjustment after-the-fact may degrade SNM accountability, artificially permit out-of-specification products to be made, add significantly to product re-work, and may result in the recall of components already in the customer's possession. Risk levels associated with the above are operationally unacceptable and the bias adjustment method needed is one which may be applied on an a-priori basis.

What Risks Do Correction Entail?

A correction which is ten percent of the measurement standard deviation is often so minute in relation to the measured value that its effect is lost in rounding error, and therefore may entail little or no incremental risk.

Let us next consider corrections for biases falling between .1σ and a threshold level where apparent biases are called "significant" at a predetermined confidence leve. (Selection of a confidence level is discussed later.) A study of bias correction methods using actual fabrication data reveals that due to the multiplicative nature of SNM measurements, the application of non-significant biases at times causes products to artificially exceed technical

What Risks Do Corrections Entail?

specifications, and production is halted. Consider the following example where bulk, element, and isotope measurement are made and the product must meet physical and fissile isotope specifications:

X_1 = bulk measurement

X_2 = element measurement

X_3 = isotope measurement

ϕ_1 max. non-significant bulk bias

ϕ_2 max. non-significant element bias

ϕ_3 max. non-significant isotope bias

CASE I Isotopic content with bias corrections would be $(X_1)\cdot(X_2)\cdot(X_3)$ since biases are not statistically different from zero.

CASE II Isotopic content with corrections would be $(X_1 + \phi_1)\cdot(X_2 + \phi_2)\cdot(X_3 + \phi_3)$

There have been real time circumstances where data has been corrected as in Case II such that when isotope specifications are satisfied, the physical specifications are not, and vice versa. However, for the same circumstance the Case I method of calculation yields an acceptance region for both physical and fissile specifications. The multiplicative nature of fissile calculations compounds the effects of bias corrections, thereby increasing the risk of artificially exceeding technical specifications.

NRC Rule Meaning

If correcting material accounting data with non-significant biases presents an unacceptable risk level, then significant corrections should be considered. The NRC requirement that corrections of the size $.1\sigma$ be made means that for a sample size of 10, one may say with only 25% certainty that the bias is different from zero, assuming a normal distribution. The rule tends toward over-responsiveness because corrections are made when they should not be made (Type I error).[1]

Because confidence levels increase very slowly with larger sample sizes, attainment of a 95% confidence level for a $.1\sigma$ correction requires approximately 400 standard runs. If this number of runs is maintained, then the probability of not correcting for bias when the correction should be made (Type II error) is greatly increased.

Significant Level Selection

One method of determining the significance level at which bias corrections are made is based on a probabilistic evaluation of risk. The significance level is chosen such that the probabilities of committing Type I and Type II errors are acceptable. Another method of determining significance level is based on expected economic impact. The probability of committing a Type I error times its economic impact is set equal to the probability of committing a Type II error times its economic impact. The equation may then be iteratively solved for the significance level.

Sample size should be selected such that the test method is responsive to real system changes while being discriminative against random excursions.

Bias Testing

The "t" test concerning means has been evaluated as a test criterion and has been found acceptable on an operational basis.

The "t" test was selected (assuming a normal distribution) because sample sizes are generally not sufficient to allow use of the central limit theorem and because σ is often unknown and must be estimated by s.[(2)]

Put It To Use!

For an operational model, we may hypothesize that bias is zero, then compare the bias estimate with $t \cdot s/\sqrt{n}$. If the bias estimate exceeds $t \cdot s/\sqrt{n}$, reject the hypothesis and correct for bias. If the bias estimate is less than $t \cdot s/\sqrt{n}$, we may accept the hypothesis.

The test model measures of effectiveness are that it is statistically justifiable, responsive to real system changes, discriminative against random excursions, and easy to apply. Why not put it to use?

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STUDY BENEFITS UTILITIES

A new study by Uranium Enrichment Associates, San Francisco, sheds considerable light on a potential ERDA program that could provide substantial benefits to utilities with ERDA enrichment contracts, according to a spokesperson for that firm.

The ERDA program, which is still in the talking stage, was first outlined to industry representatives at the Oak Ridge Uranium Enrichment Conference in February 1975, and again at the most recent conference on the subject in Oak Ridge in November.

On both occasions **Frank P. Baranowski,** director of ERDA's Fuel Cycle and Production Division, invited utility comment on a plan whereby existing ERDA-utility contracts could be altered so that the utility would receive part of its required fuel from ERDA and part from a private enricher.

By shifting part of its enrichment demand to a private enricher while maintaining its existing ERDA contract, the utility would then avoid having to pay an increased outlay for feed to compensate for the higher tails at which the ERDA plants would be operating in the absence of plutonium recycle.

Under ERDA's proposal, which Baranowski called the Variable Tails Assay Option, the first step would be for the utility to specify a lower tails assay than ERDA's contracting assay at that time. Since this modified enrichment contract would be at lower tails, the amount of uranium feed and enriched uranium product would be reduced. The utility would then sign a supplemental contract with a private enricher for the balance of the utility's enrichment needs, also contracting with the private enricher at the optimum tails assay. ERDA is now soliciting utility comments on the proposed program.

UEA has performed a cost-benefit analysis of the Variable Tails Assay Option to determine how the utilities might be affected if ERDA decides to go ahead with the plan. One aspect of UEA's analysis was to identify potential savings to a utility with an ERDA enrichment contract for a typical 1000 megawatt light water reactor.

According to the study, the utility with such a contract would receive an average annual cost savings of $2.6 million if a utility's required nuclear fuel for a typical reactor were to be provided at an operating tails assay of 0.2 percent instead of 0.36 percent, the projected ERDA operating tails assay. This savings assumes an ore price of $40 per pound and an enrichment cost of $100 per SWU in 1975 dollars for the additional enrichment which would be required.

The 30 year savings which a utility would realize by exercising the suggested variable tails option for a 1000 megawatt reactor was then figured by UEA for three cases as shown in the attached figure, in which the savings is calculated as the cost of the ore saved minus the cost of the additional SWUs purchased.

While the ERDA contract assay depends upon ERDA's ultimate contracting level in gigawatts, and on the availability of plutonium and uranium recycle, scenarios in which this contracting assay ranges from 0.3 to 0.4 and above can be anticipated. On the other hand, optimum tails could be 0.2 or below, or by an extreme set of assumptions, as high as 0.26. The figure illustrates the cost savings to the utility based on various combinations of the above contracting and optimum tails assay.

As a result of its analysis, UEA concludes that the variable tails option appears to offer utilities a significant cost savings. The cumulative cost savings to the nation, as a result of ERDA's proposed program, could approach $1.2 billion by mid-1984, according to the UEA study.

Background Note on Optimum Tails—Optimum tails—the point at which uranium feed and enrichment services are used most economically in the enrichment process to produce the reactor fuel—is determined by the prices for uranium feed and separative work, and is independent of the particular technology used in enrichment work.

The attached figure shows how optimum tails is determined by the tradeoff between separative work price and uranium ore price. For example, if separative work sells for $57/SWU and ore is at $10/lb, optimum tails is 0.3. However, if separative work is priced at $57/SWU (ERDA's current price) and ore is priced at $25/lb, the optimum tails assay drops to 0.2. If the SWU price stays constant, and the ore price increases—toward current market offerings—optimum tails falls below 0.2.

The significance of optimum tails from the utility viewpoint is this: If the enrichment plant is contracted to a level where enrichment services must be performed at higher than optimum tails to provide the required nuclear fuel for the contracting utility, then the utility must provide a disproportionate amount of feed and the higher cost of power will have to be passed to the customer. Obviously, the impact of this situation will also be felt by the raw materials supply industry.

TRADEOFF BETWEEN SEPARATIVE WORK PRICE AND URANIUM ORE PRICE AT OPTIMUM TAILS

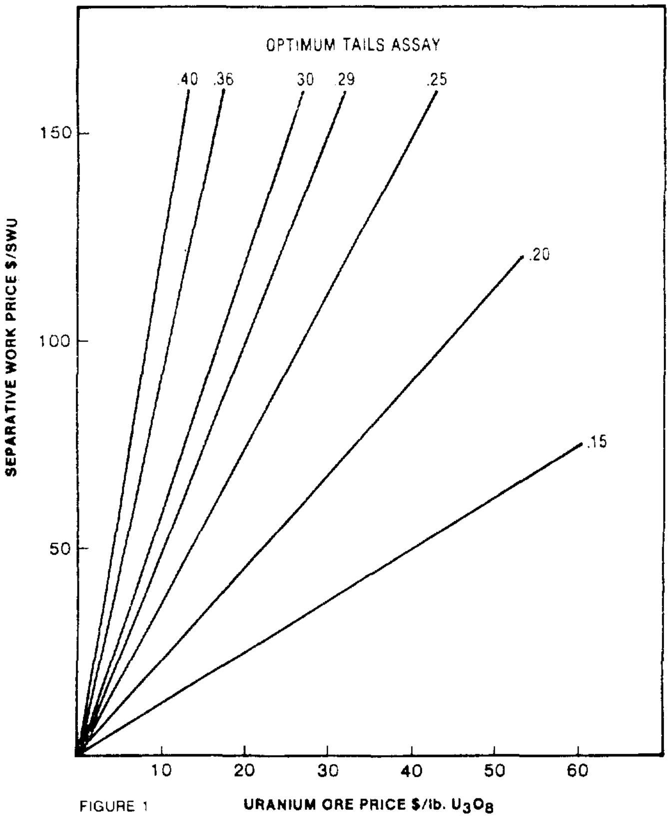
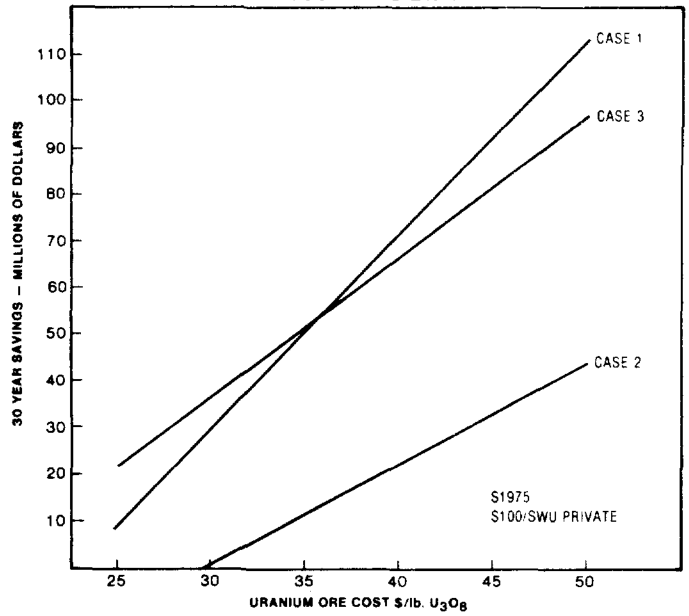


FIGURE 1

30 YEAR SAVINGS TO A UTILITY EXERCISING SUGGESTED ERDA VARIABLE TAILS OPTION AND PURCHASING ADDITIONAL REQUIRED SEPARATIVE WORK FROM A PRIVATE ENRICHER 1000 MWe LWR



	ERDA Contract Assay	Variable Tails Option Assay	Utility Contract With UEA at Assay
CASE 1	0.36	0.20	0.20
CASE 2	0.30	0.20	0.20
CASE 3	0.36	0.26	0.26

The above discussion becomes pertinent in view of the recent announcement by ERDA's **Frank P. Baranowski** that a decision on the operating tails for ERDA plants will be made in April 1976.

Speaking at the Oak Ridge, Tenn., Uranium Enrichment Conference on November 11, Mr. Baranowski outlined a proposed ERDA plan whereby utilities might be allowed to alter present ERDA contracts so as to split their enrichment requirements between the ERDA plants and private enrichers. This proposed program, called the Variable Tails Assay Option, would allow utilities to achieve substantial economies in feed requirements, as ERDA plants begin to operate at greater than optimum tails assays. (See separate UEA release: "New UEA Cost-Benefit Analysis Focuses on ERDA's Variable Tails Assay Option.")

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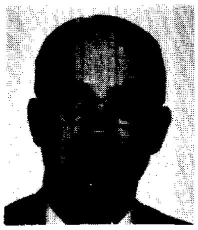
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HEADACHES AND OPPORTUNITIES

(Continued from page 1)

to make the IAEA as effective as possible. It can do this by setting an example of fully cooperating. This does not mean that we should volunteer for the maximum amount of inspection but rather that the arrangements with IAEA should be made as effective for its needs as possible, recognizing that IAEA manpower will be limited. We should look at the negotiations from IAEA's point of view and, as its inspection goes into operation, consider how its system could be improved.