SECOND ISSUE — CONTENTS

INMM

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HAVE YOU JOINED INMM?

A one-year membership in the Institute of Nuclear Materials Management, Inc., costs $15. A membership includes a subscription to NUCLEAR MATERIALS MANAGEMENT, journal of I.N.M.M. The journal publishes three regular issues and a proceedings of the annual I.N.M.M. meeting.

To get your membership application(s), phone (AC 614 299-3151, Ext. 1742) or write to: R. L. Jackson, INMM Membership Chairman, 505 King Avenue, Columbus, Ohio 43201.

Editorials

Dr. Curtis G. Chezem

MBA-99

One of the advantages that accrue to the lightplane pilot attending a national meeting is the flexibility he has in setting schedules. First, the Boston meeting allowed the editor to disappear into a northeast Maine island for the weekend prior to the sessions. Second, we determined that an instrument approach to Boston-Logan doesn't offer a problem of mixing light aircraft and the jet-birds if you choose the off hours.

It's hard to single out one person for a salute and thanks for a good meeting. We'll thank Yankee Atomic Electric Company for backing our effort so effectively. It was great! So well handled, indeed, that the editor will have to eat his words about the idea of having a meeting in Boston.

After many years of dealing with meetings in the high rent areas we have found ourselves increasingly joining with the low per diem club at nearby low-rate hotels. We are pleased that our credit card "space bank" usually, though reluctantly, finds acceptable methods of beating the system for us.

At the moment, your editor is screaming about the proposed meeting site at Sun Valley. How do we justify that one with the comptroller? We also speculate that even our helpful "space bank" can't prevent us from having to dig deep into our double knits for the extra coin to feed the kitty.

We encourage you to send news notes, gossip, etc. We appreciate the new product information and hope that one-paragraph summaries are attached. We are a small staff; the two editors, Tom's wife and a sometimes secretary.

LETTERS—WHERE ARE THEY??

Frankly, the Managing Editor of this journal is a little bit surprised. Following the first issue, he was expecting some feedback. Much came at the annual meeting May 31-June 2 in Boston in the form of informal comments of a complimentary or constructive nature. However, the Editor indicated that letters-to-the-editor would commence this issue. To my amazement, none have come forth.

Since the next issue, a proceedings of the 13th annual I.N.M.M. meeting in Boston, will come out in September, the next regular issue of the journal will be published in January 1973. If you would like to comment on the first issue, this one (July 1972), or some other issue related to nuclear materials management which is of concern to you, let us hear from you. Try to limit your remarks to 200-250 words.

Deadline for letters for the January 1973 issue is Oct. 1.

THE CHAIRMEN SPEAK

H. L. Toy
New Chairman

J. E. Lovett
Outgoing Chairman

THE OUTGOING CHAIRMAN GOES OUT —OR DOES HE?

It has been an eventful, and in my opinion a successful, two years. That it was eventful is something for which I can take no credit. That it was successful, if it was, is also something for which I can take only limited credit. As in any organization, the leader can glory in his success only so long, until he comes to the sobering thought that if no one had followed, his fantastic leadership would have led to failure.

I count my successes as being three in number. This journal, which took nearly the whole two years to reach fruition, I count as the most important. The others are the development of a mutually-recognized two-way channel of communication with the AEC, and the issuance of a completely redone INMM Manual. Other successes which occurred but which I do not pretend to claim include two very successful annual meetings. Credit for these can only go to Harley Toy and his annual meeting committees. I should also mention the publication of several INMM-sponsored standards. Credit for these must go to Bob Delnay, to the members of standards committee N-15, and to the many subcommittee members who developed the standards.

When I had finished one year in office, and was seeking re-election, I felt that two years was not long enough for a chairman to accomplish much, and I toyed (very unsuccessfully) with by-laws changes which would give future chairmen a longer term. Now that my second year is at end, I feel differently. Two years is long enough. Two years, first of all, is about all that a person has any right to ask his employer to subsidize. Even more important, two years is as long as the INMM should head in one direction, without stopping to examine whether a mid-course correction is needed.

Thus it is with a happy feeling that I give leadership of the INMM to the new chairman, Harley Toy. I have accomplished pretty much what I set out to accomplish. It is time for a new leader, with new ideas. If those ideas coincide with mine, I will be honored. If they do not, I will return the favor he gave me, and examine his ideas on their merits. I call on you to do likewise.

Finally, for those who thought they were finally rid of Jim Lovett, no such luck. My series of articles in the Newsletter and Journal on the philosophy of nuclear materials management has been generally well-received, and I have agreed to continue the series. Elsewhere in this issue you will find my current contribution, drawing what I consider is a very close analogy between nuclear material control and cost accounting.

Thank you for your cooperation.

THE INCOMING CHAIRMAN LOOKS AHEAD

In looking ahead in an attempt to develop and chart a sound course for the Institute I am prompted and influenced by the past. Reflecting over the past fourteen or so years when some nineteen individuals gathered in Pittsburgh to launch a professional society dedicated to furthering the advancement of nuclear materials management, I am truly amazed at the accomplishments and progress to date. I had the privilege of serving as the first program chairman for the Institute. It was evident to me back in 1960 that the mere ability of the Institute to stage a timely, informative, and stimulating meeting was in fact one fantastic accomplishment. This same conviction holds true today as evidenced by our recent Boston meeting. Certainly there is total agreement on the high caliber of the papers presented at Boston and the overall atmosphere that contributed to the free flow of information. Annual meetings just don't happen—many months of hard thinking, preparation, and planning make up a successful meeting. Our Boston meeting was outstanding due mainly to the efforts of Armand Soucy, our Local Host and Roy Cardwell, Program Chairman. Roy was ably assisted by Doug George and Shelly Kops.

As I stated in Boston I don't have any startling or major statements regarding specific accomplishments for the Institute during the coming year. I would hope to continue the steady course that Jim Lovett and his predecessors have set forth. I have a great deal of confidence in the role the Institute can play this year. As I see it we are in somewhat of a new ball game with the recent reorganization of AEC's Regulatory structure. At the moment it is somewhat difficult to determine just "where and how" we will interface with the new three directorates. Needless to say we must move quickly to establish a dialogue with the Directorate of Regulatory Standards and the Directorate of Regulatory Operations. Within the coming weeks the Executive Committee will be meeting with Regulatory to establish liaison and to explore areas where the Institute can assist in the licensing process as it relates to nuclear materials management and safeguards. One final word in regard to the regulatory shakeup. The restructuring into three directorates makes a lot of sense to me. It would appear that Mr. Muntzing is moving ahead to create real "definition" to the licensing process. Time will tell.

In the coming months our role in the American National Standards Institute (ANSI) will be expanded. We are now represented officially on the Nuclear Technical Advisory Board (NTAB) of ANSI. This board oversees and advises ANSI in the area of nuclear standards. Dr. Fred Forscher represents the Institute as a member of NTAB. Without doubt the "name of the game" today is standards which is quite obvious with the creation of the Directorate of Regulatory Standards. The Institute can certainly point with pride to the accomplishments of ANSI Standards Committee N15. Under the proven leadership of Bob Delnay the Institute has generated some six ANSI Standards in the area of nuclear materials control. N15, under Delnay, is probably the most prolific of all ANSI standards committees. I have had the privilege of working with Bob as secretary of N15 since its inception. We have had our "ups and downs" in N15 activities as Delnay reported at the Boston meeting. One of the major hang-ups confronting N15 is that of government imposed safeguards regulations. Throughout the existence of N15 we have struggled with this problem. Our interpretation of the scope of N15 has been that government imposed regulations (safeguards) are outside the scope of N15. I will ask the Executive Committee to take a hard look at this situation. In looking over the Institute's constitution under Article II - Purpose, one notes that we are to promote, encourage, and establish standards **consistent** with professional and **regulatory** standards for use in nuclear materials management. I am sure that the multitude of the Institute members involved in the standards work under N15 would argue that the published N15 standards to date are **consistent** with regulatory requirements. It is not my intent to make waves. As stated earlier, N15 has a proven tract record. As I understand Delnay and Dick Alto, the new N15 secretary, will be holding a committee meeting of all N15 representatives in late August or September. I am hopeful that at that time we will be able to resolve the differences within N15 and move ahead with a clear and definitive scope.

I wish to recognize and congratulate the new members of the Executive Committee: Armand Soucy, Vice Chairman, Armand brings to the Executive Committee the nuclear utility viewpoint and proven capabilities as we all witnessed in Boston. Jim W. Lee, Member of the Executive Committee, Jim's contributions to the Institute go back several years the most notable being the 1971 Annual Meeting in West Palm Beach. As Local Host, Jim staged an outstanding meeting. Dr. John E. Van Hoomissen, new member of the Executive Committee, has all the credentials. As Manager, Nuclear Materials Management for the General Electric Company, John will bring forth industry expertise to the Executive Committee. John W. Arendt, Dr. Russell P.

(Continued on Page 3)

New Chairman Looks Ahead

(Continued from Page 2)

Wischow, and James E. Lovett make up the remaining members of the Executive Committee. My experience tells me that these three individuals will keep your Executive Committee real honest during the coming year. Mr. Ralph Jones, your new Treasurer, has certainly picked up where our talented past Treasurer, Russ Weber, left off. I am sure you can appreciate the job Ralph did in Boston. The remaining officer making up the total team for this coming year is Lynn K. Hurst, our reelected Secretary. As a past chairman and perennial contributor to the Institute, Lynn represents the steadying influence on the Executive Committee. I look forward to being a part of this distinguished team and the role the Institute can play with such available expertise.

During this coming year it is my intention to call upon the past chairmen to serve as an ad hoc committee to take a hard look at the Institute—where we are today—evaluate our efforts to date—reexamine our objectives and how best can we utilize our talents and influence. I can think of no other group that is more qualified to conduct such a study than our past chairmen. Certainly we are a viable professional society at this date with substantial membership and financial resources. It is within this light we would ask our past chairmen to consider our present and future course.

I would hope that during the coming year we could entice the nuclear utility community to play a larger role in the Institute's activities. A casual scan of the Institute's membership roster reveals an obvious absence of the nuclear utility community. I feel that nuclear utility involvement in the Institute's activities is a **must** if we are to realize the objectives of the Institute. In the coming months we will make a concerted effort to increase nuclear utility membership and participation in the Institute.

One final note in regard to the new Journal of the INMM. I definitely endorse Chairman Lovett's remarks carried in the initial issue of the journal. It is indeed "a bold step." It represents a true challenge to the Institute—one that must be taken if we are to accept our position as a "now" professional society with direct responsibilities to the membership and the nuclear industry. I foresee a bright future for the journal—a future that will depend largely upon direct and sustained support from the membership. I would like to extend public appreciation to Dr. Curt Chezem and Tom Gerdis for their "above and beyond" efforts in bringing about the Journal—the new voice and communications link for the membership.—Harley L. Toy.

NEWS

CERTIFIED NUCLEAR MATERIALS MANAGERS

Two INMM members have recently been designated as Certified Nuclear Materials Managers. They are Warnell Brown, 800 Concourse Village W., 5-L, Bronx, NY 10451, and Thomas J. Collopy, United Nuclear Corp., Rt. 21A, Hematite, MO 63047.

Institute members join in congratulating Brown and Collopy on their attainments.

HALF-LIFE MICRO-CALORIMETERS

DEL MAR, CALIF. — A new line of micro-calorimeters, designed to determine the half-life characteristics of radio-active materials and wastes has been introduced by International Thermal Instrument Co. (Box 309, Del Mar, CA 92014). Designated as the CR-100 series, these micro-calorimeters are furnished in 3-, 4-, and 5-inch or larger sizes.

Operating of the "thermal gradient principle," radio-active test specimens after being placed in the sample test chamber, transfer all heat developed to a surrounding heat sink with a stabilized temperature. Heat conducted through the calorimeter wall termo-electrically transduces an electrical signal directly proportional to the energy release of the reaction.

Transient and steady-state energy releases are measured by recording the calories per unit time vs time. Energy release, however short, is computed from the resultant decay curve.

WASTE MANAGEMENT MANAGER NAMED AT MOUND LABORATORY

MIAMISBURG, OHIO — Richard A. Wolfe, Waynesville, Ohio, has been named manager of waste management at Mound Laboratory. Mound's multi-faceted waste management program has focused on the unique challenges associated with handling radioactive materials as well as the normal environmental concerns of an industrial operation.

Wolfe received his M.S. in nuclear engineering from the University of Cincinnati and is scheduled to receive his Ph.D. in that field from UC in August. Wolfe joined Mound in 1961 shortly after graduating from Virginia Polytechnic Institute with a B.S. in chemical engineering.

NEW MEMBERS

The following individuals have been recently accepted into INMM membership through June 30, 1972. They are: George J. Bernstein, Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439; Dennis M. Bishop, General Electric, Vallecitos Nuclear Center, P. O. Box 846, Pleasanton, CA 94566; Warnell Brown, 800 Concourse Village W., 5-L, Bronx, NY 10451; Everett A. De Ver, 2155 E. Central Ave., Miamisburg, OH 45342; Leonard E. Link, 5722 Wanda Pl., Downers Grove, IL 60515; John Mangusi, Transnuclear, Inc., 919 Third, New York, NY 10022; Erick L. May Jr., Atomic Energy Commission, Region I, Regulatory Operations, 970 Broad St., Newark NJ 17102; Dr. James A. Powers, 11315 Old Club Rd., Rockville, MD 20852; Marvin R. Schneller, E. 1824 S. Riverton, Apt. 205, Spokane, WA 99207; Dr. Thomas E. Shea, Atomic Energy Commission, RS-MPS 008, Washington, DC 20545; Charles N. Smith, Physicist, National Bureau of Standards, Radiation Physics Building, C-216, Washington, DC 20234; and Richard C. Yates, 27525 Mt. Radnor St., Damascus, MD 20750.

TWO SAFEGUARDS TRAINING COURSES

The Argonne Center for Educational Affairs (ACEA) conducted two training courses in nuclear material safeguards in June.

The first was an "Advanced Statistical Method in Material Control" course given by John L. Jaech, Jersey Nuclear, Richland, Wash., and chairman of the INMM committee on statistics.

The workshop was attended by five participants representing the AEC, AEC contractors and private industries. Although ACEA has presented a number of courses in statistical method, this was the first that carried the basic ideas beyond an introductory stage.

The second course was a one-week course in "Nuclear Material Safeguards—An Overview for Professional Accountants." This course was designed for a person with a basic background, who became familiar with a balance accountance.

Twelve participants were enrolled from public accounting firms, nuclear fuel fabricators, electrical utilities and the AEC.

(Continued on Page 4)

SAFEGUARDS COURSES

(Continued from Page 3)

The AEC Division of Nuclear Material Security will sponsor 10 weeks of courses and workshops in the ACEA program in 1973-74. Announcements on these sessions will be announced in future issues of NUCLEAR MATERIALS MANAGEMENT.

CHANGES OF ADDRESS

The following are new addresses for members of the Institute of Nuclear Materials Management, Inc.: Dr. G. D. Atkinson Jr., 10202 Oak Hollow Cr., Austin, TX 78758; Clyde P. Jupiter, EG&G, Inc., 680 E. Sunset Rd., Las Vegas, NV 89109; Robert D. Lucy Jr., 4300 Osceola St., Denver, CO 80212; and L. F. Wirfs, 16620 S. Westland Dr., Gaithersburg, MD 20760.

Robert L. Delnay

A.N.S.I. Standards Okayed

By Robert L. (Bob) Delnay

Dow Chemical U.S.A.
Rocky Flats Division

You have heard the old cliche, "What a difference a day makes." I'll exercise some literary freedom. I'll multiply the cliche by 365 and say "What a difference a year makes!" Last year in West Palm Beach, I reported that we had one standard approved and published by ANSI. Since that time, ANSI approved two standards in 1971, and four more so far in 1972. As of May 24, 1972, we have seven standards that have been approved by the American National Standards Institute. Four of the seven have been published.

The following is a list of the N15 American National Standards.

N15.1-1970 — "Classification of Unirradiated Uranium Scrap," prepared by Joe Barkman and his task group was approved on January 15, 1970.

N15.2-1971 — "Record and Reporting Units for Nuclear Materials Control," prepared by Russ Weber and his subcommittee was approved on November 1, 1971.

N15.3-1972 — "Physical Inventories for Nuclear Materials," prepared by Doug George and his subcommittee was approved on February 17, 1972.

N15.4-1971 — "Nuclear Material Control Systems for Conversion Facilities, A Guide to Practice," prepared by Ralph

(Continued on Page 5)

CONFIDENTIAL SALARY SURVEY

At the Nov. 8, 1971 meeting of the Executive Committee of the INMM, a confidential survey of salaries in the general field of nuclear materials management was authorized and Douglas E. George was requested to undertake the task.

By letter dated Jan. 31, 1972, a questionnaire was sent to all INMM members. The following data are the result.

	No.	Percent
Questionnaires sent out:	369	
Questionnaires returned:	210	56.91
Questionnaires not applicable-retired	47	22.38
Questionnaires used in Summary	163	77.62

For the questionnaires returned, the employment of the membership is divided as follows:

	No.	Percent
USAEC	38	23.31
Other Government	4	2.45
AEC Production	35	21.48
AEC Research	27	16.56
Educational	3	1.84
Convertor-Fabricator-Processor	33	20.25
Utility	5	3.07
Other	18	11.04
Total	163	100.00

N.B. Because of the small response in the "Other Government," "Education," and "Utility," extrapolation of the percentages to the total membership is risky.

Experience of those returning their questionnaires revealed that the average experience in the current position was seven (7) years and the average prior experience was eleven (11) years. While the average in the current position was seven (7) years, it is interesting to note that the most frequent responses given were twenty three (23) for three (3) years, and twenty one (21) for four (4) years.

The preponderance of the responses indicated the members were largely in the "Management" category, as the results below show:

	No.	Percent
Manager	107	65.85
Engineer, etc.	34	20.73
Accountant	14	8.54
Other	8	4.88
Total	163	100.00

The average salary of all responses was $20,268, using the average within each range given as the basis of the computations. The most frequent response was in the $15,001 - $20,000 range (average $17,500).

When the average salaries are shown by employment, the following data result. Again, the average within each range given was used as the basis of the computations:

	Avg. Salary
USAEC	$ 24,506
Other Government	18,437
AEC Production	17,607
AEC Research	20,185
Educational	19,583
Convertor-Fabricator-Processor	19,318
Utility	17,750
Other	19,583

In response to the question of the extent to which being in the field of nuclear materials management had aided the career of the members, the following results are presented:

	No.	Percent
Significantly	67	41.10
Modestly	59	36.20
No discernible effect	37	22.70
Total	163	100.00

MONSANTO GROUP STREAMLINES SYSTEM

MIAMISBURG, OHIO — The new Operational Support Facility will enable the Data Processing section, to occupy one floor of the four-story structure, to expand its services and capabilities.

As a result, the Nuclear Materials Management group is planning to streamline its data collection system. The new system will involve the use of input terminals to be located throughout the laboratory. Information fed into the terminal is relayed back to the computer center where it is automatically tabulated.

This data-base system will provide Nuclear Materials Management with better control and improved accountability of nuclear materials at all times. It also will improve Nuclear Material Management's ability to respond to information needs of Mound Laboratory management and Atomic Energy Commission officials.

NON-DESTRUCTIVE ASSAY MACHINE

Precise determination, to plus or minus ½ percent relative precision, of enrichment or fissile content of individual nuclear fuel pellets or powder samples can now be carried out with a non-destructive assay machine. Manufacturer is National Nuclear Corp., 3150 Spring St., Redwood City, CA 94063 (Herman Miller, President).

The machine is for use in quality control, accountability and safeguards applications. Quick, simple measurements are a feature of this machine which is based on the NNC patented coincidence fuel assay method. Write Miller for more information on this unit.

A.N.S.I. Standards Okayed

(Continued from Page 4)

Jones and his task group was approved on October 20, 1971.

N15.5-1972 — "Statistical Terminology and Notation," prepared by John Jaech and his subcommittee was approved on May 24, 1972.

N15.6-1972 — "Accountability of Uranium Tetrafluoride, Analytical Standards For," prepared by J. C. Barton and his task group was approved on April 20, 1972.

N15.7-1972 — "Accountability of Uranium Hexafluoride, Analytical Standards For," prepared by J. C. Barton and his task group was approved on April 20, 1972.

There are four proposed standards that have been submitted to N15 for approval.

N15.8 — "Nuclear Materials Control Systems for Nuclear Power Reactors, A Guide to Practice." This proposed standard was prepared by a task group chaired by Dick Cordin. This standard is currently undergoing its second letter ballot in N15 as it was revised significantly in an attempt to resolve two negative ballots.

N15.9 — "Nuclear Materials Control Systems for Fuel Fabrication Plants, A Guide to Practice." D. Hayman's task group prepared this proposed standard. It is undergoing its first letter ballot in N15 with a concurrent public review conducted by the American National Standards Institute.

N15.10 — "Classification of Unirradiated Plutonium Scrap." A task group chaired by Joe Barkman prepared this proposed standard. Both the letter ballot and ANSI's public review have been completed. All N15 letter ballots were affirmative. There were no adverse comments from the public review. The proposed standard was submitted to the Board of Standards Review on May 26, 1972 for final approval.

N15.11 — "Auditing Nuclear Material Statements." Bruce Smith and his subcommittee prepared this proposed standard. The standard is being reviewed for format and structure prior to N15 letter ballot.

EDITOR ACCEPTS NEW POSITION

NEW ORLEANS, La. — Dr. Curtis G. Chezem, Editor of NUCLEAR MATERIALS MANAGEMENT, journal of I.N.M.M., has joined Middle South Services, Inc., as Manager of Nuclear Activities.

The appointment was effective July 17. Chezem had been Black & Veatch Professor and Head of Nuclear Engineering at Kansas State University, Manhattan. He will continue as Editor of this journal.

CALL FOR PAPERS FOR 1973 MEETING TO BE MAILED IN AUGUST

Roy G. Cardwell, Program Chairman for the 1973 annual meeting of the Institute of Nuclear Materials Management, Inc., reports that a call for papers for that meeting will be mailed to I.N.M.M. members and selected persons in industry and government in late August. The annual meeting is set for next June in San Diego, Calif. If information is needed right away concerning that meeting, phone (AC 615 483-6638) or write to Cardwell in care of Metals and Ceramics Division, OAK RIDGE NATIONAL LABORATORY, P.O. Box X, Oak Ridge, TN 37830.

I.N.M.M. TREASURER R. J. JONES ACCEPTS A.E.C. POSITION

Ralph J. Jones, new Treasurer of the Institute of Nuclear Materials Management, Inc., July 17 joined the U. S. Atomic Energy Commission, Directorate of Regulatory Standards as Operations Analyst.

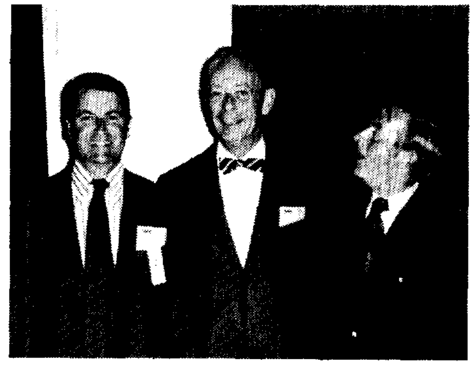
Before accepting his new position, Jones was Manager of Nuclear Materials Control for Nuclear Fuel Services, Inc., Rockville, Md.

FORMER I.N.M.M. Chairman Bernard Gessiness of NL Industries, Cincinnati, Ohio, and his wife Naomi, attended the reception preceding the annual banquet at Boston.

I.S.A.F. ACTIVE OR PASSIVE

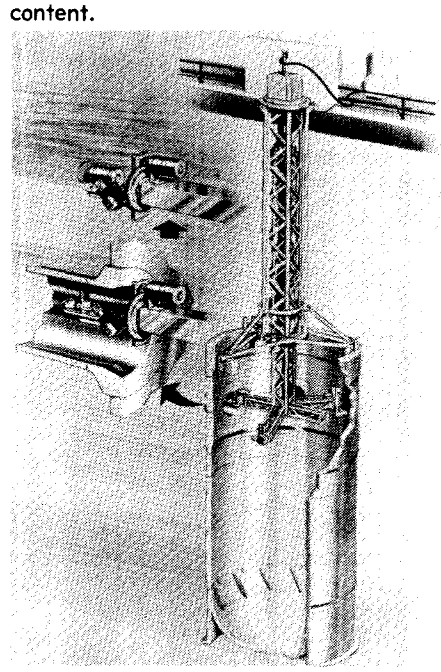
The Gulf ISAF system (Gulf Radiation Technology, P. O. Box 608, San Diego, CA 92112) can be used with a ^{241}Am Li (433 year half life) isotopic neutron source, or passively without neutron source. In either operating mode, the ISAF is nondestructive to the sample being assayed.

When used passively, the system will



BANQUET SPEAKER was Donald G. Allen (c.), President of Yankee Atomic Electric Co., Westborough, Mass., at the 13th annual meeting of the Institute. He was photographed by James W. Lee with Armand Soucy (l.), new I.N.M.M. Vice Chairman, and Harley Toy, incoming Chairman.

measure the ^{240}Pu content of a sample; actively the system will measure the fissile material (^{235}U or ^{239}Pu) content of homogeneous dry oxides, compounds, residues, calcined ash, scrap, and solutions or materials with a known hydrogenous content.



AUTOMATED REACTOR INSPECTION SYSTEM

Babcock & Wilcox has ordered an automated reactor inspection system (ARIS), one of a new class of highly advanced inspection systems for upgrading the safety of reactor vessels in use at nuclear power plants.

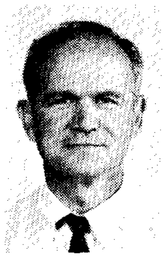
First use for the ARIS will be in baseline and in-service inspection at Duke Power Company's Oconee, S.C., nuclear plant. The Oconee plant consists of three B&W PWR nuclear steam systems with Once-Through Steam Generators. Each unit is rated at 841-Mwe net.

ARIS (TexTran, Newark, Ohio) is said to be the most advanced system ever designed for in-service inspection of nuclear pressure vessels.

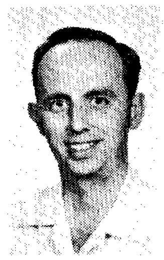
F. A. Costanzi

W. J. Gallagher

J. L. Jaech



R. B. Leachman



J. E. Lovett

AUTHORS FOR THIS ISSUE

Frank A. Costanzi (Ph.D., theoretical physics, Northwestern University) came to Kansas State in June, 1971, to participate in the Diversion Safeguards Program. Prior to his joining K-State he was a member of the Physics Department faculty at the Chicago Circle campus of the University of Illinois. He has worked in the areas of high energy and nuclear physics, as well as safeguards. He is presently at the Regulatory Division of the Atomic Energy Commission.

William J. (Bill) Gallagher is Manager of commercial safeguards applications for Gulf Radiation Technology, San Diego, Calif. He participates actively in developing and marketing commercial assay equipment to meet the nuclear materials management and safeguards needs of industry. Before joining Gulf, Gallagher was Nuclear Materials Manager for United Nuclear Corp. A chemist by training and an engineer by experience, he received his education at Cornell University and Siena College. He has extensive experience in the nuclear industry, coupled with a strong drive to develop nuclear materials management into an efficient, recognized profession.

J. L. Jaech (B.S., Mathematics, M.S., Mathematical Statistics, University of Washington) is Staff Consultant, Statistics for Jersey Nuclear Company. Jaech has been a statistical consultant in the nuclear field for 19 years. Prior to joining Jersey Nuclear in May, 1970, he was manager of the Applied Mathematics Department at Battelle-Northwest (1967-1970), following work as a statistician for General Electric at Vallecitos (1963-1967) and at Hanford (1953-1963). He is chairman of the INMM sponsored ANSI Subcommittee on Statistics, and has presented courses on statistical methods in nuclear materials control at the Argonne Safeguards School. Jaech has authored 15 open literature publications on statistical methods and applications in various journals.

Robert B. Leachman (Ph.D., Iowa State University) has been at Kansas State University since 1967 as director of the Nuclear Science Laboratories and until 1971 as the head of the Physics Department. He was principal investigator of the NSF-sponsored interdisciplinary research diversion safeguards described in this article. From 1950 to 1967 he was at the Los Alamos Scientific Laboratory working principally on fission research. He was a Guggenheim Fellow at the Nobel Institute in 1955-56 and a Fulbright Fellow at the Niels Bohr Institute in 1962-63. This fall he joins the Defense Nuclear Agency.

BOOTH AT BOSTON — Ralph J. Jones (left), new INMM treasurer, and Roy G. Cardwell, program chairman for the 13th annual INMM meeting in Boston May 31-June 2, pose with Ann Jones and Dale Mulkern of Yankee Atomic Electric Co., Westboro, Mass., in front of the Institute booth in the Sheraton-Boston Hotel.

YVONNE FERRIS was the only woman presenting a paper at the annual INMM meeting May 31-June 2 in Boston, Mass. She is shown with Ralph F. Lumb (c.) and new INMM chairman Harley L. Toy at the banquet.

LADIES PROGRAM AT BOSTON — An extensive ladies' program for the wives of INMM members and guests attending the annual meeting in Boston was offered. The program included numerous tours and activities.

James E. Lovett (B.S., Chemistry, University of Kansas) was formerly Manager of Nuclear Materials Control for six and a half years at Nuclear Equipment and Materials Corp., Apollo, Pa. A Certified Nuclear Materials Manager, Lovett had been with the U.S. Atomic Energy Commission for 10 years in Washington, D. C., and two years in Albuquerque, N. Mex. Prior to that, he was with the Rocky Flats Division, Dow Chemical Company, Golden, Colo.

ISOTOPIC NEUTRON SOURCE ASSAY SYSTEMS: THEIR ADVANTAGES AND DISADVANTAGES

By William J. Gallagher

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Introduction

An active assay system is defined as one that acts upon a nuclear sample to induce a measurable reaction. In contrast, passive systems (such as the gamma spectrometer) do not influence the sample, but measure the radiation naturally emitted by it instead.

As a result of U.S.A.E.C.-sponsored programs within the past two years, a new class of nuclear measurement instruments has been developed: active assay systems using isotopic neutron sources. These systems, although certainly not a panacea for nuclear assay problems, promise to aid in the resolution of many of them.

Components

A simplified isotopic neutron source assay system consists of:

1. A sample-handling device or holder.
2. An isotopic neutron source to produce fission in the sample.
3. Detectors and electronics to detect, process, and summarize signals from the sample.

Theory of Operation

Typical neutron interrogation assay systems irradiate a sample with neutrons from an isotopic source. This causes some of the fissile (and, under certain conditions, some of the fertile) material within the sample to fission and emit prompt gamma radiation and fission neutrons. Emissions (signals) from the sample are measurable and proportional to the amount of fissile and-or fertile material within the sample.

The quantity of fissile or fertile material undergoing fission during the active assay is too small to be measured by ordinary means; hence, the technique described above can be classified as non-destructive.

Energy of Interrogating Neutrons

The interrogating neutrons from the isotopic source are classified, according to their energy, in electron volts (eV). Fissile materials, such as ^{235}U, fission when interrogated with slow, low-energy neutrons of less than 1 eV in energy, while fertile materials, such as ^{238}U, require interrogating neutrons of approximately 1 million electron volts (MeV). These widely varying fission properties can be used to advantage in measuring fissile and fertile materials separately within a single sample.

Designing an active assay system requires compromises when applying the energy of the interrogating neutrons to the operating characteristics of the system. Interrogating neutrons of less than 1 MeV in energy (sub-MeV neutrons) cause a greater response from fissile material than those of more than 1 MeV in energy (super-MeV neutrons). The sub-MeV assay systems should, therefore, be more sensitive, that is, have a lower limit of fissile material detection, than the super-MeV systems. However, this greater sensitivity can be more than offset by the lower penetrability into the sample of the sub-MeV interrogating neutrons. Figures 1 and 2 illustrate the sensitivity of two different types of active assay systems utilizing sub-MeV interrogating neutrons from Am^{241}-Li and ^{252}Cf neutron sources, respectively.

Generally, the sub-MeV assay systems are satisfactory for measuring homogeneous materials or light-density heterogeneous materials. They are the best systems for measuring small samples containing tenth-gram quantities of fissile material (including fuel rods). The sub-MeV systems also require less radiation shielding and are usually less expensive than the super-MeV systems.

Sub-MeV assay systems are influenced to a greater degree by density variations within large samples than the super-MeV systems, and they are usually more closely dependent on correlation of samples to calibration standards.

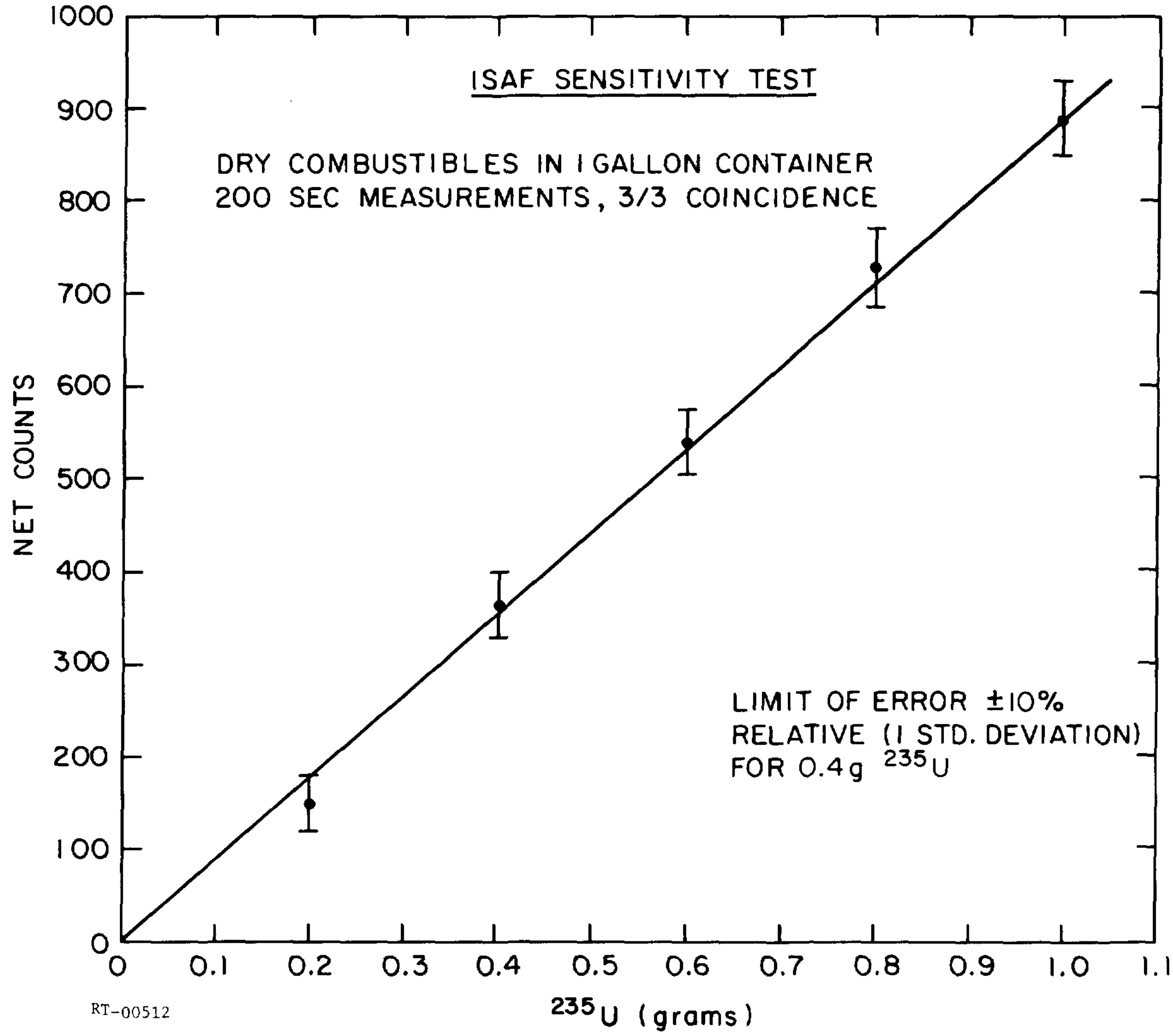
Sub-MeV systems cannot be used for active assays of fertile materials.

Active assay systems using super-MeV interrogating neutrons are more satisfactory than sub-MeV systems for measuring dense or heterogeneous materials, large bulk samples, or samples of questionable composition. A significant advantage of these systems is that the interrogating neutrons can be easily moderated to sub-MeV energy levels through the use of moderating materials such as parafin. This technique is particularly advantageous in those instances when interrogation by sub-MeV neutrons is clearly preferable. Another advantage of the super-MeV systems is that either fissile or fertile materials can be measured.[1]

Isotopic Neutron Sources

Interrogating neutrons can be obtained from a number of isotopic sources, some of which have distinct advantages over others for specific applications. The goal is to match the source to the requirements of the particular system.

For a multipurpose active assay system, a source such as Californium-252 should be considered first. This spon-



ISOTOPIC NEUTRON SOURCE ASSAY SYSTEMS:
THEIR ADVANTAGES AND DISADVANTAGES
Wm. J. Gallagher
Fig. 1

taneous fission source has a half-life of 2.6 years, produces neutrons of 2.3 MeV average energy, is small in size, and has a high specific activity of approximately 2.3 x 10^6 neutrons / second / microgram. This source is available commercially at a cost of approximately $2,700 per 25 micrograms.

Sub-MeV neutrons are usually derived from alpha-emitting isotopes, such as ^{241}Am, ^{238}Pu, or ^{210}Po, combined with an appropriate target material (e.g., Li). These sources are also available commercially.

The sub-MeV sources are generally large in size; for example, a 40-curie ^{241}Am-Li source, emitting 0.4 MeV neutrons, is approximately 1.5 by 3.5 inches. Because of their low specific neutron activity (0.03 x 10^6 neutrons / second / curie), multi-curie MeV sources are in common use, but shielding requirements are negligible because of the low energy of these sources.

The specific application frequently dictates the energy of the interrogating neutrons. For example, fertile material measurements can only be performed with interrogating neutrons of approximately 1 MeV or more in energy and, therefore, require a neutron source with energies above 1 MeV (e.g., ^{252}Cf or ^{238}PuBe). High-speed fuel rod scanners, which detect individual "rogue" pellets of misidentified enrichment, require sub-MeV interrogating neutrons for high sensitivity. However, a sufficient flux of interrogating neutrons cannot normally be obtained from sub-MeV isotopic sources. Thus, high-speed fuel rod scanners are usually designed around high-intensity super-MeV interrogating neutrons that are moderated to sub-MeV energies.(2)

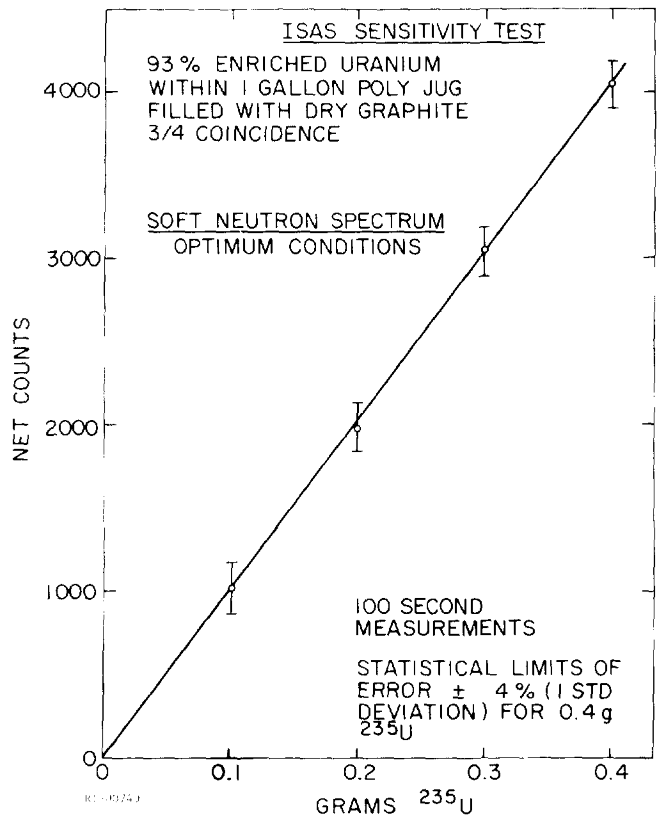
Signal-to-Background Ratio

Neutrons and / or gamma radiations are emitted from both the isotopic source and the sample undergoing interrogation in an active assay system. The sensitivity and precision of this type of system depend on it detecting as many radiations as possible from the sample and as few as possible from the source; that is, the system must have a high signal-to-background ratio.

Three common methods of achieving the separation of signal and background radiation are:

1. The assay system can be designed around a single detector that is adjusted to detect only high-energy fission events in the sample and to be relatively insensitive to the lower energy interrogating neutrons. This system is relatively inexpensive to build and satisfactory for many applications with the nuclear industry. Its disadvantages include relatively poor sensitivity and signal-to-background ratio. This type of detector is satisfactory only for sub-MeV neutron assay systems.

2. A signal from the sample can be distinguished from the radiation of a super-MeV source by carefully moderating the source so that the source plus moderator is effectively



ISOTOPIC NEUTRON SOURCE ASSAY SYSTEMS:
THEIR ADVANTAGES AND DISADVANTAGES
Wm. J. Gallagher
Fig. 2

sub-MeV with a small component of neutrons above 1 MeV. A high-energy neutron detector is then placed adjacent to the sample to detect high-energy fission neutrons.

3. The assay system can utilize a coincidence counting circuit. Each fission event occuring within a sample results in the simultaneous emission of several neutrons (about 2.5 on the average) and gamma rays (about 7.0). Thus, a fission event is characterized by high multiplicity. The interrogating neutrons from the isotopic source are of much lower multiplicity or of uncorrelated single events. To distinguish the radiation of the fission events from the background radiation of the isotopic source, a multidetector system incorporates two or more detectors that must each, within a very short time period, simultaneously detect a gamma ray and/or a neutron for the assay system to register one count. A single detector can be used for coincidence counting through the utilization of the relatively long lifetime of thermal neutrons in moderators. The detector is required to register two or more neutron detections within the thermal neutron life-time (approximately 100 microseconds).

Coincidence-counting assay systems can be used with either sub-MeV or super-MeV interrogating neutrons. In such systems, the isotopic neutron source can be brought into close proximity to the sample. For super-MeV interrogation, the source must be shielded from the detector to keep the coincidence rate from the source sufficiently low.

Coincidence systems usually have greater sensitivity, better accuracy, and a better signal-to-background ratio than active assay systems using other types of counting circuits. The disadvantage of these systems is that they are more expensive than other types of active assay systems.

Optimization

Each active assay system must be optimized to specific user requirements. This can be as simple as choosing the appropriate combination of isotopic source and detector(s), and possibly matching the energy of the interrogating neutron beam to the type of material to be measured.

Limitations

There are circumstances in which an active assay system gives erroneous measurements. For example:

1. Thorium-232 can be accurately measured only if the age of the unknown sample is approximately that of the known standard used to calibrate the system. This is due to the fact that after ^{232}Th is separated from the ore, the background from passive gamma radiation changes with time. Research to discover methods of compensating for this effect is being vigorously pursued by Gulf Radiation Technology.

2. Low-energy, rather than high-energy, interrogating neutrons are more likely to cause fission in fissile material. Water is an excellent moderator in that it slows high-energy neutrons to sub-MeV energies. Water in a sample, therefore, increases the signal or response from any fissile material that is present. Samples of enriched uranium in solution yield a larger signal than the same amount of material in a dry state. This is an advantage when small quantities of fissile material in solution are measured. However, unknown, yet significant, amounts of water in a sample also cause an increased signal and give erroneous assay results. Three techniques are being used by Gulf Radiation Technology to eliminate or lessen the possibility of interference from unknown quantities of water in the sample:

(a) The sample is dried prior to assay.

(b) The sample is fully flooded with water prior to active assay.

(c) The sample is interrogated with fully moderated sub-MeV neutrons, which are less influenced by water than the higher energy super-MeV neutrons.

3. Uranium-238 can be actively assayed only for enrichments of approximately 10 percent ^{235}U or less. Above this enrichment level, the signal from the ^{235}U overcomes the signal from the ^{238}U. Techniques to eliminate this effect have not as yet been developed.

Help is Available Now

Many measurement problems in the nuclear industry can be resolved or significantly reduced in the very near future if concerned organizations seek and put into operation the methods presently available.

Government-sponsored and private laboratories are engaged in continuing research and development to assist the nuclear industry in improving the measuring and safeguarding of nuclear materials. These laboratories offer advice and consultation, some on a no-cost basis, on active assay techniques.

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SAFEGUARDS AT KANSAS STATE UNIVERSITY: PART I*

By F. A. Costanzi and
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EDITOR'S NOTE: This article has been divided into two parts. The first installment will cover research undertaken in the social-political sphere. The topics discussed are titled: **Social-Psychological Research, Criminal Typologies,** and **Control Preference Surveys.** The succeeding issue will present the more technical aspects of safeguards under the titles: **Inspector-Diverter Game Theory, Optimization of Inspections,** and **Non-Destructive Analysis of Dissolved Spent Fuel.** The research reported herein was conducted under grant GI-9 from the Research Applied to National Needs office of the National Science Foundation.

Introduction

The Diversion Safeguards Program at Kansas State University began on 1 June 1970 as one of the initial grants of the Research Applied to National Needs (then called Interdisciplinary Research Relevant to Problems of Our Society) program of the National Science Foundation. The purpose of our Program was to coordinate a varied group of scholars in research on a single problem concerned with public policy in a technological matter of growing concern, viz., nuclear materials safeguards.

The value of this University study was in providing a bridge between technical and political elements which facilitated efforts to come to an understanding of the impact of this technological matter on society. Accordingly, much of our research was composed of joint endeavors by scholars of various disciplines:

political science,
physical sciences,
psychology,
engineering,
criminology.

In this article, we summarize the progress made by the Diversion Safeguards Program (now ended) in the study of the interaction between technological and human factors in Diversion Safeguards. The names of the principals involved appear under each topic.

Social-Psychological Research

L. H. Rappoport and
J. D. Pettinelli

This section of the KSU safeguards project has been in operation for 21 months (September 1970 to June 1972). It was begun and subsequently carried out on the premise that substantial problems in the nuclear safeguards field could be approached from the standpoint of social-psychological research on human judgment. More specifically, our analysis of the general problem suggested the empirical methods employed for basic research studies of decision-making in the face of uncertainty could be adapted for application to the safeguards field.

A two stage research strategy was planned emphasizing (a) assessment of perceived dangers and uncertainties in the nuclear fuels environment, and (b) simulation of judgmental behaviors associated with the more ambiguous aspects of safeguards. The first stage of the research was implemented by distributing a survey of materials management hazards to a large number of knowledgable persons in government, industry, and laboratories.

Designed to assess the opinions of experts about the risks and uncertainties existing at various points in the nuclear fuel cycle, this questionnaire survey was mailed to a selected sample of 488 persons in government, industry and laboratories. Completed questionnaires were returned by 27 persons in government, 59 in industry, 33 in U. S. laboratories and 8 academic people involved with nuclear materials management. The total of 127 persons responding (26 percent) is considered to be an excellent return rate by commercial survey research standards, but should be noted as a possible source of bias.

The main results of the survey are discussed in a report[1] titled "Social Psychological Studies of the Safeguards Problem." These results may be summarized as follows:

a. **Loss** of fissionable materials is considered to be likely during fabrication, reprocessing, and transportation, in that order. Deliberate **diversion** is considered to be most likely during transportation, fabrication, and reprocessing, in that order. Furthermore, government personnel generally see the chances of loss or diversion to be higher than industry personnel.

b. Rating eight different nuclear fuel substances in terms of their **vulnerability to diversion,** there is a small but regular tendency for government respondents to indicate higher levels of vulnerability than industry respondents.

c. When presented with hypothetical situations specifying varying amounts of uranium and plutonium as unaccounted for (input-output discrepancies), all respondents indicate that they are more likely to suspect diversion as the size of the discrepancy increases. It is noteworthy, however, that even when very large discrepancies are specified, no more than fifty percent of respondents indicate a judgment of diversion or abnormal error.

Simulation of judgmental behaviors commenced with the design of three different tasks.

a. The evaluative judgment task. Twenty science graduate students familiar with the safeguards problem were required to evaluate the general desirability of hypothetical control systems constructed by project personnel D. W. Brady and D. A. Zollman. The five systems varied in stringency, and the students were instructed to rate each system in terms of how well it would protect industrial secrecy ("proprietory information"); its financial cost; and the security it would provide against diversion.

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*Research Supported by the Research Applied to National Needs (RANN) Office of the National Science Foundation.

b. The inspector decision task. Arranged in the form of test booklets, sixteen different inspector problems were constructed in order to investigate what kinds of evidence would be weighed most heavily when judgments are made about the likelihood of diversion. Nineteen science graduate students were instructed to act as chief inspectors who had encountered the information given in each problem. While going through the information in the booklet, they were required to judge the likelihood of diversion at various points.

Data analyses indicated the following results:

1. During the initial steps of the problem when only the information concerning material unaccounted for, physical security anomalies, and quality of material is available, judgments of diversion are largely determined by the relative size of the MUF factor and the number of security anomalies given. The quality of the material involved and the absolute magnitude of the MUF are **not** important sources of variability in judgments of diversion.

2. In later phases of the problem when information is given about normal operational losses (NOL), bookkeeping errors, physical measures and counts of inventory, the most important factors influencing judgments of diversion are the NOL and physical inventory checks. Abnormally high NOL data and physical inventory errors both excite the suspicions of our simulated inspectors and lead them to raise their estimates that diversion has occurred.

c. The safeguards system negotiation task. The students performing the above tasks were divided randomly into two groups and instructed to think of themselves as representatives of either industry or government who were charged with negotiating agreements for a general safeguards system.

Each group elected delegates who conducted the actual negotiations, and who reported back to their constituent groups to seek ratification of tentative agreements or further instructions.

The group representing industry was more effective in achieving its goals than the government group. Industry negotiators were able to follow a relatively simple policy which allowed them to concentrate on obtaining concessions regarding key points of concern to their constituency. The government negotiators, however, were often divided among themselves on key points, apparently because of ambiguities or conflicting purposes in their constituent group. Difficulties for those acting the government role reached a climax when the group decided to replace the delegates they had initially elected. The issues provoking the greatest disagreements within and between the two groups concerned matters of opinion about potential risks of diversion. The issues were substantially similar to those mentioned in the results of the hazards survey as being a source of conflict or confusion.

All of the simulation work described above was initially conceived as pilot tests or "feasibility" studies. Because they turned out to be workable sources of useful information, it was decided to re-design and / or replicate the three tasks adding refinements suggested by consultants and by the quality of the pilot data. Consequently, rather than performing exhaustive quantitative analyses of the pilot data, our main effort was preparing for a second run, now complete. A report of our findings will be submitted to NSF as soon as appropriate analyses and write-ups have been completed. We presently estimate that the supplementary report will be ready early in September of this year.

Criminal Typologies

R. B. Leachman

In view of the serious consequences of criminal acts with fissile material, effort is warranted in trying to establish the typologies of likely criminals and crimes **before** any such act has been committed. Criminal typologies heretofore have been studied only on the basis of actual crimes committed. For example, typologies have been reported for actual hijackers of airplanes.[2] However, different methods of investigation are obviously required for yet uncommitted crimes. Opinions were sought from experts having applicable knowledge. Accordingly, the survey was in two parts with basically different groups of elites: (1) a survey of elites outside of the nuclear industry but actively involved broadly in law enforcement of criminal justice or else having knowledge of crime prevention in a relevant field of specialization, and (2) criminological and security questions contained in the Hazards Survey conducted by Rappoport and Pettinelli.[1] The survey (1) included personal interviews as well as mailings; also undertaken was a study of legal regulations in each of the specialized fields. Results are contained in detailed reports.[3,4]

1) Thefts of Specialized Materials

Separate questionnaires were prepared on five different fields of crime for which experience exists and which possess most of the distinguishing traits of what is expected to be involved in any theft of fissile material. By this means, the respondents were involved with topics on which they had knowledge, thereby eliminating any need for involvement with what was to the respondents the unfamiliar field of fissile materials.

Particular care was taken to delineate the monetary magnitude and time span of the crime in the questionnaire in these other fields so they would be comparable to the nuclear theft of concern. A one-year time span for executing the theft was specified, since particularly in the management of fissile materials a longer time span would lead to detection of any attrition. The minimum theft specified in the questionnaires was set at $70,000 for the value of the stolen items in question. This is the monetary equivalent of the plutonium for the 10 kg effective considered by Avenhaus and Gupta.[5] This monetary minimum assured that responses were confined to unusual and rare crimes. This restriction is acknowledged to unavoidably act as a severe restraint upon the number of qualified responses than can be obtained.

For the survey, the other criminological fields studied were selected to have as many as possible of the characteristics of fissile materials:

a) high unit value
b) limited marketability for disposal
c) special technology in handling
d) under U. S. governmental control or license

The following fields were characterized best by a) through d) and so were individually studied in the survey:

I) data (particularly in computers)
II) weapons (particularly automatic-fire weapons)
III) narcotics
IV) objects of art
V) precious metals and gems (particularly gold)

Including mailings and interviews, responses ranged from a high of 22 for narcotics to a low of 14 for objects of art. As a result of these small sample sizes, findings from the survey are regarded as only suggestive rather than precise despite the expertise of the respondents.

The following Table presents results for the five criminological fields. Respondents overwhelmingly believed data thefts would be by employees and that thefts both of precious metals and gems and of objects of art would be by non-employees; therefore responses only for these employment classifications have adequate sample size for inclusion in the following Table. On the other hand, questionnaire responses for fields of weapons and of narcotics were similar in number for thefts by employees and by non-employees; for these two fields, responses for both employment classifications are given in this Table.

2) Survey Regarding Nuclear Materials

Questions were part of the Hazards Survey conducted by Rappoport and Pettinelli.[1] The respondents were assumed to know the security exerted for fissile materials and the technical difficulties involved in any theft and any illicit use. These responses probably reflect the attitudes and

TABLE

Characteristics and Motives of Thieves of Large-Values of Specialized Materials as Determined by Survey Responses.

	Data	Weapons		Narcotics		Objects of Art	Precious Metals and Gems
Employment Category	Employee	Employee	Non-Employee	Employee	Non-Employee	Non-Employee	Non-Employee
Age							
up to 25	19%	60%	33%		67%		
25 - 40	75%	20%	67%	75%	33%	57%	71%
40 & over	6%	20%		25%		43%	29%
Number of Responses	16	5	6	8	12	7	14
Education							
Less than High School		40%	50%	17%	45%	17%	29%
High School Graduate	31%	40%	50%	83%	45%	33%	71%
College Graduate	69%	20%			10%	50%	
Number of Responses	16	5	6	6	11	6	14
Motive							
Profit	80%	71%	33%	100%	100%	100%	100%
Political	7%	29%	67%				
Personal	13%						
Number of Responses	15	7	6	7	10	6	14

background beliefs of persons actually responsible for security of fissile materials in the United States.

Respondents were asked to list which groups or persons were most likely to divert materials. Following are the categories together with the percentage of responses:

Dissident U. S. Group	24 percent
Organized Crime	19 percent
Foreign Countries	14 percent
Dissident Foreign Group	11 percent
Psychopaths	8 percent
Plant Employees	8 percent
Confidence Type People	5 percent
Professional Criminal	4 percent
Amateur or Situational Criminal	4 percent
Group for Profit or Power	3 percent

In the above listing the leading four categories, comprising 48 percent of responses, were groups organized for purposes other than simply performing the theft. Except for weapons thefts by non-employees, this result is in sharp contrast to the results of the previous survey on other criminological fields. These opinions from experts in nuclear fuel management could be explained by either

a) a realization of the different criminological attractions of fissile materials or

b) by their being misled by popularized versions of crimes while possessing limited knowledge of criminological patterns in large-valued thefts of specialized materials.

The correctness of this group-theft concept by respondents cannot be tested by experience. Nevertheless, this concept might be underlying present security precautions taken by officials for fissile material management.

Respondents to the Rappoport and Pettinelli survey are seen from the following table to identify both profit or political reasons as motives for diversion of fissile materials. Only in the case of weapons thefts by non-employees was the political motive similarly cited in the first survey, as is seen on the previous Table.

In both surveys, respondents were asked the same question about how effectively present personnel selection insured against hiring persons prone to theft. Persons involved with nuclear fuels responded with a significantly higher rating for personnel selection than the corresponding ratings by criminological respondents.

TABLE

Motives for Diversion of Nuclear Materials Obtained from 108 Responses by Experts in Nuclear Fuel Management

	Most Likely Motive	Least Likely Motive
Profit	46%	20%
Political	43%	16%
Personal Grievances	11%	64%

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NUCLEAR MATERIAL COST ACCOUNTING

By James E. Lovett

Apollo, Pa.

It is generally accepted within the nuclear industry that material control is, by and large, one of the necessary evils of doing business. I do not share or understand that philosophy. To my mind, nuclear material control is an essential part of the nuclear industry, fully capable of justifying its existence on economic grounds.

There is an analogy between nuclear material control and cost accounting which I believe is very nearly perfect. Nearly all companies agree that it is totally unacceptable to complete an extended accounting period, such as six months or one year, and have available only one item of accounting data, namely the magnitude of the profit or loss for the entire facility for the entire accounting period. In order to provide more detailed information, they subdivide their facilities into smaller units, often called cost centers. They also subdivide their fiscal year into smaller time units, usually months but sometimes even weeks. The existence of this cost accounting system does not in itself either reduce costs or increase profits. Rather, it provides the detailed information which is necessary for management investigation and possible action. The cost reductions, if any, come as a result of separate management decisions, decisions which can be credited to the cost accounting system only in the sense that that system provided basic input information.

Exactly the same situation exists in the area of nuclear material control. It is, or ought to be, unacceptable for any nuclear facility to operate for six months or one year and then have available only one number concerning the total magnitude of SNM losses for the period. If proper management decisions concerning the feasibility of reducing SNM losses are to be made, there must be available a framework of detailed loss information, subdivided according to cost center (here called material balance area) and time unit (month).

The analogy can be extended further. One of the major "adjustments" in cost accounting concerns the allocation of cash outflow between current expenses and capital purchases. Few if any would accept the idea that capital should be estimated at say 20 percent of total cash outflow. In particular, they would not accept the circular argument that 20 percent must be about right because it results in a profit of about the magnitude anticipated. Why then does the nuclear industry accept nuclear material control in which the SNM content of some major scrap material is only estimated, and then justify that estimate on the grounds that it results in an apparent SNM loss of about the expected magnitude?

If a manager considers every individual decision carefully, he ought not to need a cost accounting system to help him control costs. That statement may sound correct, but it is not generally accepted. The parallel argument, that a good manager does not need a nuclear material control system to help him reduce losses, for some reason is generally accepted. Just as a company assumes that its managers, regardless of how good they may be, cannot properly control dollar costs unless they have detailed dollar cost information, so it seems logical to me that these same managers cannot properly control SNM losses unless they have detailed SNM loss information.

In short, if potential dollar cost reductions justify cost accounting systems, why do not potential SNM loss reductions justify nuclear material control systems?

ADVERTISING INDEX

A NEW APPROACH TO CALCULATING LE-MUF

By John L. Jaech
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Introduction

The approach commonly used to find the variance of material unaccounted for (MUF) involves expressing MUF as a linear combination of beginning and ending inventories, plant inputs, and plant outputs. The variance is found for each of these components, and the variance of MUF is then found by appropriately combining the component variances. Covariances that may exist between the various quantities are often ignored or, at best, only partially accounted for.

A modification of this approach is suggested. This modification directs attention away from finding the variances separately for the inputs, outputs, and inventories, and is motivated by the need to more easily recognize the covariance sources, and properly account for them.

The MUF is, of course, simply an algebraic sum of individual terms. The same is true of other quantities of interest to safeguards, such as total inventory of a given type material. Thus, the results in this paper may be applied to any algebraic sum which satisfies the assumptions on model structure, even though attention is focused on calculating the variance of MUF.

In this paper, it is assumed that the basic safeguards measurements consist of net weights, element factors (uranium or plutonium), and isotopic factors. In this treatment, the use of non-destructive assay measurements, (e.g., on solid wastes), is not covered explicitly, but their inclusion is not difficult. Further, although presented with reference to a fuel fabrication facility, the results are readily applicable to other types of facilities as well.

The Model

The following notation is introduced. Let

w_i = observed net weight of item i material

p_i = assigned element factor for item i

t_i = assigned isotopic factor for item i

In the initial part of this discussion, attention will be restricted to element weights; isotope weights will be included later. Then, a general algebraic sum of interest may be written

$$S = \Sigma S_i = \Sigma a_i w_i p_i$$

This general sum could be, for example, the total element weight for a number of cans of UO_2 powder, in which case all the a_i would equal 1, and the p_i may all be equal. For MUF, each a_i would be either positive or negative one.

Now, w_i and p_i are random variables. The observed net weight, w_i, is affected by the systematic and random errors in the weighing procedure, while p_i is affected by systematic and random errors due to sampling and analytical. Specifically, ignoring the i subscript for simplicity, write

$$w = W\delta\varepsilon$$

$$\text{and} \quad p = P\Delta\beta\theta\eta\omega$$

where

W = true net weight of total material.
δ = systematic error component due to weighing.
ε = random error component due to weighing.
P = true element factor.
Δ = systematic error component due to sampling.
β = short term systematic error component due to analysis.
θ = long term systematic error component due to analysis.
η = random error component due to sampling.
ω = random error component due to analytical.

Attention is directed to two features of this model. First, the choice is made to write the model in a multiplicative form, rather than additive, because the various errors are usually expressed on a relative percentage basis. Each of these error component random variables is generally assumed to be normally distributed with mean one and standard deviation expressed as a relative amount. For example, if a particular standard deviation were 0.01 percent, this would be expressed as $\sigma = .0001$.

Secondly, the concept of a short-term systematic error analytical component is introduced. This describes the "shifting bias" that often exists in a laboratory in the sense that analyses performed at one time will tend to differ on the average from those performed at another time because of a shift in conditions which may or may not be identified as such. Neither the random nor the systematic error concepts adequately describe this characteristic behavior. Thus, a distinction is made between a short-term and a long-term systematic error. (It is noted that one can envision more complicated models in which there are several "levels" of short-term systematic errors. However, this introduces unnecessary complications in the current model, which is considered adequate for illustrative purposes).

Error Propagation

For the general algebraic sum in equation (1), each item in the sum must be characterized by the scale used to determine the item weight, and by the **element factor** used to convert item net weight to element weight. Items are correlated, for example, when they are weighed on the same scale, or when they share a common element factor, or perhaps when they have different factors, but both are based on the same analytical method.

The various element factors must be further characterized by noting the **material type** from which samples were drawn to estimate the factor, the **analytical methods** used, the **numbers of samples** drawn, the **numbers of analyses** performed (per sample or on a composited sample), and the set of **analytical conditions** applicable to each analysis. Once these identifications have been made, the propagation of errors can proceed in standard fashion. This results in seven rules for propagating errors. The rules are simple to apply, and require little if any familiarity with statistical error propagation methods.

Rule for Propagating Errors (Element Weights)

(The sums referred to in these rules are algebraic sums, taking into account the sign of each term in the sum.)*

(1) $\sigma^2_{\delta_j}$ is the systematic variance due to weighing on scale j. To find its coefficient, sum the element weights for all items weighed on scale j, and square the sum.

(2) $\sigma^2_{\varepsilon_j}$ is the random variance due to weighing on scale j. To find its coefficient, square each element weight for items weighed on scale j, and sum the squares.

(3) $\sigma^2_{\Delta_j}$ is the systematic variance due to sampling from material j. To find its coefficient, sum the element weights for all items with element factors based on sampling from material j, and square the sum.

(4) $\sigma^2_{\eta_j}$ is the random variance due to sampling from material j. To find its coefficient, sum the element weights over all items that have a common element factor based on sampling from material j, square the sum, and divide by the number of samples on which this factor is based. Then, sum these terms over all groups of items which have element factors based on sampling of material j.

(5) $\sigma^2_{\beta_j}$ is the short-term systematic variance for analytical method j. To find its coefficient, find the sum of element weights for each element factor based on analytical method j. Multiply each such sum by the proportion of total analyses performed for that factor under a given set of analytical conditions (i.e., no change in short-term analytical bias), sum these terms over all factors, and square the resulting sum. Then, sum these squares over all sets of analytical conditions.

(6) $\sigma^2_{\theta_j}$ is the long-term systematic variance for analytical method j. To find the coefficient, sum the element weights for all items with element factors based on analytical method j, and square the sum.

(7) $\sigma^2_{\omega_j}$ is the random variance for analytical method j. To find the coefficient, sum the element weights over all items that have a common element factor based on analytical method j, square the sum, and divide by the number of analyses on which this factor is based. Then, sum these terms over all groups of items which have element factors based on analytical method j.

*To avoid an excess of notation, the index j is used to refer to either the scale, material type, or analytical method. This should cause no confusion since it is always evident what is meant.

Example

Consider an example to illustrate the application of these rules. Assume there are n= 10 discrete items in the algebraic sum with

$a_1 = a_2 = a_5 = a_7 = a_8 = a_9 = a_{10} = +1$

$a_3 = a_4 = a_6 = -1$

Further, make the following assumptions:

(1) Each discrete item is weighed once with three scales in use.

- scale 1 for items 1, 2, 8
- scale 2 for items 3, 10
- scale 3 for items 4, 5, 6, 7, 9

(2) Three element factors are used

- factor 1 for items 1, 2, 5, 6
- factor 2 for items 3, 9
- factor 3 for items 4, 7, 8, 10

(3) The factors are based on sampling from three types of material

- factor 1 from material type 1
- factor 2 from material type 2
- factor 3 from material type 3

(4) Two analytical methods are used

- factors 1 and 2 use method 1
- factor 3 uses method 2

(5) For each analytical method, analyses are performed under different sets of condtions, where, within a given set of conditions, the short-term systematic error component does not change.

- analytical method 1
  - factor 1 based on 3 analyses under condition 1 and 5 analyses under condition 2.
  - factor 2 based on 2 analyses under condition 2, and 8 analyses under condition 3.
- analytical method 2
  - factor 3 based on 8 analyses under condition 1, 2 under condition 2, and 10 under condition 3.

(6) The number of samples and analyses used to calculate each factor are as follows:

- factor 1 is based on 4 samples with 2 analyses per sample
- factor 2 is based on 20 samples total with each group of 4 samples composited (5 composites), and two analyses performed on each composite
- factor 3 is based on 20 samples with one analysis per sample

The rules for propagating the error may now be applied to give the following components of variance.

Rule (1) (Systematic error in weighing)

Scale 1: $(S_1 + S_2 + S_8)^2\sigma^2_{\delta_1}$

Scale 2: $(-S_3 + S_{10})^2\sigma^2_{\delta_2}$

Scale 3: $(-S_4 + S_5 - S_6 + S_7 + S_9)^2\sigma^2_{\delta_3}$

Rule (2) (Random error in weighing)

Scale 1: $(S_1^2 + S_2^2 + S_8^2)\sigma^2_{\varepsilon_1}$

Scale 2: $(S_1^2 + S_{10}^2)\sigma^2_{\varepsilon_1}$

Scale 3: $(S_4^2 + S_5^2 + S_6^2 + S_7^2 + S_9^2)\sigma^2_{\varepsilon_3}$

Rule (3) (Systematic error in sampling)

Material 1: $(S_1 + S_2 + S_5 - S_6)^2\sigma^2_{\Delta_1}$

Material 2: $(-S_3 + S_9)^2\sigma^2_{\Delta_2}$

Material 3: $(-S_4 + S_7 + S_8 + S_{10})^2\sigma^2_{\Delta_3}$

Rule (4) (Random error in sampling)

Material 1: $[(S_1 + S_2 + S_5 - S_6)^2 \div 4]\sigma^2_{\eta_1}$

Material 2: $[(-S_3 + S_9)^2 \div 20]\sigma^2_{\eta_2}$

Material 3: $[(-S_4 + S_7 + S_8 + S_{10})^2 \div 20]\sigma^2_{\eta_3}$

Rule (5) (Short-term systematic error in analytical)

Method 1: $\{[S_1 + S_2 + S_5 - S_6)(3/8)$

$+ (-S_3 + S_9)(0)]^2$

$+ [(S_1 + S_2 + S_5 - S_6)(5/8)$

$+ (-S_3 + S_9)(2/10)]^2$

$+ [(S_1 + S_2 + S_5 - S_6)(0)$

$+ (-S_3 + S_9)(8/10)]^2\}\sigma^2_{\beta_1}$

Rule (6) (Long-term systematic error in analytical)

Method 1: $(S_1 + S_2 - S_3 + S_5 - S_6 + S_9)^2\sigma^2_{\theta_1}$

Method 2: $(-S_4 + S_7 + S_8 + S_{10})^2\sigma^2_{\theta_2}$

Rule (7) (Random Error in analytical)

Method 1: $\{[(S_1 + S_2 + S_5 - S_6)^2 \div 8]$

$+ [(-S_3 + S_9)^2 \div 10]\}\sigma^2_{\omega_1}$

Method 2: $[(-S_4 + S_7 + S_8 + S_{10})^2 \div 20]\sigma^2_{\omega_2}$

Error Propagation for Isotopic Weights

Thus far, attention has been restricted to propagating errors for **element** weights. For **isotopic** weights, the above seven rules still apply except that the "element" weights are replaced by "isotopic" weights. **In addition,** five more rules must be applied.

Before giving these additional rules, it is pointed out that, unlike common element factors, common isotopic factors may logically be based on sampling from different materials. For example, samples may be drawn from UF_6 cylinders and from cans of the product UO_2 powder with the average isotopic factor then applied to both types of material. Further, different factors, (e.g., corresponding to different enrichment levels) may be related through the systematic error structure by virtue of having been sampled from the same type of material. These possibilities must be accounted for when propagating the errors.

Some additional error notation is required. Initially ignoring the subscripts, let

λ = systematic error component due to sampling for isotopic.
μ = random error component due to sampling for isotopic.
γ = long term systematic error component due to isotopic analysis.
α = short term systematic error component due to isotopic analysis.
ν = random error component due to isotopic analysis.

Five additional rules are now required to include the contributions of uncertainties arising from estimating the isotopic factors. These are given below as rules (8) - (12).

Additional Rules for Propagating Errors for Isotopic Weights

(8) $\sigma^2_{\lambda_j}$ is the systematic variance due to sampling for isotopic from material type j. To find its coefficient, find the sum of isotopic weights for each isotopic factor based partially or wholly on sampling from this material type. Multiply each such sum by the ratio of the number of samples drawn from this material type to the total number of samples on which the factor

in question is based. Sum the resulting terms over all appropriate factors, and square this sum.

(9) $\sigma^2_{\mu_j}$ is the random variance due to sampling for isotopic from material type j. To find its coefficient, divide each ratio in rule (8) by the total number of samples on which the corresponding factor is based and multiply this quotient by the squared sum of isotopic weights based on the factor in question. Then, sum these terms over all appropriate factors.

(10) $\sigma^2_{\alpha_j}$ is the short-term systematic variance due to isotopic analysis for analytical method j. To find its coefficient, find the sum of isotopic weights for each isotopic factor based on this analytical method. Multiply each such sum by the ratio of the number of analyses performed under a given set of analytical conditions to the total number of analyses performed for that factor. Sum these terms, over all appropriate factors, and square the resulting sum. Then, sum these squares over all sets of analytical conditions.

(11) $\sigma^2_{\gamma_j}$ is the long-term systematic variance due to isotopic analysis for analytical method j. To find the coefficient, sum the isotopic weights for all items with isotopic factors based on this analytical method, and square the sum.

(12) $\sigma^2_{\nu_j}$ is the random variance due to isotopic analysis for analytical method j. To find its coefficient, sum the weights over all items that have a common isotopic factor determined by this method, square the sum, and divide by the number of analyses in which this factor is based. Then, sum these terms over all groups of items whose factors are based on this method.

By applying these rules along with the 7 rules previously given with "element" weights changed to "isotopic" weights, the variance for the algebraic sum of isotopic weights for any group of items can be found.

ARGONNE SAFEGUARDS TRAINING — John L. Jaech (c.) of Jersey Nuclear, Richland, Wash., recently taught a course in advanced statistical method in material control at Argonne (Ill.) National Laboratory. Taking part (l. to r.): Albert D. Parent, Westinghouse Nuclear Fuel Division; David A. Lewis, Nuclear Materials and Equipment Corp.; Robert A. Harris, AEC; Jaech; Byron Disselhorst, Gulf Energy & Environmental Systems; Robert J. Slough, Goodyear Atomic Corp.; and Dr. Manuel A. Kanter, Argonne. See related news item in news section.