20TH ANNIVERSARY

1958-1978

CONTENTS

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EDITORIAL

A New Way of Thinking

By W.A. Higinbotham
Brookhaven National Laboratory
Upton, Long Island, N.Y.

At the request of the Carter Administration, most of the world is engaged in the International Nuclear Fuel Cycle Evaluation study, a two year effort to find technical and political arrangements for nuclear power to fulfill society's energy needs while offering more security from nuclear weapons proliferation than the present program, which could lead to widespread use of plutonium in many dispersed facilities. The INFCE study is divided into eight major topics, assigned to eight working groups.

1. Fuel and heavy water availability
2. Enrichment availability
3. Assurances of long-term supply of technology
4. Reprocessing, plutonium handling, recycle
5. Fast breeders
6. Spent fuel management
7. Waste management and disposal
8. Advanced fuel cycle and reactor concepts.

The United States is especially interested in the last of these (The U.S. is chairman of this group). The alternative fuel cycle studies initiated under President Ford in 1976 have been extended and expanded under President Carter. DOE and its contractors are assessing the technical feasibility, resource utilization, and economics of some 30 odd alternative fuel cycles, employing every type of reactor that was ever invented, in combination with the supporting facilities, dispersed or enclosed in multinational nuclear centers to better protect the more tempting materials from national diversion or seizure.

Some of these alternatives should be eliminated on technical or economic grounds. A few, such as fusion-fission breeders should be eliminated since they would be likely to produce even more pure fissile material than the LMFBR fuel cycle. But the nub of the problem is to assess the safeguards-proliferation implications of those fuel cycles which appear to be feasible options.

Those of us who may be asked to help in designing safeguards for selected fuel cycles will have to develop a new way of thinking. Up to now, we have been thinking primarily in rather narrow terms about material control, accounting, and physical protection to prevent theft, diversion, or sabotage by domestic adversaries. The equipment and techniques have been developed for application in nuclear facilities by the facility management. Little thought has been given as to how NRC or DOE is going to inspect these systems, and even less to the problems faced by the IAEA.

(Continued on Page 35)

Dr. Higinbotham

On Information and Mis-Information

By Roy G. Cardwell, Chairman
Institute of Nuclear Materials Management, Inc.

Since our editor has threatened each of us with extinction if we regular Journal contributors don't meet the new policy deadlines (which we set for him incidentally), I am putting down my thoughts for this issue as I ride with the Delta folks out to San Francisco.

The occasion of this particular trip to the West Coast is to follow up on an invitation to give a paper at their winter meeting on recent goings on of the Institute in standards and education work.

The material for the first topic came after several phone calls—to and a lot of help from N-15 Chairman **John Jaech** who has guided me into a pretty good coverage of our current ANSI work; particularly respective to **Dennis Bishop's** NDA organization now cranking out several standards under INMM-9.

For the second topic, I also leaned on John concerning his statistics course which is approaching continuing seminar status by having enjoyed the longest run of our education courses so far. In addition, because of the new intense interest in physical security by DOE and NRC, the Institute has a proposal out to co-sponsor a continuing seminar in guard force organization and supervision. For this effort I was privileged to work with **Jack Denton,** Deputy Director, and **Howard Rosser** Chief of Physical Security, ORO Security Division. Our results will also be a part of the ANS paper.

I am pleased that INMM has continued to maintain a successful pro-tech education program since the first successful efforts of **Manny Kanter** several years ago. I am equally concerned that we are not accomplishing enough toward a public education program.

The need for this latter effort was brought forcefully to my attention last week when I was standing in the composing room of our local newspaper discussing the breeder reactor with one of the editors who was more than casually interested in it. A delightful young lady, putting copy together nearby, walked over to us and said "please let me ask you a question."

Cardwell

E.R. Johnson (left) of E.R. Johnson Associates, Washington, D.C., in a serious moment at the 1977 INMM annual meeting with Chairman Roy Cardwell of ORNL.

Well, of course, I was flattered by the attention of this young lady and immediately concentrated on her inquiry.

"Why," she said, "are you promoting nuclear reactors when all we have to do to solve our energy problems is to cut our energy consumption 25% and use solar?"

Who in the world (I mentally mumbled to myself) could have fascinated this super-chic into believing such a facade?

I then launched into my song and dance routine number 12 which explains (1) reducing energy consumption by 25% would trigger a substantial rise in unemployment and (2) solar energy is not only 20-25 years away as a significant contributor to our total energy needs, but is also so expensive in capital installation at this point in time as to be almost impractical. I also reminded her that in the center of East Tennessee (where we were standing) with a rainfall average of 50-55 inches per year that it was a bit impractical as a single, dependable source.

I think I was convincing, at least she was courteous in a rather affirmative response to my argument. But the event made a strong point to me. Serious misinformation on energy is still being craftly dispersed to the public, and we need to bend our serious efforts, with others, in a good, continuing public information program.

Regular and Special Feature Articles

Favorable Reaction To 1977 Meeting

By G. Robert Keepin
INMM Vice Chairman
Los Alamos (N.M.) Scientific Laboratory

The follow-up questionnaire that was sent to all attendees of the Institute's 18th Annual meeting in Washington, D.C. has resulted in extremely valuable and informative input for planning future INMM Annual meetings. Many of the individual responses were received too late to be collected, summarized and reported in the previous (Summer, 1977) issue of the Journal, so we are summarizing all responses received to date (totaling approximately 100) in this Winter issue.

Reflecting the broad spectrum of interests, disciplines, professional affiliations and activities represented by the INMM membership, reactions to the Washington meeting ranged from accolades and enthusiastic approval to constructive criticism and in a few cases even spirited disapproval. The overall consensus, however, was clearly a very positive and favorable reaction to the Washington meeting in nearly all respects. The general response in each of the individual categories listed in the follow-up questionnaire can be summarized briefly as follows:

Opening Plenary Session The great majority of respondents (about 80%) felt that the opening session in Washington achieved about the right mix of "political" versus "technical" speakers. Many comments were very complimentary of the session program and speakers. Among the nearly 20% negative responses were individual comments such as: too many political talks; some papers were of poor quality; too few political talks; some talks were too long; need more nuclear critics; need more variety year to year; need more stimulating discussion, perhaps thru stimulated critiquing by designated experts.

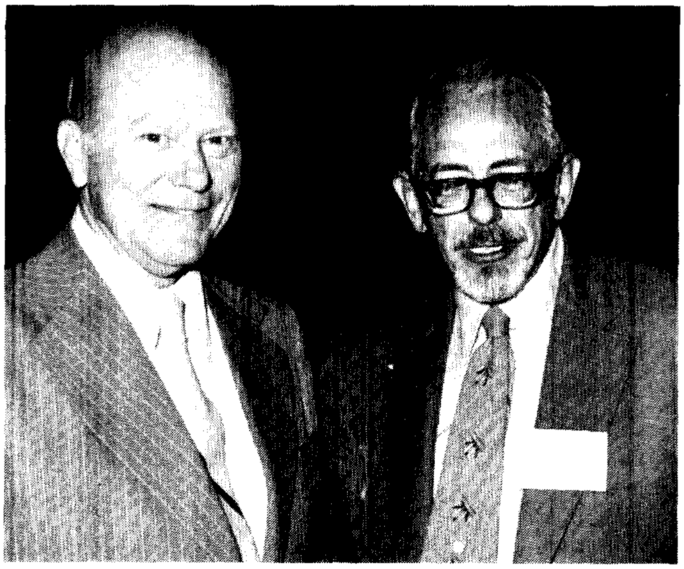
Panel Discussion General positive reaction by over 75% of respondents. Some individual criticisms and suggestions were: opening statements were too long (and indeed they were!—it won't happen again!); reporters should only ask questions—not editorialize; select more specific topics; allow time for more questions from floor; bring in more outsiders and critics. Suggested topics for future panel discussions included: Public Understanding/Acceptance of Safeguards; MUF (BPID); International Nuclear Fuel Cycle Evaluation Program (INFCEP); Reprocessing, and Breeder Reactors.

G. Robert Keepin

Frank Graham (left) of the Atomic Industrial Forum makes a point regarding nuclear safeguards to Roy Nilson of Exxon Nuclear during the 1977 INMM annual meeting at Stouffer's in Arlington, Va.

Technical Seminars Most attendees apparently felt the coverage of subject matter in the technical sessions was "about right." Several respondents to the questionnaire, however, indicated their desire to see more papers on nondestructive assay technology and NDA applications. Many urged more emphasis generally on practical applications, in-plant experience with new materials management methods, etc., while a few called for less emphasis on "models" and "paper studies." Some respondents expressed a desire for more papers on measurement and sampling techniques other than NDA, and still others want greater coverage of European, Japanese and IAEA programs and new technology developments.

Regarding the admittedly vexing problem of tricurrent sessions, there was a clear 2:1 consensus against them, but at the same time many seemed resigned to the reality that with the growing attendance and participation in INMM Annual Meetings, we have few alter-



INMM SOCIAL ADJUSTMENT—Charles Moeller (left) and Charles Bean of the Argonne (Ill.) Safeguards Study Group enjoying the "Tennessee Manner" of social adjustment at the Chairman's Reception at the 1977 INMM annual meeting at Stouffer's in Arlington, Va.

natives to tricurrent sessions. Some individual suggestions in regard to this perennial problem were: try to combine similar or closely related papers, if possible, to reduce numbers while preserving overall technical coverage; run an extra day or hold an evening session to avoid tricurrent sessions; try the "rapporteur" method used by some other societies to reduce presentation time and allow more time for discussion; if tricurrent sessions are unavoidable, do best possible job of planning session agendas to minimize "overlapping" of technical content.

Arrangements and Services Questionnaire respondents seemed generally quite pleased with the arrangements and services at the 1977 Annual meeting. Judging from the number of comments, two weak areas appeared to be 1) sightseeing information and 2) exhibits. Several felt the luncheon was too long, that the luncheon program should in general be limited to a single featured speaker and the presentation of only one outstanding award (e.g., the Institute's Annual Industry Award)—all other awards, citations, individual recognitions, etc., to be made at the Annual Business Meeting.

Mrs. Roy (Barbara) Cardwell (left) enjoys the morning hospitality session on the Roof Terrace with Mrs. Herman (Joanne) Miller. Mrs. James W. (Janet) Lee concentrates on her continental breakfast.

General Comments on the Washington meeting were by-and-large very favorable (about 5:1) as regards meeting format, location, scheduling, arrangements and overall impact. Some specific criticisms and suggestions for future improvement were: some technical sessions could be better planned, e.g., sequence and grouping of papers into a session could be improved; should have more publicity and interaction with community, local news media, etc.; need more stimulating questions and discussions—e.g., by assigning an appropriate individual as discussion stimulator for each session; pursue the concept of training seminars held in conjunction with INMM Annual Meeting (n.b. this specific concept has already been developed by Dick Chanda and is discussed elsewhere in this issue of the Journal); the Institute should devote greater attention to "real problems" such as improvement and clarification of Federal Regulations and DOE Manual Chapters that govern day-to-day safeguards and materials management practices; INMM should strive to put safeguards in the public docket in the environmental impact process, etc.

Ladies Program—Brunch, fun, food and kids.

In summary, both the magnitude and the quality of the response to the Washington meeting follow-up questionnaire was indeed most heartening and greatly appreciated; it was also, we believe, clearly indicative of a healthy and vital Institute with a concerned and involved membership. Many respondents whole-heartedly endorsed the basic idea of the questionnaire and the opportunity for free and candid expression ("pro" or "con") that it afforded to each individual attendee. As promised on the questionnaire, the INMM Program Committee is evaluating all responses and will make every effort to factor this vital input into the planning of future INMM Annual Meetings. In addition, building upon the invaluable experience and feedback gained from the Washington meeting questionnaire, we now intend to institute an "INMM Suggestion Box" at all future meetings. With your essential input, constructive criticism and support, we shall continually strive to improve the Institute's Annual Meetings and try to make them ever more responsive to the needs and wishes of the INMM membership.

INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT

Treasurer's Report for Fiscal Year 1977

July 1, 1976 Through June 30, 1977

Cash Balance July 1, 1976:		$ 3,124.37
Receipts:		
Dues	$ 9,529.00	
Journal Income		
Subscriptions	3,324.25	
Advertising	1,949.00	
Proceedings	1,300.00	
Page Charges	1,065.00	
Miscellaneous	668.01	
Miscellaneous Income	24.89	
Safeguards School	8,952.05	
Annual Meeting		
Registration	31,039.69	
Exhibitors	1,250.50	
Williamsburg Tour	524.75	
Ladies Luncheon Tickets	412.00	
Total Receipts:		$60,039.14
Expenditures:		
Journal Editor	$ 4,850.00	
Journal Editor—Travel	1,248.00	
Journal		
Printing	11,506.78	
Postage	2,519.94	
Clerical Assistance	1,216.83	
Miscellaneous	481.12	
Annual Meeting		
Meeting Expenses	3,541.67	
Miscellaneous	775.00	
Registration Refunds	1,110.00	
Reception	2,848.31	
Ladies Program	499.44	
Luncheon	3,450.54	
Speakers Breakfast	357.10	
General Miscellaneous	613.87	
Executive Committee	1,927.98	
Safeguards School	6,151.01	
Total Expenditures:		$43,097.59
Cash Balance June 30, 1977:		$20,065.92
Savings Account July 1, 1976:		15,081.00
Interest Income		1,027.25
Saving Account Balance June 30, 1977		$16,108.25
Net Gain or Loss:		
Total Receipts		$60,039.14
Interest Income		1,027.25
Total Income		$61,066.39
Total Expenditures		43,097.59
Net Gain		$17,968.90

SECRETARY'S CORNER

INMM Has Successful Year

By V.J. DeVito
Secretary of INMM
Goodyear Atomic Corp.

The fall meeting of the Executive Committee was held on October 20 and 21, 1977 in Orlando, Florida.

The financial statements presented by the Treasurer showed a net gain of $17,968 for fiscal year 1977 activity. The cash balance at the end of the year was $20,065, excluding $16,108 held in the savings account. The cash balance position improved primarily because of the registration of 461 at the 18th Annual Meeting in Washington, D.C.

In October, **Ed Owings** was appointed Treasurer to replace **Bob Curl** who resigned to take an appointment with IAEA in Vienna. **Syl Suda** was appointed Chairman of the Safeguards Committee to replace **Dennis Wilson** who was elected to the Executive Committee. **Duane Dunn** was appointed Registration Chairman to replace Ed Owings. Chairman for the Standing Committees and other appointments approved at the October meeting were as follows:

Program	**G.F. Molen**
Membership	**J.W. Lee**
Journal-Technical Editor	**W.A. Higinbotham**
Journal-Managing Editor	**T.A. Gerdis**
Safeguards	**S.C. Suda**
N-15	**J.L. Jaech**
N-15 Secretary	**R.A. Alto**
Education	**H.L. Toy**
Site Selection	**R.E. Lang**
Certification	**F. Forscher**
Awards	**T.B. Bowie**
Nominating	**A.R. Soucy**
Registration	**D.A. Dunn**

The Certification Committee is very active again and a new program with proposed qualification is to be ready for approval by annual meeting time.

The annual meeting for 1978 has been set for the week of June 25, and will be held at Stouffer's in Cincinnati, OH. Since 1978 is the 20th anniversary of the formation of the INMM, the non-technical program will be highlighted by nostalgic events.

The 1979 annual meeting will be in New Mexico at the Hilton Hotel in Santa Fe or Albuquerque. The Site Selection Committee is reviewing sites in Florida for the 1980 meeting and San Francisco for the 1981 meeting.

On October 1, 1977 there were 550 members in the Institute of which 63 resided in countries other than the U.S. There are now 26 members in Japan, 11 in Vienna, 6 in England, 4 each in Canada and Italy, 2 each in Luxembourg and Germany, and 1 each in Brazil, France, and Netherlands.

FALL 1977 EXECUTIVE MEETING—Officers, members of the Executive Committee joined by standing and ad hoc committee chairmen met in Orlando, Florida, October 20-21, for the regular fall INMM Executive Meeting. Seated on the front row (from left): Ed Owings, new treasurer; Bob Keepin, vice chairman; Roy Cardwell, chairman; and Vince DeVito, secretary. Standing (from left): Tom Gerdis, Herman Miller, Bernie Gessiness, Bill DeMerschmann, Dennis Wilson, Fred Forscher, Gary Molen, John Ladesich and Syl Suda (Photo by James W. Lee).

Service Award To Ralph Jones

Ralph J. Jones, former Treasurer of the INMM who served on the Institute's Executive Committee during 1976-1977, is the recipient of the Meritorious Service Award of the U.S. NRC.

His citation presented on November 4 indicated he was recognized for "the extent and the quality of leadership, judgment, and wise counsel which Jones has brought to the NRC safeguards program.

It was stated in his citation,

"In the past several years, he has played a major role in the development of a number of important standards and rules which have been put in place as the regulatory basis of national safeguards policy for the commercial nuclear industry. His sound judgment and command of careful staff analysis have assured balance in this work among the diverse and sometimes competitive interests of national security, public health and safety, and other broad societal values. His objectivity in the face of intense national debate over safeguards has increased the value of his counsel to the Commission and its senior management."

"Jones is a capable and efficient supervisor and a frequent and successful arbiter of diverse staff views. He is a constant source of practical safeguards expertise and has contributed significantly to the form and substance of standards and regulations in both the material control and the physical security aspects of the technology."

Jones was born in Kansas, received his B.Sc. degree in Industrial Chemistry from Kansas State University in 1944 and his M.B.A. in Business Administration from Rutgers University in 1955.

He has more than 20 years' experience in the fields of material control and quality control. Ten of these years were with Merck & Company, Inc., a pharmaceutical manufacturer, where Mr. Jones served in various capacities in the Quality Control Department. He has served two hitches in the U.S. Navy, one 1945 to 1947 and the second 1952 to 1953.

His experience in the nuclear field dates from 1957 when he joined the U.S. A.E.C. headquarters staff in the Division of Nuclear Materials Management. He first served as Senior Chemist in the Chemistry and Physics Branch. In this capacity he was responsible for development of the technical procedures involved in nuclear material control and compiled and edited an analytical manual, "Selected Measurement Methods for Uranium and Plutonium in the Nuclear Fuel Cycle."

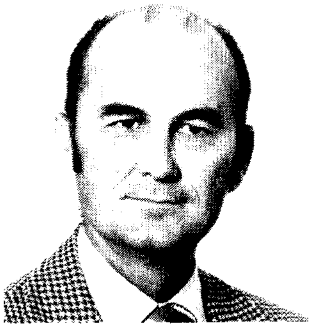
He next served the A.E.C. as Chief of the Survey and Appraisal Branch in which capacity he was responsible for development and maintenance of agency-wide policy and procedures for control of source and special nuclear materials. His next position with the A.E.C. was as Chief of the Technical Studies Branch in which he was responsible for technical research and development programs in support of the U.S. Safeguards Program, both domestic and international.

Jones joined Nuclear Fuel Services, Inc., as Corporate Manager, Nuclear Material Control, in February, 1969. He received the designation "Certified Nuclear Materials Manager" from the Institute in August, 1969.

He returned to government service in July of 1972 in the Regulatory Operations part of the A.E.C. In 1975, he was appointed as Chief of the Materials Protection Standards Branch in the Office of Standards Development of the new Nuclear Regulatory Commission.

Ralph is past president of a local PTA and an ex-scoutmaster. He lives in Damascus, Maryland, with his wife and one child Danny. The three other children are no longer at home. One is living in Florida working as an engineer for the Florida State Department of Transportation. One is a sophomore at Kansas State and the third is Assistant Chef and Garde-Manager at a resort hotel on St. Thomas, U.S. Virgin Islands.

Jones



ANSI INMM N-15 COMMITTEE REPORT

Coordination Necessary

By John L. Jaech, Chairman
Exxon Nuclear Co., Inc.
Richland, Washington

As many readers of this Journal are aware, the nuclear standards activity has received unfavorable publicity within recent years. Problems in coordination between writing groups have been identified and, more importantly, there have been instances were the NRC has failed to endorse published ANSI standards even though no indication had apparently been received that such action would be taken while the standards were being prepared.

The INMM standards organization, N15, is vitally interested in this issue. With our limited resources, we are forced to depend on others for coordination. It is important that ANSI provide this coordination in an effective manner so that N15 can develop standards that are in fact needed, and that will be endorsed by the NRC upon publication.

To improve coordination, the ANSI President appointed a special committee some time ago to audit ANSI's nuclear standards program. The August 26, 1977 issue of the **ANSI Reporter**, published biweekly by ANSI, reports on the findings of this special committee. This report, which sheds light on the workings of the NSMB and of ANSI, reads as follows:

"ANSI President **John W. Landis** has announced that the ANSI Board of Directors has examined the report of the special committee appointed to audit the Institute's nuclear standards program and has agreed to prompt implementation of the committee's main recommendation: that staff support for the Nuclear Standard Management Board be increased.

The committee was charged with conducting a thorough and objective analysis and recommending to the Board the action required to ensure that the nuclear standards program meets critical needs on a timely basis. Formation of the committee was authorized by the Board of Directors at its March 31 meeting after it received conflicting opinions concerning the program.

In performing its audit the committee met with ANSI's Nuclear Standards Management Board, the Nuclear Regulatory Commission, the Edison Electric Institute, and the staffs and voluntary leadership of the organizations responsible for the development of the majority of nuclear standards. It also received advice from ANSI's Nuclear Standards Policy Committee.

Jaech

The audit committee concluded "that the nuclear program is not in the disarray that recent publicity would imply." All parties interviewed, it stated, agreed that the recently reorganized Nuclear Standards Management Board should be able to improve the coordination of work by the various voluntary organizations involved in the program and thus play a strong leadership role in the production of nuclear standards. To do this, however, the NSMB will need additional staff assistance, the committee said. The committee also expressed its opinion that the NSMB, not the ANSI staff, should maintain liaison with the Nuclear Regulatory Commission.

The specific findings and recommendations of the committee are:

- ANSI's efforts should be directed to managing the nuclear standards program by coordinating cooperative efforts of standard writing groups, auditing their implementation of procedures and their capabilities to produce nuclear standards, and reconciling overlaps or gaps in standards activities. Management does not connote executive direction of standards writing groups or dictation of the technical content of standards.

- ANSI's Nuclear Standards Management Board, which is responsible for the coordination function in this field, is willing and capable of effectively managing the program. Its efforts, however, need supplementation. The special committee, while suggesting that the need for supplemental support should be determined by the NSMB itself, felt it was apparent that it requires additional staff assistance. Therefore funds should be provided to add one additional person to ANSI's professional nuclear staff, with necessary clerical support, and to permit short-term specific staff engagements that may be required. If the NSMB fulfills its potential, there will be no need for an ANSI staff professional to provide liaison with the Nuclear Regulatory Commission and other federal government agencies.

- While it was impossible in the time allotted to fairly assess the performance of the major organizations responsible for nuclear standards development, it is apparent that some have completed more standards under their sponsorship than others and that they vary widely as to supporting staff and physical facilities. The Nuclear

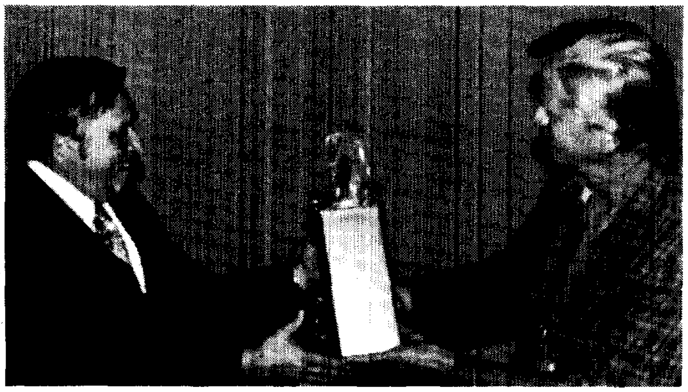
(Continued on Page 27)

Japan Chapter Elects Officers

1. DATE
August 9th, 1977 from 17:00 to 18:00 hour
2. PLACE
Conference Room, Nuclear Material Control Center, Tokyo, Japan.
3. ATTENDANTS
K. Ikawa, K. Uematsu, Y. Kawashima, R. Kiyose, H. Kurihara, M. Shibata, S. Suenaga, R. Hara, M. Hirata—(member)
H. Okashita, S. Koreki, K. Tsutsumi, H. Natsume, K. Horino, S. Miyasaka—(non-member, being proposed to be member)
4. CONTENTS OF MEETING
(1) Report of establishment of the Japan Chapter Mr. **Y. Kawashima,** temporary chairman, explained how the Japan Chapter of the INMM had come to be established. According to his explanation petition for establishment of the Japan Chapter was sent to the INMM on August 30th 1976 and was approved by the Executive Committee of the Institute on September 15th 1976.

Subsequently, draft Constitution and Bylaws of the Japan Chapter was sent to the INMM in May 1977 and was approved by the Executive Committee of the Institute in June 1977. At the Annual Meeting of the INMM which was held in Washington, D.C. from June 29th to July 1st 1977, establishment of the Japan Chapter was reported by the Chairman to the members of the INMM and the banner of the Japan Chapter was handed to Mr. Kawashima representing the Japan Chapter.

(2) Contents of Constitution and Bylaws of Japan Chapter was explained to the members by Dr. **R. Hara.**



EXPRESSION OF GOODWILL—At a recent INMM Executive Committee meeting in Orlando, Florida (October 19-21, 1977), Institute Chairman Roy Cardwell of ORNL and Vice Chairman Bob Keepin (right) of LASL proudly display a gift graciously sent by Dr. Yoshio Kawashima, Chairman of the Japan Chapter of the INMM, and Executive Director of Japan's Nuclear Material Control Center, Tokyo.

Officers, Members of Japan Chapter

(3) Officers of the Japan Chapter
As to election of officers it was agreed that temporary officers nominated by the temporary chairman would serve until June 30th 1978.
Election of the officers will be carried out according to Constitution and Bylaws by June 30th 1978 and the new members of the Executive Committee will start to work on July 1, 1978.
The officers of the Japan Chapter nominated by the temporary chairman and approved by the members are as follows;

Chairman	**Mr. Y. Kawashima**
Vice Chairman	**Mr. R. Kiyose**
Secretary	**Mr. M. Hirata**
Treasurer	**Mr. R. Hara**

As to the remaining four members of the Executive Committee, the chairman was authorized to nominate them at later date when more members joined the Chapter and was requested to report the results to the members of the Chapter.

(4) Office of the Japan Chapter
It was agreed that office of the Japan Chapter would be located for the time being at the Nuclear Material Control Center, Akasaka Park Bldg. 2-3-4 Akasaka Minato-ku Tokyo.

(5) Activities of the Chapter, suggested by the members
As to the future activities of the Chapter, it was suggested that efforts should be made to increase number of the members of the Japan Chapter. It was also proposed that personal contact between members of the Institute and those of the Chapter should be encouraged by holding the meetings at the time of the visits of INMM members to Japan.

Secretary, M. Hirata

Celebrate GAT 25th September 18

PIKETON, Ohio—Goodyear Atomic Corporation celebrated its 25th anniversary September 18 with an employee open house at the uranium enrichment plant here.

The plant, which became fully operational in 1956 after four years of building and training personnel, originally produced Uranium-235 for national defense purposes. Now the product goes largely into peaceful uses, primarily as nuclear fuel for electric power generation.

A $4.2 to $4.5 billion addition to the Piketon facility, announced in July by President Carter, will provide four new production units for uranium enrichment using the centrifuge process. Availability of the new centrifuge capacity, combined with improvements now being made at the three existing gaseous diffusion plants, will more than double U.S. enrichment capacity.

Guided bus tours for employees and their families through the sprawling complex which is operated by Goodyear Atomic for ERDA highlighted the anniversary celebration.

TECH PAPER

A technical paper, "Gaseous Tritium Recovery System: Effects of Design Requirements on Cost," is available from Engelhard Industries. It describes features of Deoxo® clean-up and recovery systems for processing radioactive tritium, tritiated hydrocarbons, and tritiated water vapor.

Written by Martin F. Collins and Peter L. Terry of Engelhard's air and gas systems department, Union, New Jersey, the paper was originally presented at a government-sponsored symposium on "Management of Low-Level Radioactive Waste" held at the Georgia Institute of Technology in Atlanta earlier this year.

For a copy of the paper contact Engelhard Industries, Systems Department, 2655 U.S. 22, Union, N.J. 07083.

NUCLEAR REACTORS BUILT

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 (48 pages, 8 x 10½, paperback) is available as TID-8200-R36, for $3.25 from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

Saalborn Directs Security Services

Nuclear Energy Services, Inc., has announced the appointment of Mr. **Otto E. Saalborn** to the position of Director, Nuclear Security Services. In this position, Mr. Saalborn will be responsible for the Company's operations in supplying security consulting services such as threat analyses, security plan and procedure review and preparation, hardware specification and selection, security training, expert witness testimony and audit/inspection services.

Mr. Saalborn holds a Bachelor of Electrical Engineering and a Master of Science in Industrial Management, both from the Polytechnic Institute of New York. He is currently active in the American Society for Industrial Security, including membership in the Public Utilities Subcommittee, the American Nuclear Society and the Institute for Nuclear Materials Management.

Prior to joining NES, Mr. Saalborn was employed by Burns International Security Services, Inc. as Chief Engineer and Manager of the Nuclear Division of Burns Management Consulting Services. He has also served in the capacities of Coordinator of Proprietary Systems Engineering, Senior Product Engineer and Advance Research Engineer.

Saalborn

Abandon ANSI Route, Develop Qualification Criteria

By Dr. Frederick Forscher, Chairman
Pittsburgh, Pennsylvania

Pursuant to a directive from the Executive Committee, the Certification Committee was reactivated last July. As currently constituted, the membership of the enlarged committee consists of: **Frederick Forscher,** Chairman, Energy Management Consultant; **Thomas Bowie,** Combustion Engineering; **Ken Duffy,** General Atomics; **Norman Hall,** General Electric-VNC; **Ralph Jones,** NRC-Standards; **Nicholas Roberts,** Univ. of California-Livermore; and **Joseph Wielang,** Allied Chemicals-Idaho.

At the July meeting it was decided to abandon the efforts to develop qualification standards for nuclear materials managers and safeguards personnel via the ANSI route. Instead, the committee will develop, before our next annual meeting, a set of "Qualification Criteria for Safeguards Professionals" that would meet the requirements of the worldwide nuclear community. It would be administered by a highly regarded certification board of, perhaps, seven members not all of which would need to be INMM members.

It is conceivable that, because of the present intense concern with non-proliferation, dangers of terrorism, and fuel cycle safeguards, the appropriate agencies may decide to license nuclear materials specialists with or without a professional certification program. Such a step, in my opinion, would be detrimental to the image of the INMM as a professional society.

The Certification Committee met October 5, at the San Francisco airport for a one-day meeting. It was decided to prepare concurrently three drafts:

1. Qualification Criteria for Nuclear Measurement Professionals,
2. Qualification Criteria for Material Control and Accounting Professionals,
3. Qualification Criteria for Security and Reactor Safeguards Professionals.

Appropriate subcommittees were established. Forscher will contact the ASIS (American Soceity for Industrial Security) which already has an ongoing program for Certified Protection Professionals.

The committee would also like to stimulate, through all channels, the availability of professional training courses, programs and curricula, so that qualified personnel could avail themselves of this training and education. As in all other professions, formal training and education is an important part of the prerequisite for professional practice and recognition.


Dr. Forscher

Fall Methods Course Huge Success

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

There continues to be a demand for **John Jaech's** "Statistical Methods for SNM Control" course as evidenced by last month's turnout at Battelle's Columbus Laboratories. Twenty attendees moved into Columbus for John's course which was presented the week of November 7. The twenty attendees represented essentially all segments of the fuel cycle, if in fact there is a fuel cycle today. International attendees at the course included Mr. **George Russinov** of IAEA and Mr. **Oichi Mizuno** of Japan's Power Reactor and Nuclear Fuel Development Corporation.

As an observer from the sidelines and discussions with the attendees, the course was a huge success. My personal thanks to John Jaech and **Lavella Adkins** of Battelle's staff for their many hours in preparations and arrangements for the course. The week was a very pleasant one for me as a number of friends stopped by. Old friends stopping by during the course included **Tom Bowie,** (Past INMM Chairman), **Lou Doher** of Atomics International (Rocky Flats), and Dr. **Frank O'Hara,** now on board at Battelle-Columbus.

Toy

Looking ahead, the Education Committee has plans for involvement in the following activities:

- Our proposed General Guard Force Supervisor Course is still on the "front burner." **Roy Cardwell** is spearheading this effort and indications at present point to early 1978 at which time site location for the course, definitive curriculum, and faculty will be resolved. Roy and I are both somewhat disappointed that this course has taken so long to get underway. As we reported in the previous Journal, we are negotiating with DOE on a joint effort in presenting the course. At this writing, we have also initiated discussions with NRC relative to their input and participation in the course.
- We are still attempting to pin down the concept of training seminars in conjunction with our annual meetings. We are hopeful that the upcoming Cincinnati meeting will include some form of training seminar. **Dick Chanda** will oversee this project.
- Our proposed Calorimeter Measurement Course plans are still alive. As reported previously, the course would be presented at Mound Laboratory under the direction of Dr. Frank O'Hara.
- Routine activities include continued responses to prospective students interested in career information in nuclear materials safeguards and control. This area presents a tremendous opportunity to the Institute in furthering our objectives.
- At the request of Dr. **Fred Forscher,** we will be looking into available college courses in NMM and Safeguards. Fred is involved in a project to determine what, if any colleges or universities are presently offering courses in our field. Fred will report in detail on this project in his report.

BEST WISHES FOR THE NEW YEAR!

INMM STATISTICS COURSE TO BE OFFERED THIS SPRING

Plans are underway to offer the INMM Course, "Selected Topics in Statistical Methods for SNM Control" this spring according to the Institute's education chairman, Mr. Harley L. Toy (standing right) of Battelle Columbus Laboratories. The course, taught by John L. Jaech (foreground, left hand on table), of Exxon Nuclear Co., Inc., Richland, Wash., was well attended the week of November 7-11 at Battelle in Columbus.

MEMBERSHIP COMMITTEE REPORT

139 New Members

By James W. Lee, Chairman
INMM Membership Committee

Several new efforts to place the advantages of membership in INMM before as many interested persons as possible have been started by your Membership Committee. Through the help of **Tom Bowie**, a nuclear industry distribution list containing about 300 names of individuals who are active in the nuclear field was obtained. After screening out about one-third, who presently are members of the Institute, an invitational letter, accompanied by a brochure and application form was mailed to the remaining 200 persons.

A similar mailing was made to another list of 50 prospects.

About 150 persons were expected to attend each of the NMSS Seminars conducted last November at the Idaho and Chicago Operations Offices of DOE. With the helpful assistance of **Ray Lang, Al Sether,** and **Harley Toy,** INMM information and membership applications were made available to the attendees.

Membership literature was included in the last mailing of the Journal to all members together with a request to each INMM member to interest at least one qualified friend or colleague toward joining the Institute.

Also under consideration by the Membership Committee is the preparation of a Member Referral Form which can be used to assist members who wish to provide names of prospects to the Committee.

While the Institute does not want new members solely for the purpose of swelling the roster, seeking instead, persons who sincerely wish to contribute to the nuclear field by their support and service to INMM; it is important that the availability and benefits of INMM membership be made known to as large a group as possible so that qualified applicants will come forward and make application to join the Institute.

Final count for the fiscal year just concluded revealed an amazing total of 139 new members—61 from government agencies, or contractors; 38 from industry; 33 foreign and seven from utilities.

And, the first quarter of the new fiscal year saw the addition of another 35 new members.

With the continued helpful support and assistance of its members, INMM memberships should forge ahead this year to an all time high.

New Members

The following 27 individuals have been accepted for INMM membership as of December 1, 1977. To each, the INMM Executive Committee extends its welcome and congratulations.

New members not mentioned in this issue will be listed in the Spring 1978 (Vol. VII, No. 1) issue to be sent out May 1, 1978.

Hiroshi Amano, Head, Division of Environmental Research, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken, Japan.

John J. Bastin, Manager, Safeguards Development, Westinghouse Nuclear Fuel Division, P.O. Box 355 (Penn Center 5-400), Pittsburgh, PA 15230.

John C. Chinault, Jr., Quality Assurance Engineer, Westinghouse, NFD, Drawer R, Columbia, SC 29250.

J. Stewart Corbett, Manager, Nuclear Safety, Chem-Nuclear Systems, Inc., P.O. Box 1866, Bellevue, WA 98009.

E. Arnold Hakkila, Staff Member, Los Alamos Scientific Laboratory, Box 1663, Group Q-4, MS-541, Los Alamos, NM 87545.

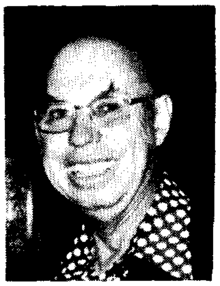
Masanori Hatchya, Assistant Division Manager, Mitsui Eng. and Shipbuilding, 6-4, Tsukiji 5, Chuo-Ku, Tokyo 104, Japan.

Koichi Horino, Nuclear Material Control Center, 2-3-4 Akasaka Minato-ku, Tokyo, Japan 107.

Ryukichi Imai, General Manager, Engineering, Japan Atomic Power Co., 1-6-1 Ohtemachi, Chiyoda-ku, Tokyo, Japan.

Kiyoshi Inoue, Deputy Manager, Uranium Enrichment Development Division, Tokai Works, Power Reactor and Nuclear Fuel Development Corp. (PNC), Tokai-Mura, Ibaraki-Ken, Japan 319-11.

Masayuki Iwanaga, Engineer in Reprocessing, Power Reactor and Nuclear Fuel Development Corp., Muramatsu, Tokai-mura, Naka-gum, Ibaraki-ken, Japan (Tokai Works).



Mr. Lee

Robert H. Karlsson, Chemistry Technology Manager, Rockwell International, P.O. Box 464, Golden, CO 80401.

Edward A. Kern, Staff Member, Los Alamos Scientific Laboratory, P.O. Box 1663, Q-4, MS-541, Los Alamos, NM 87545.

Harvey E. Lyon, Director, Safeguards and Security, Department of Energy, MS A2-1016, Century XXI, Washington, DC 20545.

Shojiro Matsuura, Principal Engineer, Japan Atomic Energy Research Institute, 319-11 Tokai-mura, Nakagun, Ibaraki-ken, Japan.

Eugene J. Miles, Treasurer of the Wyoming Mineral Corp. of Pittsburgh, Pa.

William C. Myre, Director, Sandia Laboratories, Org. 1700, P.O. Box 5800, Albuquerque, NM 87115.

Kentaro Nakajima, Manager, Reprocessing Plant, Construction Office, Power Reactor and Nuclear Fuel, Development Corporation, 1-9-13, Akasaka, Minato-ku, Tokyo.

Haruo Natsume, Deputy Head, Division of Chemistry, Japan Atomic Energy Research Institute, Shirakata, Tokai-mura, Naka-gun, Ibaraki-ken, Japan 319-11.

William P. Neal, Manager, Nuclear Material Accountability and Control, Babcock and Wilcox, Nuclear Materials Division, 601 Warren Avenue, Apollo, PA 15013.

David H. Nichols, Group Leader Records and Control EGand G, Idaho Falls, Idaho.

Hiroshi Okashita, Chief, Nuclear Chemistry Laboratory, Japan Atomic Energy Research Institute, Tokai Research Establishment, Tokai-mura, Ibaraki-ken 319-11.

James E. Schmid, Nuclear Engineer, Science Applications, Inc., 1200 Prospect St., La Jolla, CA 92037.

Dale M. Shultz, Manager, Compliance, United Nuclear Corporation, Fuel Recovery Operation, Wood River Junction, RI 02894.

Theodore S. Sherr, Chief, Technology Assessment Br., Div. of Safeguards, US NRC. Washington, D.C. 20555.

Loren E. Shuler, STDS Engineer, Rockwell International, Rocky Flats, P.O. Box 464, Golden, CO 80401.

Ken-ichi Tsutsumi, Deputy Manager, Planning Division, Nuclear Material Control Center, 2-3-4, Akasaka, Minato-ku, Tokyo, Japan 107.

Kumihiko Uematsu, Manager, Fuels and Materials, Power Reactor and Nuclear Fuel, Development Corp., 1-9-13, Akasaka, Minato-ku, Tokyo, Japan.

Address Changes

The following changes of address have been received as of December 1, 1977 by the INMM Publications Office at Kansas State University, Manhattan:

C. Buchler, International Atomic Energy Agency, P.O. Box 590, Vienna 1, Austria.

G.R. Cullington, 37 Rue de l'Europe, Bereldange, Luxembourg G. D.

Paul Desneiges, Commissariat a l'Energie Atomique, SCGMN, BP n^{o}6, 92660 Fontenay-aux-Roses (France).

Otto E. Saalborn, Director of Security Services, Nuclear Energy Services Division, Shelter Rock Road, Danbury CT 06810.

NBS Catalog

A complete listing of all scientific, technical, and consumer publications issued by the Commerce Department's National Bureau of Standards during 1976 is now in print and available for $8.25. This catalog documents the largest annual production of printed pages in the Bureau's history.

The catalog, entitled **Publications of the National Bureau of Standards,** cites some 2,200 papers, consisting of 60,727 pages, and tells how each paper can be obtained.

The 1976 catalog, edited by **B.L. Burris,** is the first to include citations of patents given to NBS inventors and grantee-contract reports prepared by NBS contractors. These additions now join the vast list of research papers, applied mathematics series, interagency reports, national standard reference data series, building science series, monographs, handbooks, special publications, federal information processing standards publications, consumer information series, voluntary product standards and technical notes that are in the catalog.

Each publication is cited by title, authors, volume taken from, abstract, and key word. Citations for papers published in the Bureau's formal program are organized by NBS publications series; NBS papers in non-NBS media are listed separately by number. In additon, a special section categorizes all 1976 papers by major primary subject area.

The 1976 catalog also contains information on previous NBS catalogs, and on the availability of NBS papers published in past years. Papers published prior to 1976 but not listed in previous catalogs are also included.

Copies of the catalog can be obtained by writing the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (orders must include the catalog's Stock Number-003-003-01743-4). Be sure to add 25% to the total cost of $8.25 if mailing outside the U.S.

BOOK REVIEW

"Nuclear Proliferation: Motivations, Capabilities, and Strategies of Control," by Ted Greenwood, Harold A. Feiveson, and Theodore B. Taylor; McGraw-Hill Book Company, New York (1977).

By Eugene V. Weinstock
Brookhaven National Laboratory

In this provocative book, sponsored by the Council of Foreign Relations as part of its 1980's Project, the political and technical aspects of the nuclear proliferation conundrum are explored in two essays, one by **Ted Greenwood** and the other by **Harold A. Feiveson** and **Theodore B. Taylor.** The 1980's Project, as we are informed in a rather long-winded and pretentious introduction, consists of a series of studies of global issues as they are likely to evolve in the 1980's and beyond. This same introduction warns at the very beginning that the proliferation issue cannot be isolated from other international issues and then goes on to tell how just this was done for the present study, Greenwood being asked to consider the motivations for proliferation and Feiveson and Taylor the capabilities. This split was most unfortunate, since it resulted in two pieces which, if they are not directly opposed, are at least nearly orthogonal.

Of the two, I think that Greenwood's is the more closely reasoned, although it is also the harder to read. The first four chapters analyze the motives for nations acquiring nuclear weapons and the ramifications of non-proliferation policy in all their mind-numbing complexity. It's almost enough to make you believe that diplomats and arms controllers are underpaid.

The first simplism he disposes of is the notion that proliferation is not only inevitable but also probably good, as witness the thirty-year stand-off between the U.S. and the U.S.S.R., who have probably been prevented from going to war with each other only by the threat of mutual nuclear annihilation. Nations and their leaders are sufficiently diverse, he warns, that "there is no assurance that future leaders of nuclear states will not regard nuclear weapons as simply equivalent to other military instruments. . . With nuclear weapons available to large numbers of states, the opportunities for escalation of conventional conflict to nuclear war . . . may increase. At least the statistical probability of nuclear accident, miscalculation, or unauthorized use rises as the number of nuclear states increases. . . In a proliferated world, nuclear warfare might become thinkable, even commonplace. . .

Weinstock

Proliferation, Greenwood believes, probably **is** inevitable, for "The march of proliferation moves in only one direction." But it can and must be slowed, so that international political systems and institutions may have time to adjust to it.

The discussion begins with an analysis of the motives for acquiring nuclear weapons: insecurity, the desire for prestige and leadership, increased influence in the council of nations, etc. There are no surprises here for those who have read even a minimum in this field. It is with the presentation of the counterarguments and the measures for preventing proliferation that the reasoning becomes dense, complex, and full of "on the one hand" and "on the other hand." For example, from a discussion of the role of security alliances and guarantees in preventing proliferation: "The international involvement of the United States might decline over the next ten years or . . . it might increase . . . This may be good or bad. . ." This constant qualification makes the reader want to throw up his hands in exasperation with an analysis that finds an equal counterargument for every argument. But that's the nature of the beast, and the message that comes through is that there is no single general principle applicable to every case, that the world is far too complex to yield to easy, universal abstractions. For example, do you think that the way to prevent proliferation is to increase security guarantees to other countries? That would lead to dividing up of the world among the three superpowers and a frozen international system, not to mention increasing the potential for superpower confrontation. Or, do you favor reducing the transfer of conventional weapons? A curtailment might spur a threatened nation into developing nuclear weapons, while an increase in such transfers might increase the ability of the nation to deliver nuclear weapons if they ever do acquire them. What about unilateral or bilateral arms-control declarations? Greenwood is less sanguine than others about the effects of these on proliferation; although the nuclear powers may **reduce** their arsenals of weapons they are unlikely, in the foreseeable future, to eliminate them altogether.

He also doesn't have much faith in the effectiveness of political or economic sanctions. They require wide cooperation and their history is not an encouraging one. The most important objection to them, however, is that joining the nuclear club is an irreversible action with physical and psychological effects that no sanctions can erase. Harsh and prolonged punishment of an entire population for the acts of a governmental elite may boomerang, as the world learned to its sorrow with Versailles.

Every once in a while in these first chapters a point comes through with startling clarity. For example, concerning the importance of the behavioral norm set by the Non-Proliferation Treaty and related treaties, ". . . a country's acceptance of the NPT and safeguards restraints should be regarded as what it almost always is: a significant national undertaking, not easily revoked." One wonders at the extent to which this view is shared by the present Administration. Again, in a discussion of political disincentives to proliferation: "Any diffusion of nuclear weapons tends to dilute the advantage of those who already possess them." Perhaps this explains the apparent indifference towards our non-proliferation concerns on the part of certain nations, who may well regard them as among the more monumental hypocrisies of history.

The best chapters are the last three, dealing with the management of the international nuclear industry, the terrorist threat, and those measures Greenwood regards as most likely to slow the spread of nuclear weapons, respectively. Here the qualifications disappear (mostly) and the arguments come through loud and clear—and persuasively. Technological denial is discarded (except in certain high-risk cases) as costly and ineffective, especially in the long run. Furthermore, it would exacerbate the North-South confrontation. Much better is the regulated transfer of technology, either under NPT or bilaterally arrived-at, IAEA-administered safeguards. The latter, he admits, is not foolproof—nor, for that matter, is any other system—but it does provide a high enough risk of detection as to make diversion unlikely and, perhaps more important, embodies "in institutional form the international norm of non-proliferation."

The threat of nuclear terrorism, enormously and inexplicably inflated in many discussions (as in Feiveson-Taylor's), is cut down to size here. "All states have an interest in maintaining a taboo against non-state possession of nuclear weapons and in punishing and suppressing its violations," Greenwood points out. Furthermore, the very terrorist groups most capable of acquiring nuclear material and making it into a weapon—namely, those with national aspirations—are the least likely to do so, since nuclear mass murder or the threat thereof would antagonize the very population whose sympathy is vital to the success of their movement.

In the last chapter Greenwood lists those measures he regards as being generally the most useful in slowing proliferation. They include maintaining, strengthening, or extending security guarantees, raising institutional and political barriers against the use of civilian nuclear materials to make weapons, rather than technical or economic barriers against access to them altogether, and discouraging the spread of sensitive, wholly national processing facilities. There are a total of ten such measures, none guaranteed by itself to prevent proliferation but all, taken together and applied judiciously after analysis of each case, calculated to check its rate.

The Feiveson-Taylor approach could not be more different. Their concern is mainly with two dangers: "latent" proliferation and nuclear terrorism. By the former is meant the gradual drift of a nation towards a nuclear weapons capability through the growth of a civilian nuclear industry that provides access to weapons-grade material in readily usable form, even though a clear, explicit decision to seek a weapons capability has never been made. The possession of certain sensitive processing facilities also blurs the distinction between the civilian and the military uses of nuclear power. As a result, if an overt move to take over the fissile material for military purposes is ever made, the time for the international community to react and bring a countervailing pressure to bear is drastically shortened.

Although they recognize the differences in the **nature** of national proliferation and nuclear terrorism, Feiveson and Taylor tend to treat them as though they were of equal importance (for example, when they are mentioned together, nuclear terrorism or criminality is often placed first). This, is my view, is both unfortunate and unwarranted. It would seem obvious that both the **probability** of national proliferation (there have already been five instances in the past thirty years) and its potential **consequences** are far greater.

The authors are also skeptical about the ability of the 50-some-odd nations who will have nuclear facilities of one kind or another during the 1980's to impose an effective international system against either proliferation or terrorism, if the world proceeds in the direction of a plutonium economy. Any such system, they feel, should obey five cardinal principles. These call for effective physical protection of all weapons-grade material at fixed sites or in transit, under international inspection; national control over the physical protection of national facilities; all civilian weapons-grade materials to be kept within well-defined physical boundaries and transfers across these boundaries to be promptly detected by international safeguards; civilian nuclear activities to be kept as distinct as possible from military ones; and all safeguards measures and restrictions to be applied equitably to all countries.

Three different possible "nuclear futures" are then examined in the light of these principles: a once-through fuel cycle, a plutonium economy, involving recycle and the breeder, and a denatured U^{233}-thorium fuel cycle. The once-through cycle, of course, is able (with certain minor restrictions) to obey all five principles, but is probably not a viable alternative because of the depletion of uranium reserves. The plutonium economy fails on virtually all counts. The U^{233}-thorium or "denatured" fuel cycle, in which enough U^{238} is mixed with the U^{233} to render it unusable for explosive weapons without further enrichment, comes through with flying colors.

Well, not quite. Because the denatured fuel cycle produces some plutonium as well as U^{233}, and because of the inability of converters to supply all the U^{233} needed, it would probably be necessary to set up international centers for the processing of the spent converter fuel to remove the plutonium and for the operation of plutonium-U^{233} breeder reactors to supply U^{233} for make-up fuel. In these centers, of course, separated plutonium and U^{233} **would** appear, but international operation and control would safeguard them against misappropriation. In addition, only denatured fuel elements, which are unusable for explosive weapons, would be sent out to the national facilities (reactors).

The main thing not clear about this proposal is why the authors expect the 50-some-odd nations referred to earlier to agree to this radical upheaval in their nuclear industry, involving the introduction of an entirely new and untried fuel cycle, when they have already been judged incapable of agreeing on the relatively minor adjustments required to protect the present, known fuel cycle. It appears to me that the Feiveson-Taylor ap-

(Continued on Page 27)

GUEST EDITORIAL

Where is the Leadership?

By Dennis W. Wilson

A number of years ago when I was a young engineer working on a variety of problems in the fledging nuclear industry, I soon learned an important lesson: There is rarely a single solution to a problem of any magnitude. Complex problems usually require approaches which lead to a variety of possible solutions. It also became apparent that implementing a solution to a complex problem really has two main steps. The first is to determine what steps present feasible solutions, and the second is determine which of the feasible solutions is the most practical. The fun part of any problem is to come up with a feasible solution. Oftentimes the hard part is to choose between optional solutions, none of which may be optimal. The former requires competent technicians, while the latter requires competent leadership.

As an inexperienced problem solver I was disappointed when "my" solution was not utilized in favor of another solution. I sometimes questioned the wisdom of the decision of my more mature leaders. However, I soon learned the wisdom in having someone with experience and good judgment charged with the responsibility to choose between acceptable alternatives. Limitations of resources often make impractical the "bringing along" of multiple possible solutions. I also learned the importance of subordinating personal desires in favor of support of acceptable alternate solutions. Progress comes slowly to fragmented effort.

In my view, the nuclear dilemma has added an interesting third dimension to the classic problem and solution drama: The difficulty in defining the problem. There appears to be an abundance of proposed solutions for the nuclear problem, and oftentimes the validity of these proposed solutions is argued before an understanding of the problem is obtained. What is desperately needed is the inspired and qualified leadership who understands the problem and then makes decisions which chart a course for resolution. Such leadership must then have support of the problem solvers to move the work in the chosen direction.

Dennis W. Wilson with his wife, Joanne . . . visiting with Mrs. Roy G. (Barbara) Cardwell (right) during the 1977 annual meeting of INMM at Stouffer's in Arlington, Virginia.

Safeguards work clearly fits into this flexible mold of problem solving. The issues are complex; the problem is difficult to define; the possible paths to solution are varied. Nonetheless, I am convinced that sufficient resources exist today to successfully and expeditiously move towards a solution down any number of possible paths. The sobering and haunting question remains: On whom falls the responsibility of making the necessary decisions? There are many pseudo leaders who profess a desire to chart the direction of energy development, and with it nuclear energy and its safeguards elements. However, none seems to have the capacity to convince others to the point of compromise support. Surely, somewhere in this great country must exist those who can make such competent decisions, who can rally the immense resources to the common cause, and who follow through to an acceptable solution.

Where is that leadership?

On Safeguards Technology
October 2-6, 1978

INTERNATIONAL SAFEGUARDS TECHNOLOGY—1978. An International Symposium on Nuclear Materials Safeguards, Vienna, October 2-6, 1978.

INMM members will recall previous international symposia related to nuclear material control and safeguards; on Nuclear Materials Management in 1965, on Progress in Safeguards Techniques in 1970 (held in Karlsruhe, FRG), and on Safeguarding Nuclear Materials in 1975. Various factors, including the costs of international travel, usually limit U.S. participation, but it is hoped that a good INMM representation can be achieved, both in terms of papers presented and in terms of general attendance.

In December 1974, in introducing the October 1975 safeguards symposium, the statement was made that, ". . . the period from 1970 to 1975 has been one of intense technical and political development. Politically the world now places an emphasis on the safeguarding of nuclear materials which is far in excess of the 1970 level." If this description was valid in 1975, there are few adjectives left to describe the current situation. Mathematically, interest in safeguards might be described in terms of an exponential function. More colloquilly, one might say that interest has mushroomed. Certainly it has not declined.

At the same time, the 2½ years since the previous invitation was prepared has been one of increasing concern. No nation has announced its intent to acquire nuclear weapons, but the danger of nuclear proliferation is perceived by some as being both real and greater than ever before. International safeguards also are of concern, both in terms of the effectiveness of current procedures and in terms of the potential effectiveness of the materials accountancy model.

The title for the symposium, "INTERNATIONAL SAFEGUARDS TECHNOLOGY—1978," was not chosen carelessly. By October 1978 the world will be well into the two year International Fuel Cycle Evaluation (INFCE). Although not specifically a part of INFCE, the symposium is expected to contribute to the overall evaluation effort by providing an opportunity for the world to take stock of where we stand and where we are headed in the field of international safeguards.

The list of topics on which papers are invited likewise was not prepared carelessly. Spent fuel storage and alternative fuel cycles, topics whose fortunes currently are in the ascendancy, are specifically included throughout the list, and it is hoped that those working in these fields will be able to make valuable presentations. At the same time reprocessing, fast breeder reactors, and mixed-oxide fuel fabrication, topics whose fortunes currently are at a low ebb, are also specifically included. It is by no means clear that the limit of "safeguardability" for plutonium has been reached, and it is hoped that the symposium can provide a more rational discussion of where the limit truly is and how near we are to it than is sometimes presented in the popular press.

The attention of INMM members is specifically drawn to topic C, "Design Features for Improved Safeguards." In defending the inclusion of this topic, my comment was, "It is a topic that was overdue ten years ago." It is a topic which is still overdue. As a group the members of INMM probably have more to contribute to this topic than to any other single topic on the list; it is my hope that the contribution will be made.

Although I would be happy to enter into an informal correspondence with anyone concerning the symposium, I cannot and will not make any commitments concerning the acceptance of papers unless they have been submitted through governmental channels. (Even then, papers must be reviewed by a selection committee.) In the U.S., the contact is John Kane at DOE, his address is given with the announcement. It is not expected that there will be invited papers. I also will take this opportunity to apologize in advance for any and all papers which cannot be accepted. Based on the 1975 symposium the rejection rate will be about 50%.

I look forward to seeing you in Vienna next October—**Jim Lovett.**

Safeguards Measurement Facility Is Moved

The New Brunswick Laboratory, the nation's nuclear materials safeguards measurement laboratory, has moved to Argonne, Ill.

From the former NBL site in New Brunswick, N.J., the staff of 62 physical scientists, electronic engineers, technicians and secretaries has moved into a newly built facility in Building 350 and the Argonne National Laboratory site. The $5.9 million, 80,000-square-foot facility houses sensitive equipment for chemistry, neutron activation, electrochemistry, nondestructive assay, isotope ratio mass spectrometry, optical emission and X-ray spectrometry, glove box laboratories for measuring transuranic elements, and instrument and machine shops.

NBL, which is supported by the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC), specializes in the chemical analysis of materials essential to the nation's nuclear energy programs. The laboratory analyzes nuclear materials, develops measurements and prepares standards for both the U.S. government and for private industry, and evaluates laboratories worldwide that measure nuclear materials. It also trains inspectors for the U.S. government and the International Atomic Energy Agency (IAEA).

During its 28-year history, NBL has achieved many nuclear milestones. The laboratory characterized the first uranium oxide material for uranium assay and supplied the National Bureau of Standards with the first uranium metal samples for use as Standard Reference Material. NBL also developed a fast, accurate method for measuring uranium. This method is used routinely in many domestic and foreign laboratories.

NBL is headed by Director **Carleton D. Bingham; Charles E. Pietri,** assistant director for operations; and **James M. Scarborough,** assistant director for development and evaluation.

The programs at NBL can be divided into the following categories:

1. Development and improvement of methods and analysis of nuclear materials and transfer of measurement technology to the nuclear community.
2. Highly reliable measurements of a broad variety of materials from nuclear facilities owned both by government and private industry.
3. Preparation, characterization and distribution of reference materials, supplementing the activities of the National Bureau of Standards (NBS).
4. Evaluation of the continuing performance of laboratories engaged in the measurement of nuclear materials.

During the NBL Dedication Open House (from left) Dr. Carleton D. Bingham, Dr. Clement J. Rodden, Dr. Sam McDowell and Sam Harvey Lyon review the preparation and certification of some of the reference materials available for purchase at NBL.

5. Technical assistance of DOE and other federal agencies on special analytical problems.
6. Training of personnel (government, the International Atomic Energy Agency (IAEA) and private industry) in specialized techniques.

In late 1976, NBL assumed the administration of the Safeguards Analytical Laboratory Evaluation (SALE) Program, which is expected to become the framework for a national nuclear materials measurement assurance program.

Dr. Bingham

Can No Longer Stand Mute

By Sylvester Suda, Chairman
INMM Safeguards Committee
Brookhaven National Laboratory

Sitting here trying to express what I believe is an appropriate (and hopefully a workable) goal for the safeguards committee, I have before me a number of newspaper clippings on the issue of nuclear energy. Here in the Northeast the opposition is organized, vocal, emotional, and enjoys a sympathetic press. One of the articles before me is in the form of a poem, first person singular, relating **Karen Silkwood's** anxiety during the last days of her life. We are reminded today, November 13, is the anniversary of her death. The historical footnote contains a calculated distortion of the facts and charges of a coverup in the investigation of her death.

The objective, set forth by **Dennis Wilson** in 1974 at the inception of the safeguards committee is "to provide a mechanism whereby the members of the Institute can examine specific safeguards issues or problems and offer professional opinions, comments and recommendations as appropriate. Specific topics normally are to confined to subjects which are

* pertinent to sound nuclear materials management

* appropriately within the scope of the INMM charter, and

* meaningful to a significant spectrum of Institute membership."

It was Dennis' vision that "an important aspect of the committee work philosophy is to provide input concepts and views of the professional Institute member involved and not necessarily those of the individual's employer. In this manner, the intent is to provide an avenue of study and response based on experience and knowledge, unencumbered by work-related policies if they are different from those of the individual involved. It is anticipated that this participation will provide an avenue for safeguards study and comment in a forum not previously available."

"Each institute member is encouraged—yes, even urged to understand the purpose of the safeguards committee and to be an active supporter. All comments and ideas received from Institute members will be greatly appreciated."

These are indeed lofty principals. Clearly, they remain a challenge to us all for the safeguards challenge remains and has intensified.

The nuclear issue is closing in on us. It has been politicized. We are told the number one problem facing the nation is energy. If that is the case, why are we delaying further development of nuclear energy? Because, we are told, breeder reactors burn and produce plutonium. Then I suggest, plutonium is the number one problem.

Where once the debate centered on reactor safety, the focus now is on the control of plutonium. It is referred to as plutonium waste in the once through fuel cycle. In the plutonium fuel cycle, the control and accounting of this resource material is safeguards. We, as a nation, are now in the middle of a value clarification process on the role plutonium will be assigned in the energy equation. Is it a waste or a resource?

I submit that we, as members of a professional organization dedicated to safeguards, can no longer stand mute on the sidelines, spectators in the great debate. I think some of the factors that may hold a member back from responding to media disinformation are the need for peer review and anonymity. The value of feedback, mutual support, and pooling of expertise derived from peer review is self evident. Anonymity to express opinions not necessarily sanctioned by the employer is another important aspect. I believe the safeguards committee can meet these need.

Consequently, I am organizing the safeguards committee into a forum through which members of the Institute may collectively speak out, in a timely manner, on problems involving nuclear materials safeguards and security. This community of practitioners, with its broad knowledge and expertise on the technological, economic and administrative realities of applying effective safeguards to the many nuclear fuel cycles, has much to offer in clarifying the issues in the nuclear debate. All too often in the past, the informed voice of the practitioner has either been silent or without a

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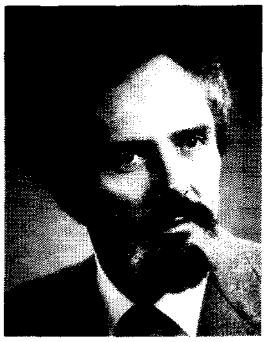
Suda



Security Plans for Sale At Public Law 91-190?

By Dr. James H. Opelka
Division of Environmental Impact Studies
Argonne National Laboratory

Pursuant to the National Environmental Policy Act of 1969 (P.L. 91-190), the public disclosure of the environmental consequence from safeguards failure scenarios is increasing. The continued ingenuity and immediate attention of the safeguards industry are required to sustain public disclosure if a liberal definition of consequence is imposed by the NRC and the federal courts.

The NEPA legislation calls, *inter alia,* for each agency to prepare an environmental impact statement (EIS) for every major federal action, discussing the environmental impact of the proposed action and alternatives to the proposed action. In the last several years, all fuel cycle facilities except reactors have included a chapter on safeguards in the EIS required at the construction permit stage. In Natural Resources Defense Council vs. Morton, the court noted that the EIS "would constitute the environmental source material available to enhance enlightenment of -and by- the public." (458 F.2d 827) The case of Environmental Defense Fund vs. Corps of Engineers states that the NEPA statement is a "full disclosure" document and must "at a minimum" alert the public to all known possible environmental consequence. (325 F. Supp. 749) The limits of this full disclosure are still being articulated in judicial decisions. There is precedent under NEPA for secret studies to be ordered public, in the case of Committee for Nuclear Responsibility vs. Schlesinger. (404 U.S. 917)

If the environmental consequence of an action under consideration only involves estimation of radiation effects due to a felonious nuclear explosion or due to a conventional explosive in a spent fuel storage pool, then the NEPA requirement is easily met. However, the determination of the likelihood of existence of an adversary and the probability of successful sabotage or theft by the adversary share podium rights with the radiation calculations if the consequence definition accepted by the courts follows the much broader ERDA-7 definition. Historically, EIS consequence analyses evolve and expand as research, on-line experience and public persuasion dictate and allow. In the evolution of the safety (safeguard's sister-topic) section of the EIS, the discussion of system failure consequences due to mechanical or operator error changed from a radiological end-effect summary to a probabilistic quantification of accident causes after the Rasmussen study (WASH-1400).

Opelka

The difficulties in preparing a Rasmussen-type safeguards risk/consequence analysis are apparent and abundant. The NRC safeguards objective implicitly recognizes the broad definition of consequence. In the absence of a Rasmussen-type analysis of safeguards, will the EIS in the near future be required to independently assess the adequacy of the NRC Division of Nuclear Materials Safety and Safeguards (NMSS) methodology and subsequent licensing decision that the applicant has achieved the safeguards objective?

The new physical security requirements proposed by NRC are being implemented through public rulemaking rather than through licensing conditions. As part of the rulemaking, NRC is issuing a NEPA document "Environmental Impact Appraisal of Amendments to 10 CFR 73" (EIA). The EIA states (Sec. II.B) that "requirements beyond the performance objectives . . . in the proposed (physical security) amendments would escalate nuclear physical protection programs beyond the scope or capability . . . of private licensee systems. . ." This statement begs the courts to liberally define "consequence" and determine the available system response to risk. NEPA, as implemented by NRC, requires a benefit/cost analysis of all environmental aspects of the project in question and alternatives which might mitigate environmental impacts. The EIA public disclosure of an asymptotic approach to perfection in an imperfect corporate world is unsupported in public documents.

"More is always better, but more is never enough," is a phrase currently heard among security professionals

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proach, far from being a purely technical solution, would require international political and economic agreements of such a scope as to dwarf those required to impose acceptable controls over the present fuel cycle and the impending plutonium economy.

In addition, the sanguine attitude towards the prospects of effective safeguarding of the international processing center for the denatured fuel cycle contrasts with the skeptical attitude towards safeguarding an essentially similar center for the uranium-plutonium cycle. If the only important difference is that in one case weapons-usable material (requiring chemical dissolution and separation, however) in the form of fabricated mixed-oxide fuel elements is shipped out to national reactors and in the other only denatured fuel is shipped, while in both types of centers weapons-grade material would be stored and processed, then the resulting gains of this proposed drastic shift in nuclear power plans would appear to be marginal indeed.

Nevertheless, these proposals are not easily brushed off. In fact, they have largely been the impetus for the present Administration's search for acceptable alternate fuel cycles. If the ideas of the authors, radical and impractical as they may seem to some, force us to pause and take stock of what we are about before we plunge irrevocably into a plutonium economy, they will have serve a useful purpose.—**E.V. Weinstock.**

Coordination Necessary

(Continued from Page 10)

Standards Management Board should ascertain the capabilities of these organizations and encourage them to undertaken standards in those areas in which they can be most effective.

- The Nuclear Standards Management Board is developing a priority system which, when implemented, will help to focus efforts on the development of those standards that are most needed. The NSMB should concentrate on the progress of standards worthy of its overview and to priorities for their development.

- Communication among affected groups is essential to the nuclear standards program. A thorough understanding of it and how standards fit into the complex interrelationships involved in licensing and regulation, design, manufacture, construction, and operation of nuclear facilities should prevent misunderstandings on what industry problems the program can and cannot solve. Therefore, a continuing dialog should be fostered with users, such as utilities and the Nuclear Regulatory Commission, and other sections by inviting various groups to attend Nuclear Standards Management Board meetings. Also the chairman of the NSMB and of its subcommittees and ANSI staff should attend meetings of standards writing organizations.

The ANSI special committee was comprised of individuals experienced in standards matters but not involved in present coordination efforts."

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to describe risk assessment. The difficulty of quantification and justification of the "more" is compounded if analyses performed under NEPA must be published absent sensitive information. In the absence of specific information, such as the security plan, generic "responsible opposing views" of public intervenors must be contemplated, according to the case of Committee for Nuclear Responsibility vs. Schlesinger. (463 F. 2nd at 787)

Very soon the NRC and the licensees may be called upon to give "public disclosure," at least *in camera,* of the substantial adequacy of safeguards. It is incumbent upon the safeguards industry to rapidly determine the safest and most accurate approach to the public disclosure of safeguards information to a concerned public.

The Use of Deadly Force By a Nuclear Facility Guard

By **Jerry J. Cadwell**
Technical Support Organization
Brookhaven National Laboratory

Recent rule making by the Nuclear Regulatory Commission[1] required nuclear facilities to "(IV) Require guards or other armed response personnel to interpose themselves between vital areas and any adversary attempting entry for purposes of industrial sabotage, and

(V) Instruct guards or other armed response personnel to prevent or delay an act of industrial sabotage by applying a sufficient degree of force to counter that degree of force directed at them including the use of deadly force when there is a reasonable belief it is necessary in self-defense or in the defense of others."

Nuclear facility operators, particularly utilities with commercial nuclear power plants must consider many areas of their particular state law while conforming to the NRC requirement stated above. However, one of the principal concerns is the use of deadly force.

Deadly force may be defined as (a) force which its user uses with the intent to cause death or serious bodily injury to another, or (b) force which he knows creates a substantial risk of death or serious bodily injury to another.

A summary of the general legal theories which may be used to justify the use of deadly force and prevent criminal liability by the guard and his employer are:

—Self-Defense
—Defense of Another
—Defense of Property
—Law Enforcement
- Effecting a lawful arrest
- Preventing an escape from custody
- Crime prevention and termination of crime

—Necessity

1) **Self-Defense:**

Briefly stated, a guard as a private citizen may defend himself against deadly force if deadly force is directed at the guard.

If the guard honestly and reasonably believes the use of deadly force is required to prevent his death or serious bodily injury he may do so even if he is mistaken as to the necessity of using deadly force.

If the guard injects himself into a gun battle to rescue other guards, he may in some states be forced to accept the same legal status of the guard being rescued and if the guard being rescued did not have a right to use deadly force then the rescuer would not have a right to use deadly force. Some states allow the rescuer to make a reasonable mistake as to the status of the guard being defended.

In additon, there is some disagreement between states regarding the necessity of retreating if it is safe to do so, before using deadly force in self-defense.

(2) **Defense of Another:**

Many states require that the defense of others be limited to defending those with a special relationship to the defended (such as husband, wife, parent, and child). This defense would not be available to a guard arguing that he was defending the whole city against nuclear threat—because he would not have the requisite relationship to those defended. However, this same argument might be available under another theory of justification called necessity.

(3) **Defense of Property:**

The use of deadly force is never reasonable in defense of property except where the unlawful interference with property is accompanied by threat of deadly force. If deadly force is threatened, then the issue is not defense of property but it is self-defense.

Under the general rule a guard could use deadly force against a trespasser who was committing a dangerous felony (dangerous felonies are limited to robbery, rape, mayhem, burglary, arson, and kidnapping).

(4) **Law Enforcement:**

A guard who is not a police officer is justified in using **reasonable** force to prevent or terminate what he reasonably believes to be the commission of a misdemeanor amounting to a breach of the peace or of a felony. It is not reasonable for a private person such as a guard to use **deadly** force to prevent the commission of a crime unless the crime is a dangerous felony.

Jerry J. Cadwell (J.D. in Law University of San Diego, B.S., Mechanical Engineering, University of Kansas) is a member of the Technical Support Organization for Nuclear Safeguards at Brookhaven National Laboratory on Long Island in New York State. He is currently involved in legal and engineering problems involved in safeguarding nuclear facilities. His previous engineering experience includes consulting work for the Legal and Legislative Analysis Group of Science Application, Inc. at La Jolla, 14 years engineering experience as design engineer and project engineer, at General Atomic in San Diego; preceded by 2 years reactor operations and engineering development at General Electric, Hanford.

[1] Part 73.55 (h) (3) (IV) and (V) of Title 10 Chapter 1 Code of Federal Regulations

A private guard acts at his peril in using deadly force for law enforcement purposes. There is no privilege to use deadly force, no allowance for a reasonable mistake (such as is allowed for peace officers), if it turns out that the person against whom the deadly force was used did not commit a dangerous felony.

(5) **Necessity:**

Except for certain self-defense arguments, most of the privileges to use deadly force have to be strained to be of much use to a private guard at a nuclear facility. The defense of "necessity" is a judicial and societal policy rule that the lesser of two evils is preferable if a choice must be made in an emergency. As a matter of public policy, the law would promote the higher values at the expense of the lesser values.

The "necessity" argument could be used to justify deadly force when it is used to save large numbers of people from the consequences of sabotage of reactors.

Necessity is an accepted defense in some areas of the law and should be accepted as a strong defense for the use of deadly force by a guard. However, a practical problem arises in the use of this argument because the guard would have to show the imminence of disaster to prove necessity.

In summary, the use of deadly force by a Nuclear Facility Guard could, if not excused by one of the previously stated defenses may subject the guard and perhaps his employer to prosecution for either murder, manslaughter, criminally negligent homicide or assault with a deadly weapon.

Cadwell

First of a Series

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

Editor's Note—As you may recall, the summer issue of the Journal contained a plea for contributed articles as well as a request that agencies and R&D laboratories regularly send in titles and abstracts of articles and reports of interest to others working in the field of safeguards. To get this activity underway, the Los Alamos safeguards groups have prepared the following listing of publications and reports issued recently by the LASL Safeguards Program.

It is hoped that this listing service will become a regular feature in the Journal. The editors will greatly appreciate your cooperation to ensure that this new Institute service is of maximum value to Journal readers. Please send appropriate listings to me for review and collation prior to publication (cf. deadline schedule on page 30 in this issue)—**W.A. Higinbotham.**

1) G.R. Keepin, "Nondestructive Assay Technology and Automated "Real-Time" Materials Control," IAEA-CN-42(VI), IAEA Int. Conf. Nucl. Power and Its Fuel Cycle, Salzburg, Austria, May 2-13, 1977.

   ABSTRACT: Significant advances in nondestructive assay techniques and instrumentation now enable rapid, accurate and direct in-plant measurement of nuclear material on a continuous or "real-time" basis as it progresses through a nuclear facility.

   A variety of passive and active assay instruments are required for the broad range of materials measurement problems encountered by safeguards inspectors and facility operators in various types of nuclear plants. Representative NDA techniques and instruments will be presented and reviewed.

2) T.D. Reilly and M.L. Evans, "Measurement Reliability for Nuclear Material Assay," Los Alamos Scientific Laboratory report LA-6574 (January 1977).

   ABSTRACT: This report discusses the reliability of nuclear material assay (including analytical chemistry, calorimetry, and nondestructive nuclear methods). The assay of feed, product, scrap, and waste is considered. Ranges of accuracy and precision are given.

3) J.P. Shipley, D.D. Cobb, R.J. Dietz, M.L. Evans, E.P. Schelonka, D.B. Smith, and R.B. Walton, "Coordinated Safeguards for Materials Management in a Mixed-Oxide Fuel Facility," Los Alamos Scientific Laboratory report LA-6536 (February 1977).

   ABSTRACT: A coordinated safeguards system is described for safeguarding strategic quantities of special nuclear materials in mixed-oxide recycle fuel fabrication facilities. The safeguards system is compatible with industrial process requirements and combines maximum effectiveness consistent with modest cost and minimal process interference. It is based on unit process accounting using a combination of conventional and state-of-the-art NDA measurement techniques. The effectiveness of the system against single and multiple thefts is evaluated using computer modeling and simulation techniques.

4) D.A. Close, "A Gamma-Ray Perimeter Security System.: Nucl. Technol. 32, 205 (1977).

   ABSTRACT: A perimeter security system is described that uses a beam of gamma rays and is extremely sensitive to interruptions of the beam. Such a system using a gamma ray of 500-1000 keV would result in a minimum number of false alarms per year. This study indicates that a 1-Ci source is adequate to protect an interval of 9300 cm. A gamma-ray source can easily be made bidirectional, which would allow 186 m of perimeter to be guarded.

   Results from Monte Carlo Calculations and data from a ^{137}Cs prototype are discussed.

5) D.A. Close, "A Gamma-Ray Perimeter Alarm System," J. Inst. Nucl. Mater. Manage. V,32 (Winter 1976-1977).

   ABSTRACT: A prototype perimeter alarm system using a beam of gamma rays from ^{137}Cs is extremely sensitive to interruptions of the beam. Monte Carlo calculations indicate that a 1-Ci source is adequate to protect an interval of 93m. A gamma-ray source can easily be made bidirectional, which would allow about 200 m of perimeter to be guarded. A system using a gamma ray having an energy in the range of 500-1000 keV would result in a minimum number of false alarms per year.

6) N. Ensslin, M.L. Evans, H.O. Menlove, J. Sapir, J.E. Swansen, "Thermal Neutron Coincidence Counting of Large Plutonium Samples," American Nuclear Society 1977 Winter Meeting November 27-December 2, 1977 in San Francisco, CA. NO ABSTRACT.

7) J.D. Brandenberger, "Associated Gamma-Ray Technique for Neutron Fluence Measurements," International Specialists Symposium on Neutron Standards and Applications, National Bureau of Standards, Gaithersburg, Maryland (1977). NO ABSTRACT

8) T. Canada, "Safeguards Technology Program, Los Alamos Scientific Laboratory, "The Atom" **14** (June 1977). NO ABSTRACT

9) T.R. Canada, D.G. Langner, J.L. Parker, J.W. Tape, "The Measurement of Special Nuclear Material Concentrations in Solution by Absorption Edge Densitometry," 21st Conference on Analytical Chemistry in Energy Technology, October 1977, Gatlinburg, TN.

ABSTRACT: Absorption-edge densitometry is reviewed and examples of data obtained at the L_{III}-edge of uranium are presented. Expressions are derived which allow the estimation of assay errors as a function of the transmission source intensity and the sample thickness for particular ranges of SNM concentration of matrix density. Specific examples are given and discussed.

10) T.R. Canada, R.C. Bearse, and J.W. Tape, "An Accurate Determination of the Plutonium K-Absorption Edge Energy Using Gamma-Ray Attenuation," Nucl. Instr. Methods **142,** 609-611 (1977).

ABSTRACT: The plutonium K-absorption edge energy is determined to be 121.795 ± 0.014 keV by measuring the plutonium mass attenuation coefficient at eleven gamma-ray energies, including that of the 121.783 keV ^{152}Eu gamma ray.

11) R.H. Augustson, N. Baron, T.L. Atwell, R.S. Marshall, J.L. Parker, J.W. Tape, E.R. Martin, and T.R. Canada, "In-Plant Nondestructive Assay Instrumentation in a Dynamic Nuclear Material Control System," presented at the 1976 International Conference of the ANS in Washington, D.C., November 1976. NO ABSTRACT

12) W. Kunz, "Portable Monitor for Special Nuclear Materials," Los Alamos Scientific Laboratory Mini-Review, LASL-77-18 (September 1977). NO ABSTRACT

13) E.A. Hakkila et al., "Coordinated Safeguards for Materials Management in a Fuel Reprocessing Plant,: Vols. I and II, Los Alamos Scientific Laboratory report LA-6881 Draft Report (August 1977).

ABSTRACT: This report describes a materials management system for safeguarding special nuclear materials in a fuel-reprocessing plant. Recently developed non-destructive-analysis techniques and process-monitoring devices are combined with conventional chemical analyses and process-control instrumentation for improved materials accounting data. Unit-process accounting based on dynamic materials balances permits localization of diversion in time and space and the application of advanced statistical methods supported by decision-analysis theory ensures optimum use of accounting information for detecting diversion. This coordinated safeguards system provides maximum effectiveness consistent with modest cost and minimum process interference. Modeling and simulation techniques are used to evaluate the sensitivity of the system to single and multiple thefts and to compare various safeguards options. The study identifies design criteria that would improve the safeguardability of future plants.

14) J.M. Hansel, Jr., C.J. Martell, G.B. Nelson, and E.A. Hakkila, "Concentration of U and Np from Pu and Pu Alloys for Determination by X-Ray Fluorescence,: X-Ray Anal. **20,** 445-452 (1977)

ABSTRACT: Methods are presented for the determination of uranium, or uranium and neptunium, in plutonium metal and plutonium alloys. Anion exchange or a combination of anion exchange-solvent extraction is used to concentrate the elements of x-ray fluorescence analysis, depending upon the impurities present and elements to be determined. The precision for determining between 3 and 250 *ug* of uranium or neptunium ranges between 30 and 2%

15) J.L. Sapir, Comp., "Nuclear Safeguards Research and Development-Program Status Report, January-April 1977," Los Alamos Scientific Laboratory report LA-6849-Pr (August 1977).

ABSTRACT: This report presents the status of the Nuclear Safeguards Research and Development program pursued by LASL Safeguards Groups Q-1, Q-2, Q-3, and Q-4 for January through April 1977. Topics covered include nondestructive assay technology development and applications, international safeguards, perimeter safeguards and surveillance, integrated safeguards systems, concepts and subsystems development (e.g., DYMAC program), training courses, and technology transfer.

16) E.J. Dowdy, C.N. Henry, D.R. Millegan, "Reduced Variance Multiplication Meter for Plutonium Sample Verification and Assay Applications, American Nuclear Society, Winter Meeting, November 27-December 2, 1977. NO ABSTRACT

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national forum. It is the object of the INMM safeguards committee to provide a clearing house for such commentary. The safeguards committee will act as a center for peer review and as a conduit for transmitting the commentaries to the media.

Commentaries released to the media shall be approved by the safeguard committee chairman or duly designated vice-chairman. Standards for such commentaries shall be those consistent with objective, responsible reporting practices.

Any member or group of members of the INMM may prepare and submit a commentary to the safeguards committee chairman for consideration. The chairman will circulate the comments to members of the committee for review and amendment as deemed necessary prior to public release.

Program Plan For U.S. Technical Assistance

By Herbert J. Kouts and William C. Bartels

The safeguards implemented by the International Atomic Energy Agency (IAEA) are of major importance to the non-proliferation objectives of the United States of America and other nations of the world. Assurance of safeguards effectiveness is mandatory to continued peaceful use of nuclear power. To enhance the ability of the IAEA to apply safeguards effectively, and to ensure that IAEA does not lack technical assistance which the U.S. could readily supply, the U.S. Congress has made available a special authorization for such technical assistance.

Substantial U.S. assistance, in addition to that included in this program is being provided to the IAEA safeguards program on the policy level. Such assistance includes: efforts through the Nuclear Suppliers Group to extend the application of IAEA safeguards; development and promotion of multi-national, regional, fuel cycle centers including international regimes for spent fuel or plutonium storage; implementation of the U.S. offer to permit application of IAEA safeguards to all U.S. nuclear facilities except those of direct national security significance; and, perhaps most importantly, strong U.S. support for needed growth of the IAEA safeguards program.

The technical assistance which this program will provide is meant to complement the methods that the IAEA would normally use to fill safeguards needs based on funding from its regular budget. This assistance is to be used for quick reaction to identified urgent needs to improve effectiveness where normal IAEA budget channels cannot respond fast enough. Special expertise will also continue to be made available from other U.S. programs to strengthen IAEA capabilities in areas where expertise is currently limited. As technical capabilities for safeguarding are advanced in U.S. research programs, tested and proven effective techniques will be made available to IAEA. Members of IAEA staff will be given opportunities in the field to become familiar with actual operating conditions that they will later encounter in the discharge of their safeguards duties. In the future, other needs for U.S. assistance may be found in particular cases, but the ones described above are of the highest identified urgency.

The program includes tasks which will contribute to the effectiveness of the overall, integrated IAEA safeguards system. In actual practice, IAEA safeguards are carried out pursuant to Agreements between IAEA and the Member States where safeguards are applied. Safeguards as applied by IAEA always consist of certain essential functions. In States adhering to the Non-Proliferation Treaty (NPT), as well as States which have only partially accepted international safeguards, each facility subject to IAEA safeguards is required to maintain complete records and is also required to report information to IAEA. IAEA reviews facility records and reports, including design information and nuclear materials accounting information. Independent verifications by IAEA include facility design verification and continuing verification of nuclear materials accountancy, including verification by assay of nuclear materials.

Safeguards, as applied by IAEA, are implemented as necessary for timely detection of any diversion of significant quantities of nuclear material subject to IAEA safeguards from peaceful nuclear activities to the manufacture of nuclear weapons/explosives or for purposes unknown. The hypothetical diversion techniques which the IAEA must be able to detect include:

1. Overstatement of materials removed from safeguards, including wastes.
2. Falsification of records and reports, including the use of floating inventories to conceal the absence of diverted material.
3. Use of accountability uncertainties, including exaggeration of measurement uncertainty to conceal the absence of diverted material.
4. Understatement of receipts or production at a safeguarded facility especially where understatement could be related to use of the safeguarded facility for other than peaceful purposes and should be detectable.

Although the Non-Proliferation Treaty has been in effect for almost seven years, the methods used by the IAEA in safeguards under the Treaty are still evolving and this evolution can be expected to continue for some time. There are several reasons for the continued change but most changes follow from the slow rate of implementing the Treaty. Neither the nature nor the amount of the Agency's workload has yet encountered the dramatic change that will soon have to be faced as safeguards under INFCIRC/153 come to be applied to the large industrial nations of Europe, and to Japan, the

United States, and the United Kingdom. Nevertheless, the safeguards program up to now has tested methods that are to be used when the really extensive problems are encountered, probably within a year.

Important problem areas have already been uncovered by the IAEA staff in its application of safeguards. Among these are:

- Under INFCIRC/153 not all areas of all facilities can be entered by inspectors, and inspection must be limited to strategic points where verification can be attempted. This leads to inability to verify significant components of inventory.
- A geat deal of fissionable material in the nuclear fuel cycle is presently difficult for the IAEA to measure or verify.
- Instruments that inspectors could use are sometimes too heavy, too bulky, or sometimes they have requirements not suited for use in some places being inspected (need for liquid nitrogen, very stable voltage, etc.).
- Information on movement of fissionable material is sometimes not easy to supply in a form usable by the IAEA's system of assimilating and analyzing such information. The system is being modified and made more flexible, but all such kinds of problems have probably not yet been encountered.
- The information on flow supplied in the IAEA's reporting system does not define the inventory in a form suited to verification of that inventory during an IAEA inspection. Therefore inspectors cannot start their work at a facility with a sampling plan previously prepared for the material they seek to verify.
- The information system of the Agency is already overloaded and is running late. Solution to this problem depends partly on new equipment, and partly on development of a new system.

Three big changes will occur in safeguards implementation during the next few years. The first will be a great increase in volume of information that must be gathered, assimilated, and analyzed as more nuclear facilities come under IAEA safeguards. The second will be initial encounters with new types or sizes of facilities central to the question of proliferation. These facilities include isotope separation plants and large spent fuel reprocessing plants, plants for fabricating mixed uranium-plutonium oxide fuel for power reactors, and plants for fabricating highly-enriched uranium fuel for research reactors. Though the IAEA has had experience with small, isolated plants of these kinds, it has little experience with safeguards in large industrial nations under agreements concluded under INFCIRC/153.

As the number and size of facilities under IAEA safeguards increase rapidly, the third change will require IAEA to deal with complete nuclear fuel cycles within single States or close international groupings, with relatively less information available on nuclear materials transfers from nuclear supplier to nuclear consumer states. The systems and techniques of IAEA safeguards will require adaptation, development, and testing in order to achieve a credible level of effectiveness in these new modes of application.

The IAEA safeguards staff is already heavily loaded by present requirements and, as pointed out above, this load is about to grow in large steps. Within this program immediate solutions encompass combinations of a growth in skilled manpower to meet the immediate new requirements and the introduction of new safeguards methods to decrease the effort required for each facility. A step increase in staff effectiveness is projected by provision of U.S. technical experts and consultants to work as cost-free experts under individual contracts with the IAEA. A number of tasks in this program are addressed to the introduction of new methods and improvement of existing techniques, including measures for containment, surveillance, and seals.

This program presents a determined attack on the above and other known problem areas and successive editions should complete the list of required actions. The tasks in this program are directed at improving IAEA's effectiveness and timeliness in detecting material missing in a State. In the area of measurement technology, specific new tasks are being directed to methodology that would be used by IAEA staff, and to supplement that staff quickly with cost-free experts. Measurement instruments transported and used by inspectors need to be more reliable and to be suitable for inventory verification by non-destructive assay of additional and significant forms of nuclear materials. There is an immediate and important need for additional surveillance equipment that could give more reliable indication of tampering, and more timely indication of diversion. Development of surveillance and containment capabilities suited to a wider range of nuclear materials and equipment can make substantial contributions to IAEA's safeguards effectiveness. Cost-free expert help can make early and substantial improvements in IAEA systems for analysis of IAEA staff reports on inspections they conduct. Inspection exercises conducted in the U.S. with IAEA participation are proving to be highly useful in establishing precedents for inspection and reporting at advanced nuclear facilities throughout worldwide nuclear fuel activities. Several planning studies are needed in the immediate future for safeguarding types of facility new to IAEA safeguards in 1977. Reviews of the status of U.S. domestic safeguards activities will facilitate the transfer to IAEA of systems and technology now in use or under development in the areas of information transfer, techniques for monitoring nuclear operations, and diversion path analysis. Several analytical studies are recommended to facilitate performance of routine safeguards planning and implementation activities by IAEA and by States subject to IAEA safeguards. Training of States officials and IAEA staff is to receive continued and broadened assistance consistent with future IAEA plans and undertakings.

This program is a full and positive response to all opportunities which were identified for useful technical assistance to IAEA safeguards in the course of a two-week meeting in November 1976, and a one-week follow-up meeting in February 1977, by teams of safeguards officials and technical experts from the IAEA and the United States. The goal of this initial program is to provide, as needed, all items of assistance which the IAEA has agreed would be useful assistance under existing safeguards agreements and items which the U.S. can supply. It is to be expected that the dynamic nature of worldwide nuclear expansion will require new future agreements, changes in IAEA safeguards functions, and consequent future changes and additions in subsequent editions of this program.

Under the leadership of the President of the United States, the Department of State, DOE, ACDA, and NRC have each accepted responsibility for parts of the program of technical assistance to IAEA safeguards (Figure). State is providing policy guidance and, through the Agency for International Development, has sought and obtained funding. DOE has established an International Safeguards Project Office (ISPO), at Brookhaven National Laboratory, for program coordination and task implementation, and DOE, ACDA, and NRC are contributing managerial and technical resources to development and implementation of the program.

DOE has substantial resources for implementing priority national programs involving nuclear technology. In expediting the initiation of this technical assistance program, full use will be made of existing ERDA laboratory resources. Participating Laboratories include: Los Alamos Scientific Laboratory; Sandia Laboratories; Argonne National Laboratory; Pacific Northwest Laboratory; Brookhaven National Laboratory; and others. The safeguards programs at these different laboratories reflect different areas of specialization.

DOE, ACDA, and NRC are contributing program management resources and, in addition, are each undertaking new specific tasks and have already initiated tasks now included in this Program Plan. All are providing full information to ISPO on the nature and progress of tasks undertaken.

The major task areas of the program have been directed at six functions of IAEA safeguards activity:

A. Measurement technology
B. Training
C. System studies
D. Information processing
E. Surveillance and containment
F. Support for field operations

One of the subtasks in the task area of information processing has been completed through an agreement between the IAEA and the Federal Republic of Germany, and is not included in this program. A data base management system for use with the computerized information system has accordingly been provided to IAEA. This system, named ADABAS, has been provided as a gift-in-kind by the FRG.

In one task area, training, the subtasks have not yet been fully defined. An evolution of the training program subtasks is expected to take place as discussions with the IAEA continue.

This is the first stage in special technical assistance by the U.S. to the IAEA on safeguarding nuclear material.

It is not suggested that these are all the areas in which special assistance by the U.S. could improve safeguards by the IAEA, nor is it suggested that the tasks in this program constitute or reflect any modified views on the character of IAEA safeguards. In fact, the tasks that are addressed originate in IAEA requests, and reflect the system of safeguards established in the Safeguards Agreements between Member States and the IAEA.

As the views of the U.S. Government solidify with respect to safeguards to be applied by the IAEA in the future, and new Agreements are discussed or negotiated, this first program will be supplemented by a second one which takes into account changes in methods, techniques, and overall structure which may be developed in the future.

A New Way of Thinking

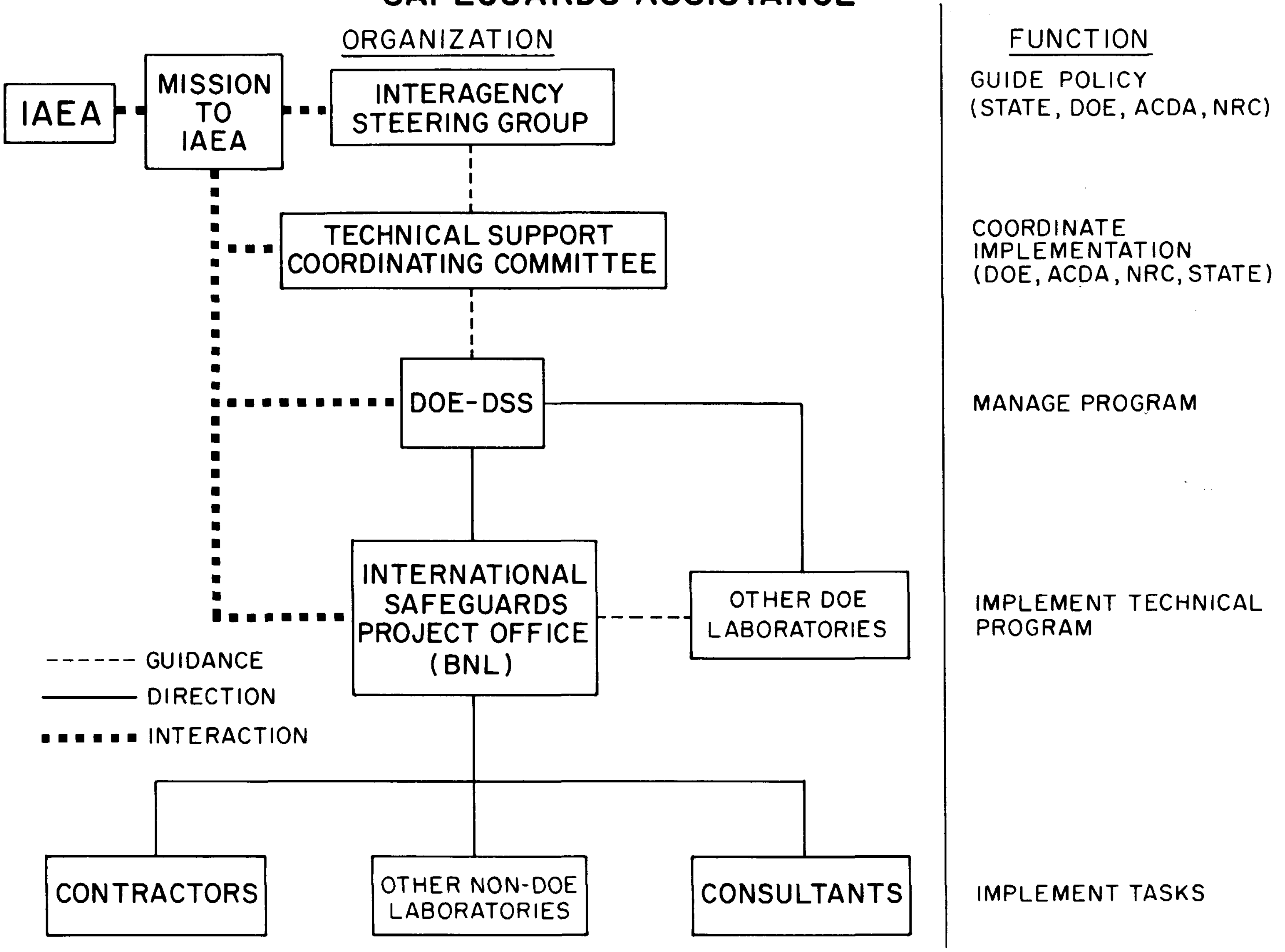
(Continued from Page 1)

This is not to say that the integrated safeguards systems **will** not be useful to the NRC or the IAEA. The questions which have to be faced are exactly how might they use them and how useful might they be? A first-rate, highly automated safeguards system would provide the operator of a plant with a high degree of protection against internal and external domestic adversaries. It would also provide tight control of the nuclear materials. If the IAEA took its data from the computer, how could it be sure that the information is honest, and that all materials pass through the key measurement points for independent verification? A better plant system might even make the IAEA's task more difficult, unless the needs of the IAEA are clearly understood and factored into the system design.

Another aspect which needs hard thought and assessment of specific, exemplary designs is that of the effectiveness of safeguards for multi-national nuclear centers against both national and sub-national threats. Just because they would be multi-national does not make them safe.

One has to go through all those games again to threat analysis, diversion path analysis, black hatting, etc., where the adversary owns the facility, or is an active partner in the enterprise. The adversary may be sub-national with limited resources or national with substantial resources and big stakes. When we finish, we will need to have made a very convincing case for the conclusions are to be presented for world approval.

U.S. - IAEA SAFEGUARDS ASSISTANCE



On Forming Linear Combinations of Accounting Data to Detect Constant Small Losses

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Introduction

Recently, there has been renewed attention focussed on the problem of using material accounting data from more than one accounting period to make inferences about the state of material control in a facility. This renewed activity was prompted in part by the so-called Rosenbaum report [1] that underscored the inability of usual MUF [2] calculated for a single accounting period to detect small losses that accumulate over time. This deficiency in the MUF statistic has been obvious to workers in the field of safeguards accountancy for many years and, for internal control purposes at least, facilities tend to put more emphasis on the accumulated MUF, rather than on any individual MUF, as a measure of the long term state of control. This emphasis on accumulated MUF does not mean that a single MUF is not a useful statistic; it is intended to detect a single large loss that occurs within the accounting period in question. Thus, both concepts are important, the one to detect continuing small losses and the other to detect single loss events.

Whether one's interest is in a single MUF or in an accumulated MUF, there are techniques that have been suggested to improve the detection efficiencies of these statistics by taking into account the structure of the data. A very early attempt was made at this by K. B. Stewart some 20 years ago [3]. Following a suggestion by C. A. Bennett, Stewart developed a minimum variance estimate of book inventory using past physical inventory and net input data. This estimate formed the beginning inventory for an accounting period, and the calculated MUF found by replacing the physical beginning inventory by this estimate has smaller variance than the usual calculated MUF. (Stewart developed this concept in detail and a full report is in reference [4]. In [4], incidentally, there is cited in the Bibliography a reference on the Kalman filter which has recently been put forth as a useful accountancy tool [5]).

Still focussing on an individual MUF, as did Stewart, other ideas have been suggested for taking into account past data [6], [7], [8], [9]. These ideas make use of the autocorrelation that exists between successive MUF's by virtue of the fact that the beginning inventory for one accounting period is identically the ending inventory for the prior period. The additional contribution to autocorrelation due to the systematic error structure is also included.

Turning now to the accumulated MUF experience to detect continuing small losses, recent work in this area was reported by Pike and Morrison [5] using a Kalman filter. Using simulated data, they compare their Kalman filter statistic with the cumulative MUF and conclude that the detection capability is greatly enhanced using the Kalman filter, at least for the examples under study. (They also compare the Kalman filter with the usual MUF for a single period, but this comparison is of little interest since the two statistics are aimed at detecting different scenarios.)

The work by Pike and and Morrison has prompted the author to reconsider the problem of how one might analyze past accounting data to detect specific loss scenarios. In particular, the loss scenario that involves a constant loss per accounting period during equilibrium operation of a facility is studied.

To put this and related work in perspective, it is important to keep in mind that properties of statistics that are derived from assumed models are only useful and meaningful to the extent that the models correspond to reality.

A particular statistic may be ideally suited to detecting constant losses, say, but what are its properties under loss scenarios that differ? Also, the work discussed here and in [5] assumes that systematic errors are of negligible importance; often, they are of dominant importance. Thus, work done thus far should be viewed as simply offering possibilities for approaches to the problem of detecting losses, but work remains to be done in examining properties of these statistics under various alternatives and with more complicated but more realistic error structures.

Notation and Assumptions

It is helpful to list the notation before proceeding further.

n = number of accounting periods

y_{i-1} = beginning physical inventory for period i

y_i = ending physical inventory for period i

w_i = net inputs (inputs-outputs) for period i

x_i = calculated MUF for period i

$\quad = y_{i-1} + w_i - y_i$

η_i = random error of measurement associated with y_i

ε_i = random error of measurement associated with w_i

$E(\eta_i) = E(\varepsilon_i) = 0$ (E is the notation for mathematical expectation)

$E(\eta_i^2) = V_1$ for all i

$E(\varepsilon_i^2) = V_2$ for all i

A = measurement variance of x_i for all $i = 2V_1 + V_2$

B = measurement covariance between x_i and x_{i-1} for all $i = -V_1$

$E(x_i) = L$ for all i

L = constant amount loss per accounting period

Linear Combinations of MUF's

Consider a linear combination of calculated MUF's:

$$Z_n = a_1 x_1 + a_2 x_2 + \ldots + a_n x_n \qquad (1)$$

The $a_i = 1$ for all i for the cumulative MUF statistic. For the Kalman filter statistic, it has been demonstrated that for $n \leq 3$, the statistic is of the form (1) where the a_i are functions of V_1, V_2, and of the initial input elements of a state error-covariance matrix. It is conjectured that for $n \geq 4$ the Kalman filter statistic is also a linear combination of the x_i as in (1).

The problem of interest is to select the a_i that is optimum according to some criterion. Clearly, it is of interest to select the a_i such that the probability of detecting the constant loss per period, L, is maximized. This is equivalent to maximizing $E(Z_n)/\sigma_{(Z_n)}$. But since $E(Z_n) = L \sum_{i=1}^{n} a_i$, by imposing the constraint that $\sum_{i=1}^{n} a_i = 1$ (or any other constant), the problem reduces to selecting the a_i that minimizes $\sigma_{(Z_n)}$.

To solve this minimization problem, rewrite

$$Z_n = a_1x_1 + a_2x_2 + \ldots + (1-a_1-a_2-\ldots-a_{n-1})x_n$$

$$= a_1(x_1-x_n) + a_2(x_2-x_n) + \ldots$$

$$+ a_{n-1}(x_{n-1}-x_n) + x_n$$

Then, noting that

$$\text{var } x_i = A$$

$$\text{var } (x_i-x_j) = 2A \text{ for } j \neq i+1$$

$$\text{var } (x_i-x_{i+1}) = 2(A-B)$$

$$\text{cov } [(x_i-x_n), (x_{i+1}-x_n)] = B+A \text{ for } i+1 \neq n-1$$

$$\text{cov } [(x_i-x_n), (x_j-x_n)] = A \text{ for } j \neq i+1,\ j \neq n-1$$

$$\text{cov } [(x_i-x_n), (x_{n-1}-x_n)] = -B+A$$

$$\text{cov } [(x_i-x_n), x_n] = -A, \text{ for } i \neq n-1$$

$$\text{cov } [(x_{n-1}-x_n), x_n] = B-A$$

The variance of Z_n, $\sigma^2_{(Z_n)}$ can be found, the partial derivatives taken with respect to a_1, a_2, ..., a_{n-1}, these equated to zero, and the system of (n-1) equations in (n-1) unknowns solved for the a_i. The solution can be expressed in matrix notation as the solution of the matrix equation:

$$\underline{A}\ \underline{a} = \underline{b} \qquad (2)$$

where

$\underline{A}$ is the (n-1) square symmetric matrix with elements:

2A in positions (i,i) for i=1, 2, ... (n-2)

2(A-B) in position (n-1, n-1)

(A+B) in positions (i, i+1) for i=1,2,...,(n-3)

(A-B) in positions (i, n-1) for i=1,2,...,(n-3)

A elsewhere

For example, if n=6, $\underline{A}$ is a 5 x 5 symmetric matrix:

$$\underline{A} = \begin{pmatrix} 2A & (A+B) & A & A & (A-B) \\ & 2A & (A+B) & A & (A-B) \\ (\text{Symm}) & & 2A & (A+B) & (A-B) \\ & & & 2A & A \\ & & & & 2(A-B) \end{pmatrix}$$

To continue, $\underline{a}$ is the (n-1) column vector defined by $\underline{a}^T = (a_1, a_2, \ldots, a_{n-1})$ and $\underline{b}$ is the (n-1) column vector defined by $\underline{b}^T = (A, A, \ldots, A, A-B)$.

Then, given V_1 and V_2, and hence A and B, the matrix of unknown a_i's can be solved for by inverting $\underline{A}$ to give $\underline{A}^{-1}$ and multiplying this into $\underline{b}$. In matrix notation:

$$\underline{a} = \underline{A}^{-1}\,\underline{b} \tag{3}$$

A computer program has been written to produce the a_i parameters very quickly for given V_1 and V_2. Once given, then the variance of Z_n, $\sigma^2(Z_n)$ is computed as

$$\sigma^2(Z_n) = A \sum_{i=1}^{n} a_i^2 + 2B \sum_{i=1}^{n-1} a_i\, a_{i+1} \tag{4}$$

Example

Consider the example on page 16 of [5]. Here, L=1, V_1 = 69.33, and V_2 = 0.10. Based on a single simulation run, Pike and Morrison demonstrated that the Kalman filter statistic was far superior to the cumulative MUF statistic in detecting this constant loss. The same is true of the Z_n statistic developed in the previous section, as will be shown quantitatively. If, as conjectured, the Kalman filter statistic can be reduced to the form (1), then it cannot be better than the Z_n statistic in detecting the constant loss.

Consider this optimum Z_n statistic. In finding the a_i, $A = 2V_1+V_2 = 138.76$ and $B = -V_1 = -69.33$. Solutions were found for the a_i for n=2 through 21. It turns out that $a_1 = a_n$, $a_2 = a_{n-1}$, $a_3 = a_{n-2}$, etc. Solutions up to n=10 are reproduced below.

Table I

a_i for Z_n Statistic

n	a_1	a_2	a_3	a_4	a_5
2	.5	.5			
3	.300014	.399971	----		
4	.200029	.299971	----		
5	.142898	.228555	.257093	----	----
6	.107194	.178571	.214234	----	----
7	.083393	.142874	.178528	.190408	----
8	.066734	.116700	.149971	.166595	----
9	.054619	.097018	.127260	.145388	.151428
10	.045533	.081881	.109096	.127218	.136272

To illustrate, if there were 3 accounting periods, the statistic would be

$$Z_3 = .30014\ x_1 + .399971\ x_2 + .300014\ x_3$$

By way of comparison, the cumulative MUF, designated by U_3, is

$$U_3 = x_1 + x_2 + x_3$$

From [5], for the input error-covariance matrix $\underline{G}(0)$ used by the authors, the Kalman filter statistic reduces to

$$k_3 = .0518\ x_1 + .0468\ x_2 + .0292\ x_3$$

For this example, Z_n and U_n can be compared on the basis of probability of detection. Assuming that "detection" consists of calculating a value for the statistic that exceeds zero by two standard deviations, then the probability of detection is the area under a standardized normal curve from (2 - E/σ) to infinity, where "E" designates the expected value of the statistic, and σ its standard deviation. These detection probabilities are given in Table II.

Table II

Detection Probabilities for Example

n	U_n(CUMUF)	Z_n
1	.028	.028
2	.034	.034
3	.040	.042
4	.048	.053
5	.058	.067
6	.068	.086
7	.080	.110
8	.093	.141
9	.108	.180
10	.124	.226
11	.142	.281
12	.162	.345
13	.184	.415
14	.207	.491
15	.232	.569
16	.258	.647
17	.286	.720
18	.315	.787
19	.346	.844
20	.377	.891
21	.409	.927

In the single trial simulation in [5] for this example, the Kalman filter statistic detected the loss at n = 12. The Z_n statistic did likewise. *This is shown in Table III below where* the x_i data are read to the nearest unit from Figure 3 of [5].

Table III

Example Calculations of Z_n

n	x_i	Z_n	$\sigma(Z_n)$	$2\sigma(Z_n)$
1	-3	$Z_1 = x_1 = -3$	11.78	23.56
2	-2	$Z_2 = .5\ x_1 + .5\ x_2 = -2.5$	5.89	11.78
3	-9	$Z_3 = .300014\ x_1 + .399971\ x_2 + .300014\ x_3 = -4.40$	3.73	7.46
4	15	-0.90	2.64	5.28
5	-11	-1.34	2.00	3.99
6	19	0.68	1.58	3.16
7	-7	0.88	1.29	2.58
8	1	0.98	1.08	2.16
9	2	1.09	0.92	1.85
10	-2	1.01	0.80	1.60
11	5	1.11	0.70	1.41
12	6	1.34*(exceeds 2σ limits)	0.62	1.25

13	-4	1.33	0.56	1.12
14	4	1.39	0.51	1.01
15	-11	1.15	0.46	0.92
16	7	1.11	0.42	0.84
17	5	0.98	0.39	0.77
18	-10	0.99	0.36	0.72
19	2	0.90	0.33	0.66
20	10	0.95	0.31	0.62
21	7	1.06	0.29	0.58

Linear Combinations of Inventories and Net Inputs

In an idealized equilibrium situation in which the net inputs (exclusive of measurement error) is constant from one period to the next, the Z_n statistic can be improved by considering a statistic that is a linear combination of inventories and net inputs. It is emphasized that the statistic to be discussed is primarily of academic interest because it is difficult to envision how the idealized model could be a valid description of reality in most applications. Nevertheless, the statistic is of interest because of its simplicity and because it may suggest a starting point for similarly constructed statistics under less idealized models.

The statistic is of the form

$$v_n = (a_0 y_0 + a_1 y_1 + \dots + a_n y_n) + (b_1 w_1 + b_2 w_2 + \dots + b_n w_n) \qquad (5)$$

which is a linear combination of the (n+1) physical inventories and of the n net inputs. Again, the parameters will be chosen to maximize the ratio: $E(v_n)/\sigma_{(v_n)}$.

Under the idealized model, write $E(w_i) = W$ for all i, so that

$$\begin{aligned} E(y_0) &= I \\ E(y_1) &= I + W - L \\ &\vdots \\ E(y_i) &= I + iW - iL \\ E(x_i) &= I + (i-1)W - (i-1)L + W - I - iW \\ &\quad - iL = L \end{aligned}$$

Then,

$$\begin{aligned} E(v_n) &= a_0 I + a_1 (I+W-L) + a_2 (I+2W-2L) + \dots \\ &\quad + (b_1 + b_2 + \dots + b_n) W \\ &= I (a_0 + a_1 + \dots + a_n) + W \\ &\quad (a_1 + 2a_2 + \dots na_n + b_1 + \dots + b_n) \\ &\quad -L (a_1 + 2a_2 + \dots na_n) \end{aligned} \qquad (6)$$

Equate $E(v_n)$ to the constant, L, which means that the following constraints are imposed on the parameters:

$$\left.\begin{aligned} & a_0 + a_1 + \dots a_n = 0 \\ & a_1 + 2a_2 + \dots + na_n + b_1 + \dots + b_n = 0 \\ & a_1 = 2a_2 + \dots + na_n = -1 \end{aligned}\right\} \quad (7)$$

The last two constraints indicate that the b_i's must sum to 1.

Since $E(v_n)$ is now a constant, the problem reduces to minimizing $\sigma(v_n)$, or $\sigma^2_{(v_n)}$. Thus, choose the a_i's and b_i's to minimize

$$\sigma^2_{(v_n)} = V_1 \sum_{i=1}^{n} a_i^2 + V_2 \sum_{i=1}^{n} b_i^2 \qquad (8)$$

subject to the constraints:

$$\sum_{i=1}^{n} a_i = 0 \qquad (9)$$

$$\sum_{i=1}^{n} i\, a_i = -1 \qquad (10)$$

$$\sum_{i=1}^{n} b_i = 1 \qquad (11)$$

It follows immediately that $b_i = 1/n$ for all i. To find the a_i, use the method of La Grange multipliers [10]. The (n+3) equations in (n+3) unknowns that must be solved simultaneously are (9), (10) and (n+1) equations of the form,

$$2\, a_i V_1 + \lambda_1 + i\lambda_2 = 0 \qquad (12)$$

for i = 0, 1, ..., n. The solutions follow rather easily to give

$$\begin{aligned} \lambda_1 &= -12\, V_1 \big/ (n+1)(n+2) \\ \lambda_2 &= 12\, V_1 \big/ n(n+1) \\ a_i &= 6\, (n-2i) \big/ n(n+1)(n+2), \\ & \qquad (i = 0, 1, \dots, n) \end{aligned} \qquad (13)$$

Then, from (8), the variance of v_n follows easily.

$$\sigma^2_{(v_n)} = [12\, V_1 + (n+1)(n+2)\, V_2] \big/ n(n+1)(n+2) \qquad (14)$$

Comparison of v_n with Cumulative MUF

It is possible to make a direct comparison of the v_n statistic with the cumulative MUF statistic,

$$u_n = x_1 + x_2 + \dots x_n \qquad (15)$$

This is done by considering the ratio

$$T = \frac{E(v_n)/\sigma(v_n)}{E(u_n)/\sigma(u_n)} \tag{16}$$

as a function of V_1, V_2, and n. Large values of T are indicative of a superiority of v_n over u_n.

From the preceding section, $E(v_n) = L$ and $\sigma^2(v_n)$ is given by (14). For the cumulative MUF, $E(u_n) = nL$ and $\sigma^2_{u_n} = 2V_1 + nV_2$. Letting $R = V_1/V_2$, T reduces to

$$T = \sqrt{\frac{(n+1)(n+2)(2R+n)}{n[12R + (n+1)(n+2)]}} \tag{17}$$

In Table IV, T is given as a function of R and n.

Table IV

Comparing v_n with u_n, the Quantity T is Tabled

n	R = .1	.5	1	5	10	25	100	500
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4	1.005	1.021	1.035	1.080	1.095	1.108	1.115	1.117
8	1.006	1.027	1.050	1.162	1.225	1.293	1.347	1.365
16	1.004	1.021	1.040	1.166	1.271	1.443	1.656	1.755
32	1.003	1.013	1.025	1.116	1.212	1.422	1.872	2.254
64	1.001	1.007	1.014	1.068	1.130	1.290	1.795	2.633
128	1.001	1.004	1.007	1.036	1.071	1.169	1.546	2.548

Table I indicates that real improvements can be made in the cumulative MUF statistic when the ratio $R = V_1/V_2$ (ratio of measurement errors in inventories to that in net inputs) becomes large.

Comparing Z_n with Cumulative MUF

Since v_n depends on a constant net input model, it is more meaningful to compare Z_n, the more practical statistic, with cumulative MUF. It's already been shown that for $V_1 = 69.33$ and $V_2 = 0.10$, which leads to an R value of 693.3, Z_n is quite superior to u_n. How do they compare at smaller values of R? This question is considered briefly for R = 0.5, 1, 2, 5, and 10. As in the prior section, the quantity tabled is T defined in (16) but with Z replacing v.

Table V

Comparing Z_n with u_n, at n=10

R	T
.5	1.010
1	1.026
2	1.059
5	1.139
10	1.223
693.3	1.475

In comparing these results with Table IV, it is seen that v_n has greater detection capability for the constant loss situation than does Z_n, but, of course, it requires more restrictive assumptions. For either to be superior to the simple cumulative MUF in practical terms, the ratio V_1/V_2 (measurement error in inventories to measurement error in net inputs) must be large.

Linear Combinations of Inventories and Net Inputs When Net Inputs is Not Constant

Under the idealized model leading to the development of the optimum v_n statistic, equation (6), it was assumed that $E(w_i) = W$ for all i. Suppose, rather, that the true net inputs is not constant, but that $E(w_i) = W_i$ for all i. Then, (6) becomes

$$\begin{aligned} E(v_n) &= I(a_0+a_1+\ldots+a_n) + W_1(a_1+a_2+\ldots+a_n+b_1) \\ &\quad + W_2(a_2+a_3+\ldots+a_n+b_2) + \ldots + W_n(a_n+b_n) \\ &\quad - L\,(a_1+2a_2+\ldots+na_n) \end{aligned} \tag{18}$$

In equating this to L by setting the coefficients of I, W_1, ..., W_n equal to 0 and the coefficient of L equal to -1, it follows that

$$b_1 = a_0$$

$$b_2 = a_0+a_1$$

$$b_3 = a_0+a_1+a_2$$

etc.

Then, v_n may be written in the form

$$\begin{aligned} v_n &= a_0y_0 + a_1y_1 + \ldots + a_ny_n + a_0w_1 \\ &\quad + (a_0+a_1)\,w_2 + \ldots\,(a_0+a_1+\ldots+a_{n-1}w_n) \\ &= a_0\,(y_0+w_1-y_1) + (a_0+a_1)\,(y_1+w_2-y_2) \\ &\quad + (a_0+a_1+a_2)\,(y_2+w_3-y_3) + \ldots \\ &\quad + (a_0+a_1+\ldots+a_{n-1})\,(y_{n-1}+w_n-y_n) \end{aligned} \tag{19}$$

But this reduces to a linear combination of MUF's, of the form of equation (1), and so the Z_n statistic is applicable.

Summary

A statistic consisting of a linear combination of observed MUF's is considered. The specific linear combination that gives the highest probability of detecting a constant loss is developed as the solution of a matrix equation involving the measurement errors in inventories and net inputs. The solution has been programmed for computer application. This optimum statistic is quite superior to the simple cumulative MUF when the ratio of measurement errors for physical inventories is large relative to that for net inputs. Systematic errors are not taken into account. In an idealized situation in which net inputs are constant, exclusive of measurement errors, another statistic is developed. This statistic is a linear combination of physical inventories and net inputs. The particular linear combination that is optimum with respect to detecting constant losses is independent of the measurement errors. When net inputs are not constant, this linear combination reduces to a linear combination of MUF's.

Acknowledgment

I am indebted to Anton Kraft who wrote the computer program that supplies the coefficients to use in the linear combination of MUF's.

References

[1] D.M. Rosenbaum, J.N. Googin, R.M. Jefferson, D.J. Kleitman, and W.D. Sullivan, "Special Safeguards Study", unpublished, ORNL Report (1974).

[2] J.L. Jaech, "Statistical Methods in Nuclear Material Control", USAEC TID-26298, pp. 247 ff (1973).

[3] K.B. Stewart, "B-PID and Inventory Estimates with Minimum Variance", Document HW-56536, General Electric Co., Hanford Atomic Products Operation (1958).

[4] K.B. Stewart, "A New Weighted Average", Technometrics, 12, No. 2, pp. 247-258 (1970).

[5] D.H. Pike and G.W. Morrison, "A New Approach to Safeguards Accounting", Document ORNL/CSD/TM-25 (1977). (Paper presented at INMM Annual Meeting, June 1977).

[6] Reference [3], pp. 241-250.

[7] J.L. Jaech, "Control Charts for MUF's", J. of the INMM, II, No. 4, pp. 16-28 (1974)

[8] E.E. Johnson, "MUF Control Charts and LEMUF Calculations Using an Autocorrelation Technique", Oak Ridge Y-12 Plant Report Y-DJ-16513 (1976).

[9] J.L. Jaech, "Can the Effects of Systematic Errors on LEMUF Be Reduced?" J. of the INMM, V, No. 3 pp 592-601 (1976).

[10] I.S. Sokolnikoff, "Advanced Calculus", P 329 ff McGraw Hill, NY (1939).

Nuclear Energy And Nuclear Proliferation

Remarks of **Victor Gilinsky,** Commissioner, U.S. Nuclear Regulatory Commission, The Washington Center of Foreign Policy Research, The School of Advanced International Studies, The Johns Hopkins University, November 3, 1977.

Introduction

I have been asked to provide a brief comment as a basis for discussion of the relationship between nuclear electric power and nuclear weapons development. This relationship is central to any policy on the use of nuclear energy internationally as well as domestically. As our understanding of it has changed over the years, so has our policy.

The most recent metamorphosis has taken place in consequence of the seriousness with which President Carter has viewed the peaceful-military connection in nuclear energy. In a major statement on nuclear policy last April 7th, and again on October 19th in remarks to the organizing session of the 40-nation International Nuclear Fuel Cycle Evaluation Conference, he outlined a clear change of attitude and direction towards civilian nuclear power and its role in increasing the danger that nuclear weapons will spread to more and more countries. As you probably know, this matter is also addressed in a bill, the Nuclear Nonproliferation Act of 1977, now before the Congress. It seeks to impose stricter rules on U.S. nuclear exports to make sure they do not get used for explosives.

The bill has passed the House by a vote of 411 to zero, but encountered heavy weather in the Senate this session, partly because of intense lobbying by some elements of the nuclear industry. Their position, in practical effect, has been that the relationship between the commercial nuclear fuel cycle and nuclear explosives is so remote that further controls are unnecessary—or, alternatively, if not remote, then so far gone that it is too late to reverse. On each side of the issues underlying a recommended nuclear export policy is a conception of the relationship between nuclear energy and nuclear proliferation. As the President said on October 19th, the subject is inherently controversial and can stand some clarification.

Access to Nuclear Explosive Materials

I do not want to dwell here on technical details, but a few remarks may be helpful. The essential nuclear explosive ingredients of nuclear warheads are plutonium or highly enriched uranium. You may recall that plutonium for our own nuclear weapons program has been produced in large special purpose reactors and separated from the spent fuel in reprocessing plants at the Hanford and Savannah River facilities. The highly enriched uranium has come from a complex of plants at Oak Ridge, Tennessee and similar facilities in Kentucky and Ohio, all of which are now used primarily to enrich uranium fuel for power reactors throughout the world.

The generation of electricity by nuclear means raises international security issues because uranium-fueled nuclear power reactors also produce plutonium. Commerical spent fuel reprocessing plants, which separate plutonium, provide easy physical access to large quantities of nuclear explosive material. And the same technology (and in some cases the same plants) used to enrich uranium for fuel can also be used to enrich it further for explosive purposes.

The essential point is this: obtaining the requisite explosive material is still the most difficult and time-consuming item in the initial production of nuclear weapons.* The operation of civilian nuclear power reactors and certain ancillary facilities—plutonium separation and uranium enrichment plants—can therefore remove key technological hurdles in this process and make it easier for a country to manufacture nuclear warheads, and quickly, once it decides to do so.

Such a decision will, of course, depend on the political and military situation in which a country finds itself at the moment of truth. Still, any serious antiproliferation policy, in addition to reducing the incentives to acquire nuclear weapons which grow out of genuine security concerns, must also aim at keeping it from being technically too easy to take up the military option. It is this latter question I want to talk about today.

The degree to which physical access to the essential nuclear explosive ingredients of nuclear warheads—either plutonium or highly enriched uranium—is facilitated by the operation of the commercial nuclear fuel cycle depends on the kinds and sizes of nuclear facilities in place and how the fuel cycle is operated. The important distinction between less dangerous and more dangerous fuel cycle activities forms the basis of current U.S. policy—which supports the relatively safe activities and seeks to restrict the dangerous. The line that is drawn between the two is not popular, either with the uncompromising opponents of nuclear energy (who regard all its aspects as equally dangerous), or with its zealous supporters (who until now have resisted labelling any aspect of the fuel cycle as dangerous).

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* See the 1975 Encyclopedia Americana article on Nuclear Weapons by **John Foster**, then the Defense Department's R & D chief and a former director of the Livermore Laboratory: "It must be appreciated that the only difficult part of making a fission bomb of some sort is the preparation of a supply of fissionable material of adequate purity; the design of the bomb itself is relatively easy."

Some Historical Perspective

Some historical perspective on this distinction is useful. U.S. nuclear energy policy was from the first based on a keen awareness of the dangerous aspect of nuclear electric power. The Acheson-Lilienthal Report of 1946 (which makes pretty good reading thirty years later) concluded that the only safe way to exploit nuclear power was under international supervision and control. The report recommended that dangerous elements in the nuclear fuel cycle—those that provided direct access to nuclear explosive materials—be placed under international ownership, but the related U.S. proposal to the United Nations was not adopted, in part, because the Soviet Union would not agree to participate. (It is interesting to speculate on what might have happened had we gone forward without the Russians.) What did happen was that by the mid-fifties individual countries were proceeding to develop their own nuclear programs, encouraged and assisted by the U.S. Atoms for Peace program.

An International Atomic Energy Agency was established in 1957, primarily to monitor the flow of commercial nuclear materials and equipment among member countries wishing to avail themselves of these services. While the fact that nuclear explosive materials were dangerous and should be kept out of harm's way was recognized—Article XII of the agency's 1957 Charter speaks of IAEA custody over "excess" quantities of plutonium as a means of avoiding their accumulation in individual states—the use of plutonium and highly enriched uranium was not specifically restricted beyond requirements for agency inspections.

The security implications of a course which led to easy access to nuclear explosive material in national stockpiles were apparently not obvious to the nuclear policymakers of the fifties and the sixties. The prospect of many nations in possession of substantial quantities of nuclear explosive materials all seemed very far away; nuclear weapons were assumed to be enormously difficult to design and fabricate; and the U.S. near monopoly on the technology, fuels and equipment for civilian nuclear power activities worldwide seemed to ensure U.S. control of the situation. Fledgling nuclear power programs were not thought then to have much to do with the development of nuclear weapons. The earlier prescience of the Acheson-Lilienthal group that they had everything to do with it was ignored. It is paradoxical that the true believers in technological progress did not contemplate the logical extension of that progress.

This may be explained in part by the fact that there was some genuine confusion on the technical side. It was once widely thought, for example, that "reactor grade" plutonium, that typically derived from spent power reactor fuel, was not suitable for use in nuclear weapons. This misconception about the possibility of "denaturing" plutonium, which seems to have originated in the Acheson-Lilienthal report, persisted until recently in many quarters—a confusion which apparently even the IAEA shared.

The unfortunate result was that many of those responsible for protection against diversion of plutonium to military uses were working under the impression that technological barriers against misuse of plutonium made their job of protecting the public easier. In fact, those technological barriers did not exist.

A Change in Circumstances

The situation is now altered and there is no longer any innocent excuse for the perpetuation of the notion that reactor-grade plutonium cannot be used for weapons. The U.S. government has stated unambiguously that this material can be used to produce militarily important nuclear weapons, and that a device using reactor grade plutonium has been successfully tested. The fact is that in simple designs for nuclear weapons plutonium from power reactors can be used to produce explosions with yields reliably in the range of kilotons—by any conventional measure highly powerful explosions. I stress this last point because some of those who argued it could not be done have fallen back to discounting the military significance of explosions of this size.

Information gaps have also been closed in the current version of the IAEA Safeguards Technical Manual, which provides the following guidance: plutonium of any grade, in either metal, oxide or nitrate form can be put in a form suitable for the manufacture of nuclear explosive devices in a matter of days to weeks.

To make full use of such a technical possibility, a country would have to perform the necessary preparatory work in advance, and secretly. This is a threat, however, that has now taken on a reality not present when the basic international rules for nuclear trade were formulated twenty years ago.

There have been other changes which contribute to the immediacy of the proliferation danger posed by commercial activities. First, the civilian nuclear power industry has grown enormously and by any reasonable measure (the plutonium production rate or the size of uranium enrichment facilities being utilized) exceeds the scale of the world's military nuclear programs. In fact, in most countries the quantities of plutonium in spent reactor fuel, if separated out and stored, will dwarf any plausible military needs.

At the same time technical possibilities expand, however, the political alternatives for a country seeking nuclear weapons are narrowing. There is no question that as the dangers of proliferation gradually sink in, the major nuclear exporters are showing less inclination to continue the laissez-faire approach which has unfortunately characterized nuclear trade in recent years. The time is fast approaching when a country can no longer count on the international community to look the other way while it openly puts together an explosives program, even if it does so without violating the strict letter of various international cooperative agreements.

The recent alarm over the possibility of a nuclear test in South Africa and the international attempt to intercept it underlines this point. Ironically, it also emphasizes to any would-be nuclear weapons state the critical importance of concealing its intentions up until the last moment before an explosion.

A New Policy for A New Situation

These considerations reflect a fundamental change in the nuclear state of affairs internationally. It is a change that forces us to confront the inescapable fact that parts of the civilian and military aspects of nuclear energy are too closely related for comfort. Once that fact is accepted, a change in nuclear policy is mandatory. The Acheson-Lilienthal group saw the dangers clearly; their view led to the decision, in 1946, to try to internationalize atomic energy. When that failed, the U.S. withdrew into a period of secrecy. Eventually we became more relaxed about the development of nuclear energy for peaceful purposes and secrecy was abandoned. Because we mistakenly thought civilian reactor safeguards could be stretched to cover the more dangerous elements in the fuel cycle—such as plutonium reprocessing when that day came—we allowed plans for the use of plutonium to go forward unhampered. There is where the damage was done.

The increased size and worldwide growth of the nuclear industry, the prospective availability of plutonium, and the inability to safeguard it properly against the possibility that it would be used for weapons as well as fuel led to a reassessment of the dangers; at the same time, the sharply increased projected costs of commercial reprocessing led to a critical reevaluation of the economic advantages of an early commitment to plutonium use. This in turn led to the shift in nuclear policy reflected in the actions of Presidents Ford and Carter in their efforts to restrict access to dangerous materials, to pause in the commitment to plutonium separation and use, and to search for alternatives to national stockpiling. In a sense we are now doing what we failed to do twenty years ago—thinking ahead.

Unfortunately it is getting a little late; our domestic industry and our international trading partners perceive the shift in nuclear policy as a threat to nuclear power and are pulling very hard in the opposite direction. The controversy is intense and every conceivable argument against making any connection between civilian and military uses of nuclear energy has been put forward.

What About Unsafeguarded Production Reactors?

It is contended, for example, that no country choosing to build nuclear weapons would turn to its civilian power reactors for the requisite explosive materials; to divert material in this way would risk detection by the IAEA inspectors, and in addition would provide too poor a grade of plutonium to interest weaponeers. Under this self-serving theory, if weapons material is wanted, a special-purpose, unsafeguarded reactor would be built. It is possible at the moment to do this legally in countries not party to the Nonproliferation Treaty and therefore not subject to inspection of **all** its indigenous nuclear facilities. This underlines the need to extend the requirements of the treaty to nonsignatory nations by conditioning nuclear trade on acceptance of international agreements and inspection on **all** nuclear activities within importing countries. There is increasing pressure to do this, and the bill now before the Congress makes this a condition for U.S. nuclear exports.

Even if legal, however, the construction of a special purpose plutonium production reactor signals a country's intention to build bombs and, in the present climate, risks premature interception of its attempt to obtain explosive material for nuclear weapons. This risk can be avoided, however, by stockpiling separated plutonium from spent power plant fuel openly and legally. A defense establishment can design and fabricate a bomb in privacy; the illegal activity is then confined to a swift, almost one-step process: appropriation from its storage place of the necessary plutonium, fabrication, and insertion into the waiting bomb. It is surely the quickest, cheapest, and least risky route to nuclear weapons. So long as individual nations are permitted to keep nuclear explosive stockpiles they are, in effect, in possession of an option to make nuclear weapons almost literally overnight.

Can We Rely on International Safeguards?

But, it is argued, if these nuclear activities are placed under the protection of international safeguards, it isn't necessary to put constraints on plutonium reprocessing or uranium enrichment. All that's needed is to beef up the IAEA's current inspections—more inspectors, more equipment. But safeguarding reactors and their fuel—typically many technological steps from use for nuclear weapons—is one thing; "safeguarding" the nuclear explosive material itself is quite another.

Periodic inspections of nuclear power programs involving only power reactors can provide a significant degree of protection by providing international warning of possible wrongdoing. This is because it takes many months or years to obtain the plutonium separation capability to turn reactor fuel into a form usable for weapons; awareness of a reliable advance warning system which would spot such activity serves as a deterrent to illicit bomb programs. It is important here to appreciate the vital element of time; the object of international inspection is to frustrate the purpose of the diversion by ringing an alarm **in time** to allow for counteraction by the international community. If sufficient time for effective response is not provided, "safeguards" won't work.

In other words, from the moment spent reactor fuel is translated into separated plutonium and stored, the element of "timely" warning, on which our present safeguards system has been relying, evaporates. The same is true, of course, for stockpiles of highly enriched uranium.

It is important to understand that so far as safeguards are concerned a stock of nuclear explosive material is a lot more like a bomb than it is like a reactor. No one would dream of suggesting that nuclear explosive devices, regardless of how labelled, should be exported under international safeguards. The Nonproliferation Treaty settled once and for all the notion that nuclear explosives came in two categories—military and peaceful. Under the treaty no such distinction is permitted. Yet strip away the electronics and the conventional high explosives and label the plutonium as intended for peaceful purposes and many nuclear spokesmen, at home and abroad, will tell you that if subject to occasional inspections it is a perfectly safe proposition: just like safeguarding power reactors.

Agreeing on Common Rules

Two Presidents have decided otherwise. They perceived a serious safeguards deficiency and moved to change U.S. policy in consequence. The primary imperative of the new policy is to develop common rules for international nuclear trade. But before these rules can be formulated, much less implemented, it will be necessary to arrive at a common understanding of what is dangerous and what is not. It is clear that such an understanding does not yet exist, as witness export sales by our nuclear trading partners of plutonium reprocessing and uranium enrichment facilities. Common understanding must extend as well as how much the spread of nuclear weapons threatens individual countries and world security. This is a tricky matter, because intense international competition in nuclear commerce is involved—with its accompanying heavy investment as well as national pride—and tends to obscure the threat.

The fear of additional controls and their impact on international markets has led our own nuclear industry to attack the validity of the distinction being drawn between nuclear reactors and their low-enriched uranium fuel (a comparatively benign combination when subject to comprehensive oversight) and the more dangerous situation in which individual countries have access to facilities for the separation and storage of the plutonium derived from the operation of their power reactors. In the face of all evidence to the contrary, they have steadfastly insisted that international inspections of plutonium reprocessing activities will adequately protect against the danger of proliferation.

Their argument has now taken an odd turn. The lobbyists against control legislation maintain that the restrictions on commercial reprocessing facilities proposed by the President and the Congress involve a sacrifice without reward—no added safety can derive from such an action. According to industry spokesmen, just as countries with legal access to plutonium might design and fabricate weapons secretly, so countries without such legal access might also, without much added effort, reprocess spent fuel secretly in a small clandestine facility. I happen to think that one is relatively easy to hide and the other more difficult and risky (certainly doing both is more risky) and that the government's effort to make a distinction between the two cases is valid. What is more interesting, however, is that this latest wrinkle in the effort to forestall implementation of the new policy has led to some strange bedfellows: by saying, in effect, that all forms of nuclear power are equally dangerous, the nuclear industry seems to be agreeing with its most uncompromising opponents that the situation is far worse than the rest of us thought. Where that will take us is something I will leave to more fertile imaginations.

NRC Staff Responds to Petition

The technical staff of the Nuclear Regulatory Commission has made a preliminary analysis of a petition filed by the Union of Concerned Scientists concerning the safety of electrical connectors and cables used in nuclear power plants. The petition asks the Commission to shut down all operating reactors and to order all construction activities to cease. The NRC staff believes no such action is warranted because the UCS has misconstrued the safety significance of the test results.

The November 4 petition, filed with the Commissioners, cited information developed in an NRC-sponsored testing program at Sandia (New Mexico) Laboratories. The petitioners concluded there are "grave safety deficienceies" affecting operating nuclear power plants.

The Sandia programs involve testing of certain electrical connectors and other equipment to determine their adequacy for the environmental conditions following a loss-of-coolant accident. Other tests of electrical cables were performed to confirm the NRC staff position that fire protection requirements should not rely solely on current flame retardancy and electrical cable separation standards but should include the additional measures now required.

In its assessment of the test results, the NRC staff said:

(1) Electrical connectors failed in the Sandia tests. However, the staff's present information is that such electrical connectors are not being used in safety systems which are required to function in environmental conditions which would be present in a loss-of-coolant accident. These conditions include steam, radiation, water, high pressure and chemical additives. Connectors are generally used in nuclear instrumentation and control rod position indicators where continuity of service during a loss-of-coolant accident is not required. The staff said it is contacting operators of the 65 nuclear power plants now in operation, as well as those under construction, to confirm its present information.

(2) The Sandia tests show that existing separation and fire retardancy standards for redundant safety cables are not sufficient, by themselves, to protect against fires and confirm the need for the present NRC licensing requirement to provide additional measures to protect against disabling of vital systems in the event of such fires. These measures include fire barriers between cable trays, fire detection systems, and systems such as sprinklers to extinguish fires.

The staff said that fire protection measures at all nuclear power plants have been upgraded since the fire at the Browns Ferry Nuclear Power Station in Alabama in 1975, and that additional modifications are underway.

Copies of memoranda exchanged by the Director of the NRC Offices of Nuclear Regulatory Research and Nuclear Reactor Regulation on the Sandia tests are being placed in the Commission's Public Document Room at 1717 H Street, NW, Wahington, D.C.

Minimum Variance Linear Unbiased Estimators of Loss and Inventory

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SUMMARY

The article illustrates a number of approaches for estimating the material balance inventory and a constant loss amount from the accountability data from a sequence of accountability periods. The approaches all lead to linear estimates that have minimum variance. Techniques are shown whereby ordinary least squares, weighted least squares and generalized least squares computer programs can be used. Two approaches are recursive in nature and lend themselves to small specialized computer programs. Another approach is developed that is easy to program; could be used with a desk calculator and can be used in a recursive way from accountability period to accountability period. Some previous results are also reviewed that are very similar in approach to the present ones and vary only in the way net throughput measurements are statistically modeled.

1. INTRODUCTION

Attempts have been made recently[1] and in the past[2,3,4] to create statistical estimates that have more power to detect losses than the traditional statistics of MUF by using more of the inherent information in the net throughput and inventory measurements that occur over a sequence of accountability periods. The earlier results[2,3,4] use the sequence of inventory and throughput measurements for accountability periods up to the present period to determine a best linear unbiased estimate of the beginning inventory of the present period. Best here means minimum variance. This beginning inventory estimate is then used in a MUF equation in order to enhance the ability to detect a loss in the present accountability period. The technique is easy to apply because simple recursion formulae exist for obtaining the estimates of the beginning inventory and the variance of the estimates from those of the previous period. The technique, under the correct conditions, provides maximum power to detect a one-time loss that occurs in the present accountability period. This is called the no-loss case because no loss parameter is used in modeling any of the inventory and net throughput measurements.

Recent results[1] use the accountability data in a similar way except that the approach is designed to detect a common loss amount that occurs in each accountability period. This is called the constant loss case because a loss parameter is used in modeling the net throughput measurements. Net throughput is defined as inputs minus outputs. The word measurement is used with the net throughput value and the inventory value to distinguish between the values that are used in an ordinary MUF, (MUF = beginning inventory measurement plus net throughput measurement minus ending inventory measurement) and the inventory estimates and loss estimate that are the subject of this article and are linear combinations of these "measurements."

One objective of this paper is to review the main results that were obtained for the no-loss case.[2,3,4]

A second objective is to describe regression techniques that can be used in the constant loss case to estimate the loss rate and the ending inventory. Five techniques are shown, all of which lead to the same minimum variance unbiased estimates of the ending inventory values and the constant loss rate. Two of the techniques are recursive in nature and another lends itself to a recursive treatment. A forthcoming article in the journal will describe the implications of these estimates under the loss and no-loss cases as functions of different kinds of losses, number of periods involved, and different kinds of measurement variance conditions. In this forthcoming article the loss detection techniques will be compared with the traditional MUF and cumulative MUF techniques.

The main shortcoming of the approaches studied in this article is the lack of provision for the effects of systematic error. See Reference 7, pp. 250-262 for a discussion of this point.

The estimates in this paper are always the minimum variance linear unbiased estimates, shortened herein to mvue's.

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2. THE MVUE'S IN THE NO-LOSS CASE

The model for x_i, the net throughput measurement for the ith period in the no-loss case, is $x_i = \mu_{i+1} - \mu_i + \delta_i$ where μ_i and μ_{i+1} are the true inventory values at the beginning of the periods i and i+1, respectively, and δ_i is a random error with variance σ_x^2. The model for y_i, the measurement of the beginning inventory for the ith period, is $y_i = \mu_i + \varepsilon_i$ where ε_i is a random error with variance σ_y^2. Let $c = \sigma_x^2/\sigma_y^2$. It can be shown that the mvue of μ_n, the beginning inventory for the nth accountability period, is

$$\hat{\mu}_n = p_{n-1}y_n + (1-p_{n-1})(\hat{\mu}_{n-1} + x_{n-1})$$

$$= p_{n-1}y_n + q_{n-1}\ (\hat{\mu}_{n-1} + x_{n-1})$$

where $q_{n-1} = 1 - p_{n-1}$, $p_0 = 1$, and p_{n-1} is obtained from the recursion relationship

$$p_{n-1} = (p_{n-2} + c)/(p_{n-2} + c + 1)$$

The limit of p_{n-1} as n increases without bound is

$$p = \frac{-c + \sqrt{(c+2)^2 - 4}}{2} .$$

It can be shown that $\sigma^2_{\hat{\mu}_n} = p_{n-1}\sigma_y^2$. These properties are useful for studying the conditions under which this moving-average type of estimator of μ_n is effective as compared to y_n, the direct measurement of μ_n.

The value p is close to one when c is large which means that when σ_x^2 is large relative to σ_y^2 most of the weight should be accorded the last measurement of the inventory. This is reasonable since most of the information about μ_n is contained in y_n. When c is small less weight is accorded y_n. In the limiting case when c is 0, all the estimates of μ_n as given by

$$z_1 = y_1+x_1+x_2+\ldots+x_n$$

$$z_2 = y_2+x_2+x_3+\ldots+x_n$$

$$\ldots$$

$$z_{n-1} = y_{n-1}+x_{n-1}$$

$$z_n = y_n$$

have equal variances as estimates of μ_n if the y values have the same variance. In this case the average z value,

$$\bar{z} = \sum^{n} z_i/n,$$

is the mvue of μ_n with variance σ_y^2/n. This is the most improvement that the mvue of μ_n can make in estimation compared to y_n, the direct inventory measurement. This implies that little is gained when net throughput variances are large relative to the variances that occur when the inventories are measured.

When c is small p_{n-1} converges more slowly in a percentage sense to p the limiting value. Thus when the appropriate situation for use occurs the practitioner would do better to calculate the individual p_{n-1} and q_{n-1} values than to use p, the limiting value as $n \to \infty$. The value p_n is the efficiency of y_{n+1} as an estimate of μ_{n+1} since $\sigma^2_{\hat{\mu}_{n+1}}/\sigma^2_{y+1} = p_n\sigma_y^2/\sigma_y^2 = p_n$.

2.1 The Effects of Bias for the No-Loss Situation

For the purposes here it is sufficient to use p, limiting value of p_i, as an approximation to p_i, $i = 1,2,\ldots,n-1$. Then

$$\hat{\mu}_n = py_n + q\ (\hat{\mu}_{n-1}+x_{n-1}) = py_n$$

$$+ pqy_{n-1} + pq^2y_{n-2} + \ldots + pq^{n-1}y_2 + q^{n-1}y_1$$

$$+ qx_{n-1} + q^2x_{n-2} + \ldots + q^{n-1}x_1$$

If every y_i value is biased by the amount β, then $E(\hat{\mu}_n) = \mu_n + \beta p(1-q^{n-1})/1-q + \beta q^{n-1} = \mu_n + \beta$. Thus this has the same bias property as the individual inventory measurement, the usual estimate of μ_n. If every x_i value is biased by α, then $E(\hat{\mu}_n) = \mu_n + \alpha q(1-q^{n-1})/1-q = \mu_n + \alpha q(1-q^{n-1})/p$. As n gets larger $E(\hat{\mu}_n) \to \mu_n + \alpha q/p$. At $c = 1/2$, $p = q$. Since $dp/dc =$

$$-1/2 + \frac{1/2}{\sqrt{1 - \left(\frac{2}{c+2}\right)^2}} > 0, \text{ p is a}$$

monotonic increasing function of c. As n gets large and as c approaches 0, $E(\hat{\mu}_n)$ approaches $\hat{\mu}_n + \alpha q/p \to \mu_n + \infty$, since $q \to 1$, $p \to 0$.

Thus in the case where $c = \sigma_x^2/\sigma_y^2$ is small and a large number of accountability periods are considered, a small bias in the net throughput values is escalated and in addition the bias can be confounded with a real loss. Using these approximations for $c = 0.01$, $n = 25$, $p = 0.09512$, $E(\hat{\mu}_{25}) = \mu_{25} + 8.6\alpha$.

3. MVUE'S IN THE CONSTANT-LOSS CASE

The objective of this section is to present methods of using inventory and net throughput measurements from successive inventory periods to obtain best linear unbiased estimated (mvue's) of the current inventory amount and of a constant loss parameter. In this case it is assumed that there is a constant loss for every period. The results are obtained from the statistical theory of the general linear hypothesis where all the Gauss-Markov minimum variance linear unbiased estimation properties apply. The variances of the inventory measurements and net throughput measurements are assumed to be known. When these variances are known or are known except for a scalar multiplier no technique can yield unbiased estimates that have smaller variances and because the variances and standard deviations represent the best that can be attained they are very useful for studying the ultimate capabilities and limitations of loss estimates and inventory amount estimates.

An outgrowth of some properties of these techniques is that it makes it possible to investigate just how much additional information can be gained by a sequential analysis

All of the random errors ε_i and δ_i are statistically independent. It will be assumed that the ε values have a known common variance σ_y^2, and the δ values have a known common variance σ_x^2. There are no added difficulties in this

of MUF's and inventory measurements as compared to the usual mass balance statistics. In order to understand the information structure here some simplifying assumptions are made. It is assumed that the random variances of throughput and inventory measurements are constant for the different periods and

that these variances are known. A knowledge of the variances allows the mvue's of the parameters to be calculated. This in turn permits indices of the ultimate capability of this sequential analysis of MUF and inventory data to be derived such as the variances and the standard deviations of the mvue and the efficiency of the present measurement value of the inventory.

3.1 Approach 1 An Overall Least Squares Solution that Requires Only Standard Least Squares Computer Programs

In the constant loss case the model for x_i, the net throughput measurement, is changed from that in the no-loss case by the addition of L, a constant loss amount so that the model of x_i in the constant loss case is $x_i = \mu_{i+1} - \mu_i + L + \delta_i$. The model for y_i, the measurement of the beginning inventory for the ith period is $y_i = \mu_i + \varepsilon_i$, the same as in the no-loss case. The x and y values for n successive accountability periods and their models can be written as

approach if the variances are different for each dependent variable so long as they are known, or are known except for a common factor. A computer program that handles weighted least squares can be used to solve for the estimates of L and μ_i directly.

$$\begin{pmatrix} y_1 \\ y_2 \\ \cdots \\ y_{n+1} \\ x_1 \\ x_2 \\ \cdots \\ x_n \end{pmatrix} = \begin{pmatrix} 1 & & & & & \\ & 1 & & & & \\ & & \cdots & & & \\ & & & & 1 & \\ -1 & 1 & & & & 1 \\ & -1 & 1 & & & 1 \\ & & \cdots & & & \\ & & & -1 & 1 & 1 \end{pmatrix} \begin{pmatrix} \mu_1 \\ \mu_2 \\ \cdots \\ \mu_{n+1} \\ L \end{pmatrix} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \varepsilon_{n+1} \\ \delta_1 \\ \delta_2 \\ \cdots \\ \delta_n \end{pmatrix}$$

Another, essentially identical way of proceeding is to premultiply by the diagonal matrix with $1/\sigma_y$ in the first n+1 diagonal elements and $1/\sigma_x$ in the next n. This yields the relationship

Since the errors now have unit variances, the above design matrix and dependent variables enables one to use an ordinary, unweighted least squares solution. In addition the Gauss-Markov properties that the estimates are mvue also apply. Write this last formulation symbolically as

$$Z = D\beta + e$$

Then the β_i estimates, $\hat{\beta} = (D'D)^{-1}D'Z$, are the desired estimates. This formulation permits many features of the patterned data to be studied:

a. If the model and the standard deviations are correct, and if the errors are normally distributed with mean zero, the residual sum of squares is distributed as χ^2 with $(2n+1) - (n + 1 + 1) = n-1$ degrees of freedom. This property can be used to test the correctness of the model and/or of the "known" variances.

b. The matrix $(D'D)^{-1}$ gives the covariance matrix of the parameter estimates.

c. Individual x and y values can be examined for conformity to the model by the normalized residuals.

This approach requires a slightly new setup at the end of each accountability period. A little ingenuity can reduce the additional work for each new accountability period to that of just changing a few input cards. For example using L as the first parameter instead of the last would help. If a specialized program is written just for this problem, the design matrix and z values can be generated within the program from the observations and number of accountability periods. Since accountability periods are sometimes as long as six months and seldom shorter than one month there should be no pressing need to treat new x_i and y_i values as feedback requiring immediate processing.

$$
\begin{pmatrix} y_1/\sigma_y \\ y_2/\sigma_y \\ \cdots \\ y_{n+1}/\sigma_y \\ x_1/\sigma_x \\ x_2/\sigma_x \\ \cdots \\ x_n/\sigma_x \end{pmatrix}
=
\begin{pmatrix}
1/\sigma_y & & & & & \\
 & 1/\sigma_y & & & & \\
 & & \cdots & & & \\
 & & & & 1/\sigma_y & \\
-1/\sigma_x & 1/\sigma_x & & & & 1/\sigma_x \\
 & -1/\sigma_x & 1/\sigma_x & & & 1/\sigma_x \\
 & & \cdots & & & \\
 & & & -1/\sigma_x & 1/\sigma_x & 1/\sigma_x
\end{pmatrix}
\begin{pmatrix} \mu_1 \\ \mu_2 \\ \cdots \\ \mu_{n+1} \\ L \end{pmatrix}
+
\begin{pmatrix} \varepsilon_1/\sigma_y \\ \varepsilon_2/\sigma_y \\ \cdots \\ \varepsilon_{n+1}/\sigma_y \\ \delta_1/\sigma_x \\ \delta_2\ \sigma_x \\ \cdots \\ \delta_n/\sigma_x \end{pmatrix}
$$

3.2 Approach 2 MUF's as Dependent Variables, a Full Scale Generalized Least Squares Approach

The interesting aspect of this approach is that MUF's are introduced as the dependent variable. Thus the weighting of the different MUF's are obtained as the coefficients of the MUF's in the loss estimate. A MUF for the ith accountability period is defined as $y_i + x_i - y_{i+1}$ and has the model $MUF_i = L + e_{MUF_i}$ where L is the constant loss amount and e_{MUF_i} is a random error. Let $q_i = MUF_i$, $i = 1,2...,n; q_{i+n} = y_i$, $i = 1,2...,n+1$. Write

$$
\begin{pmatrix} MUF_1 \\ MUF_2 \\ \cdots \\ MUF_n \\ y_1 \\ y_2 \\ \cdots \\ y_{n+1} \end{pmatrix}
=
\begin{pmatrix} q_1 \\ q_2 \\ \cdots \\ q_n \\ q_{n+1} \\ q_{n+2} \\ \cdots \\ q_{2n+1} \end{pmatrix}
=
\begin{pmatrix}
1 & & & & \\
1 & & & & \\
\cdots & & & & \\
1 & & & & \\
 & 1 & & & \\
 & & 1 & & \\
 & & & \cdots & \\
 & & & & 1
\end{pmatrix}
\begin{pmatrix} L \\ \mu_1 \\ \mu_2 \\ \cdots \\ \mu_{n+1} \end{pmatrix}
+
\begin{pmatrix} e_i \\ e_2 \\ \cdots \\ e_n \\ e_{n+1} \\ e_{n+2} \\ \cdots \\ e_{2n+1} \end{pmatrix}
$$

or in matrix notation

$$Q = B\gamma + e$$

The covariance matrix of the errors is of the form

$$\sum\nolimits_e = \left(\begin{array}{ccccc|cccc}
2a+b & -a & \cdots & & & a & -a & & \\
-a & 2a+b & -a & & & & a & -a & \\
 & & \cdots & & & & & & \\
 & & & -a & 2a+b & & & & a \\
\hline
a & & & & & a & & & \\
-a & a & & & & & a & & \\
 & & \cdots & & & & & \cdots & \\
 & & & -a & a & & & & a
\end{array}\right)$$

where $a = \sigma_y^2$, $b = \sigma_x^2$ and the upper left and lower right square submatrices have n and n+1 rows, respectively. Then the mvue of the loss and inventory values are

$$\bar{Y} = (B'\Sigma_e^{-1}B)^{-1}B'\Sigma_e^{-1}\,Q = HQ$$

The elements in the first row of H give the coefficients of the MUF values used to obtain L, the constant loss estimate. The coefficients that multiply the individual MUF's are the same as those obtained by Jaech.[6] The variances and covariances of the parameter estimates using this approach are obtained from the $(B'\Sigma_e^{-1}B)^{-1}$ matrix.

3.3 Approach 3 A Recursive Solution

This approach gives the mvue's of μ_i, μ_{i+1}, and L based on the data from i accountability periods (μ_{i+1} is the value of the ending inventory for the ith accountability period). Let $\hat{\mu}_{(i),i}$, $\hat{\mu}_{(i),i+1}$, $\hat{L}_{(i)}$ denote, respectively, the mvue's of μ_i, μ_{i+1} and L based on i accountability periods. After i-1 periods one has $\hat{\mu}_{(i-1),i}$ and $\hat{L}_{(i-1)}$. After the next accountability period two new pieces of information are added, viz, x_i and y_{i+1} so that the models for these four dependent variables are

$$\begin{pmatrix} \hat{\mu}_{(i-1),i} \\ \hat{L}_{(i-1)} \\ y_{i+1} \\ x_i \end{pmatrix} = \begin{pmatrix} 1 & & \\ & 1 & \\ & & 1 \\ -1 & 1 & 1 \end{pmatrix} \begin{pmatrix} \mu_i \\ L \\ \mu_{i+1} \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{pmatrix}$$

or symbolically

$$Z = DP + e$$

The variables have a covariance matrix of the form

$$\sum\nolimits_e = \begin{pmatrix} a & f & 0 & 0 \\ f & b & 0 & 0 \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & d \end{pmatrix}$$

The new and more precise estimates of μ_i and L, and of the new parameter μ_{i+1} are given by

$$\begin{pmatrix} \hat{\mu}_{(i),i} \\ \hat{L}_{(i)} \\ \hat{\mu}_{(i),i+1} \end{pmatrix} = (D'\Sigma_e^{-1}D)^{-1}\,D'\Sigma_e^{-1}\,Z$$

with covariance matrix $V = (D'\Sigma_e^{-1}D)^{-1}$. The elements v_{22}, v_{23} and v_{33} in V are used for the next period and will be the elements $a = v_{33}$, $b = v_{22}$, $f = v_{23}$ in the next accountability period estimation. For the initial $\hat{\mu}_{(1),1}$, $\hat{\mu}_{(1),2}$ and $\hat{L}_{(1)}$ estimates use $\hat{\mu}_{(1),1} = y_1$, $\hat{\mu}_{(1),2} = y_2$, $\hat{L}_{(1)} = y_1 + x_1 - y_2$, $a = \sigma_y^2$, $b = 2\,\sigma_y^2 + \sigma_x^2$, $f = -\,\sigma_y^2$ and for all periods $c = \sigma_y^2$, $d = \sigma_x^2$.

The 4 x 4 matrix Σ_e is easy to invert because of its form and the matrix $D'\Sigma_e^{-1}D$ is 3 x 3 and easily inverted. The cofactor method is not usually recommended as a numerical matrix inversion procedure but it works well enough with these small matrices. Because of symmetry only six cofactors of $D'\Sigma_e^{-1}D$ have to be calculated and a computer program using approach 3 is easily written.

In the exposition of the recursive approaches as given in 3.3. and 3.4. the convention is used that the results for period i are obtained from those from period i-1, i=1,2,...,n.

When the total data set is considered, the last period is denoted by n. It is hoped that this is not confusing.

3.4 Approach 4 Recursive Estimation Without Matrices

The following approach gives the same parameter estimated without using matrices or generalized least squares. For the ith accountability periods define z_k, k = 1,2,3,4 as

$$z_1 = \hat{\mu}_{(i-1),i}/\sigma_{\hat{\mu}_{(i-1),i}}$$

$$z_2 = a_1\hat{\mu}_{(i-1),i} + a_2\hat{L}_{(i-1)}$$

$$z_3 = y_{i+1}/\sigma_y$$

$$z_4 = x_i/\sigma_x$$

where

$$a_1 = -\sigma_{\hat{\mu}_{(i-1),i}\hat{L}_{(i-1)}} \Big/ \left(D\,\sigma_{\hat{\mu}_{(i-1),i}} \right)$$

$$a_2 = \sigma_{\hat{\mu}_{(i-1),i}}/D$$

where

$$D = \sqrt{\sigma^2_{\hat{\mu}_{(i-1),i}}\,\sigma^2_{\hat{L}_{(i-1)}} - \sigma^2_{\hat{\mu}_{(i-1),i}\hat{L}_{(i-1)}}}$$

These z_i values have unit variances, zero covariances and the following expected values

$$E(z_1) = \mu_i/\sigma_{\hat{\mu}_{(i-1),i}} = \mu_i/\sigma_1$$

$$E(z_2) = a_1\mu_i + a_2L$$

$$E(z_3) = \mu_{i+1}/\sigma_y = \mu_{i+1}/\sigma_3$$

$$E(z_4) = (-\mu_i + L + \mu_{i+1})/\sigma_x$$

$$= (-\mu_i + L + \mu_{i+1})/\sigma_4$$

Minimizing $Q = \sum^4 [z_i - E(z_i)]^2$ and solving for $\hat{\mu}_{(i),i}$, $\hat{\mu}_{(i),i+1}$ and $\hat{L}_{(i)}$ gives the mvue's of μ_i, μ_{i+1}, and L at the end of the ith accountability period. The formulae for $\hat{\mu}_{(1),i+1}$, $L_{(i)}$ and $\sigma^2_{\hat{\mu}_{(i),i+1}}$, $\sigma^2_{\hat{L}_{(i)}}$ and $\sigma_{\hat{\mu}_{(i),i+1}L_{(i)}}$ are obtained as follows:

Let $c_1 = 1/\sigma_1^2$, $c_3 = 1/\sigma_3^2$, $c_4 = 1/\sigma_4^2$,

$$\Delta = (c_1+a_1^2+c_4)(a_2^2+c_4)(c_3+c_4) - 2c_4^2(a_1a_2-c_4)$$
$$- (c_1+a_1^2+c_4)c_4^2 - (a_1a_2-c_4)^2(c_3+c_4)$$
$$- (a_2^2+c_4)c_4^2$$

and $d_{21} = \left[-(a_1a_2-c_4)(c_3+c_4) - c_4^2\right]/\Delta$

$$d_{22} = \left[(c_1+a_1^2+c_4)(c_3+c_4) - c_4^2\right]/\Delta$$

$$d_{23} = -(c_1+a_1^2+a_1a_2)c_4/\Delta$$

$$d_{31} = (a_1a_2+a_2^2)c_4/\Delta$$

$$d_{32} = d_{23}$$

$$d_{33} = \left[(c_1+a_1^2+c_4)(a_2^2+c_4) - (a_1a_2-c_4)^2\right]/\Delta$$

Let

$$u_1 = z_1/\sigma_1+a_1z_2 - z_4/\sigma_4$$

$$u_2 = a_2z_2 + z_4/\sigma_4$$

$$u_3 = z_3/\sigma_3 + z_4/\sigma_4$$

Then

$$\hat{L}_{(i)} = d_{21}u_1 + d_{22}u_2 + d_{23}u_3$$

$$\hat{\mu}_{(i),i+1} = d_{31}u_1 + d_{32}u_2 + d_{33}u_3$$

and

$$\sigma^2_{\hat{L}_{(1)}} = d_{22}, \qquad \sigma^2_{\hat{\mu}_{(i),i+1}} = d_{33},$$

$$\sigma_{\hat{\mu}_{(i),i+1}\hat{L}_{(i)}} = d_{23}.$$

These are all the relationships needed to generate the estimates for the next accountability period when augmented by x_{i+1} and y_{i+2}.

3.5 Approach 5 An Approach Based on Some Previous Results

This approach is based on an extension of some previous results,(2,3,4) and gives easy methods for calculating $\hat{\mu}_{(n),n+1}$, $\hat{L}_{(n)}$, $\sigma_{\hat{\mu}_{(n),n+1}}$, $\sigma_{\hat{L}_{(n)}}$ and the covariance between $\hat{L}_{(n)}$ and $\hat{L}_{(n+1)}$. Several intermediate steps will be stated without proof.(3,4)

It can be shown that the values $M_i = \hat{I}_i + x_i - y_{i+1}$; i=1,2...,n have zero covariance where the $\hat{I}_i$ inventory estimates are obtained recursively from the relationship

$$\hat{I}_i = p_{i-1}y_i + (1-p_{i-1})\,(\hat{I}_{i-1} + x_{i-1})$$

$$= p_{i-1}y_i + q_{i-1}(\hat{I}_{i-1} + x_{i-1})$$

The p_{i-1} values are obtained from a recursive relationship as shown in Section 2. The $\hat{I}_i$ value, as calculated here is algebraically identical to $\hat{\mu}_i$ as given in Section 2. The different notations for algebraically identical values is introduced to distinguish between $\hat{I}_i$, a biased estimate in a constant loss situation from $\hat{\mu}_i$, a mvue in a no-loss situation. For the constant loss situation the expected value of M_i is

$$E(M_i) = L(1 + q_{i-1} + q_{i-1}q_{i-2} + \dots + q_{i-1}q_{i-2}\cdots q_2q_1)$$

$$= L\theta_i \text{ say}$$

where $\theta_1 = 1$. The standard deviation of M_i is

$$\sigma_{M_i} = \sqrt{\sigma_y^2(1 + p_{i-1}) + \sigma_x^2} = \frac{\sigma_y}{\sqrt{q_i}}$$

Then $(M_i - L\theta_i)/\sigma_{M_i}$ has zero mean and unit variance. Let

$$Q = \sum_{i=1}^{n}\left(\frac{M_i - L\theta_i}{\sigma_{M_i}}\right)^2$$

$$= \frac{1}{\sigma_y^2}\sum^{n} q_i(M_i - L\theta_i)^2$$

Q is minimized when L has the value

$$\hat{L}_{(n)} = \frac{\sum^{n} M_i\theta_i/\sigma_{M_i}^2}{\sum^{n} \theta_i^2/\sigma_{M_i}^2} = \frac{\sum^{n} q_iM_i\theta_i}{\sum^{n} q_i\theta_i^2}$$

$$= \frac{\sum^{n} (\theta_{i+1} - 1)M_i}{\sum^{n} q_i\theta_i^2}$$

with standard deviation

$$\sigma_{\hat{L}_{(n)}} = \frac{1}{\sqrt{\sum^{n} \theta_i^2\,\sigma_{M_i}^2}} = \frac{\sigma_y}{\sqrt{\sum^{n} q_i\theta_i^2}}$$

The mvue of the last inventory value can be obtained from

$$\hat{\mu}_{(n),n+1} = \hat{I}_{(n+1)} - \hat{L}_{(n)}(\theta_{n+1} - 1)$$

which has a standard deviation of

$$\sigma_{\hat{\mu}_{(n),n+1}} = \sigma_y\sqrt{p_n + \frac{(\theta_{n+1} - 1)^2}{\sum^{n} q_i\theta_i^2}}$$

(It can be shown that $\hat{I}_{(n+1)}$ and $\hat{L}_{(n)}$ have zero covariance.) These relationships can be used to determine how much additional information can be gained from a sequential analysis of MUF and inventory data. This method presents a simple way of calculating the covariance between $\hat{L}_{(n)}$ and $\hat{L}_{(n+1)}$ which is $\sigma^2_{\hat{L}_{(n+1)}}$.

Since $\theta_i = q_{i-1}\theta_{i-1} + 1$; p_i and q_i are found from simple recursive relationships from p_{i-1} and q_{i-1}; $\hat{I}_i = p_{i-1}y_i + q_{i-1}(\hat{I}_{i-1} + x_{i-1})$; it is apparent that this approach is easy to use in a recursive way. The variances of $\hat{L}_{(i)}$ and $\hat{\mu}_{(i),i+1}$ can also be determined recursively.

It can be shown that

$$M_n = MUF_n + q_{n-1}MUF_{n-1} + q_{n-1}q_{n-2}MUF_{n-2} + \dots + q_{n-1}q_{n-2}\cdots q_2q_1MUF_1,$$

so that the coefficient of MUF_n in $\hat{L}_{(n)}$ is $q_n\theta_n/{}^{n}\, q_i\theta_i^2$. This has implications regarding the robustness of $\hat{L}_{(n)}$ as a detection statistic against all kinds of diversion strategies.

The fact that $E(M_n) = L\theta_n > L$, actually enhances the ability to detect a loss in the constant loss situation. However M_n is not as sensitive as $\hat{L}_{(n)}$ in the constant loss case but is more powerful in the block loss case where the loss occurs in the last period.

DISCUSSION

The assumption that the random variances in the x and y variables are known will in many cases be valid for all practical purposes. Net throughput or inventory measurements usually consist of the sum and/or differences of the amounts of many items and in this sense the random errors of measurement of x and y are sums of random errors so that the total random error as represented in an x or y values is diminished in a percentage and probabilistic sense as compared to the random error in an individual item.

As long as the design matrix is correct, the estimates of the parameters will be unbiased. If the design matrix is correct but the form of the error structure is incorrectly represented, the estimates are still unbiased but the variances ascribed to these estimates could be seriously in error. If the design matrix is correct, the pattern of the error structure is correctly represented and the variance and covariance estimates are off to only a small degree, the effect will be small on the mvue properties of the parameter estimates and on estimating the variance of the parameter estimates. As indicated before the residual variance can sometimes be used to gauge the correctness of the variance and covariance estimates.

For the situation where an occasional loss occurs, the technique of using a regression model with no loss parameter and looking at the *normalized residual* of the x (*net throughput*) variables may be the most sensitive. A normalized residual is $r_i/\sigma r_i$, where r_i is $x_i-\hat{x}_i$ or $y_i-\hat{y}_1$, as the case may be.

The most serious objection of all to the approaches given herein is that they do not include systematic errors of measurement. In many mass balance situations the systematic error variance components tend to be the largest part of the variance of MUF. The procedures discussed create estimates that have minimum variance as far as the random variance components are concerned but often this is only one small part of the overall MUF uncertainty problem.

A future article in the Journal will relate $\hat{L}_{(n)}$ and M_n to each other and to MUF and cumulative MUF, the usual loss statistics, by the use of tables and power-to-detect-loss curves. The comparisons will be based on $c = \sigma_x^2/\sigma_y^2$; n, the number of accountability periods and whether the loss is of a constant or one-time nature.

The main result of this paper is that there are a number of ways of obtaining the mvue's of the loss amount and the ending inventory, and the way of proceeding depends upon computer capabilities and preference as to the approach to take. It might not be a bad idea to use several approaches in order to check out the computer programs.

SYMBOLS AND TERMINOLOGY

y_i	The inventory measurement at the beginning of the ith period
x_i	The net throughput measurement for the ith period
σ_x^2	The variance in the net throughput
σ_y^2	An inventory variance
c	$c = \sigma_x^2/\sigma_y^2$
μ_j	The true value of the jth inventory
$\mu_{(i),j}$	The mvue of μ_j based on the information from i accountability periods in the constant loss.
p_j	A continued fraction obtainable from $p_j = (p_{j-1}+c)/(p_{j-1}+c+1)$
q_j	$q_j = 1 - p_j$
$\hat{I}_j$	The estimate of the jth inventory based on the recursion relationship $\hat{I}_j = p_{j-1}\, y_j + q_{j-1}\,(\hat{I}_{j-1} + x_{j-1}),\ p_0 = 1$ in the constant loss case.
$\hat{\mu}_j$	The estimate of the jth inventory in the no-loss case. It is algebraically identical to $\hat{I}_j$.
mvue	Minimum variance unbiased estimate
θ_n	The expected value in $M_{(n)}$ in the constant loss case is $L\theta_n$.
$\hat{L}_{(i)}$	The mvue of the constant loss amount at the end of the ith period
MUF_i	$MUF_i = y_i + x_i - y_{i+1}$
M_i	$M_i = \hat{I}_i + x_i - y_{i+1}$

REFERENCES

1. Pike, D. H., and G. H. Morrison, A New Approach to Safeguards Accounting, ORNL/CSD/TM-25, March 1977.

2. Stewart, K. B., B-PID and Inventory Estimates with Minimum Variance, HW-56536, Hanford Atomic Products Operation, Richland, WA., July 28, 1958.

3. Stewart, K. B., "A New Weighted Average," Technometrics, 12, May 1970, pp. 247-258.

4. Stewart, K. B., Statistical Techniques for Enhancing the Role of Materials Balance Accounting in Safeguards, BNWL-1386, UC-15, May 1970.

5. Bennett, C. A., "Some Effects of False Positives," Proceedings 14th Annual Meeting, INMM, Vol II, No. 3, Fall 1973, pp. 110-125.

Reconstruction of An Account's Past

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ABSTRACT

Historical records and data frequently have been reduced by combination of accounts. The problem we address is that of finding all ways a given set of accounts could have been combined to give some given set of reduced accounts. An algorithm has been developed to accomplish this task and a computer code in FORTRAN is given. An example with some MUF data is also presented.

1. Introduction

Recent interest in accountability and safeguards has prompted investigation into historical records and historical data. These records and data have been reduced by combination of accounts. In this situation, MUFs from various accounts were added to form a reduced number of MUFs associated with new accounts. Records on which accounts were combined are frequently missing. Sometimes it is not even clear what accounts are candidates for forming the new accounts.

Thus the problem of current interest is retracing the (paper) tracks of an account. Our formulation of the problem is that we are given a possible set of m accounts $\{x_1, x_2, \ldots, x_m\}$ which may have been combined to give a new set of n accounts $\{y_1, \ldots, y_n\}$. The solution is a program which produces as output all possibilities (if any exist) for producing the desired result.

Another situation to which our results might be applied is when the set $\{x_1, \ldots, x_m\}$ are measurements of m initial accounts and the set $\{y_1, \ldots, y_n\}$ are measurements of n accounts which are measured after the initial accounts were physically combined. This situation motivates us to find all ways of combining x's to give y's with an error bound.

In the next section we give a careful and precise description of the problem and discuss its solution.

2. Algorithm

To make a formal statement of the problem, some notation must be introduced. Let

$$\underset{\sim}{x} = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{pmatrix},$$

$$\underset{\sim}{y} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix},$$

and

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & & \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{pmatrix}$$

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where $a_{ij} = 0$ or 1 and $\sum_{i=1}^{n} a_{ij} \le 1$ for all j. Our object is to find all A satisfying the above conditions such that

$$\text{(I)} \quad A\underset{\sim}{x} = \underset{\sim}{y}$$

or

$$\text{(II)} \quad |(A\underset{\sim}{x})_j - y_j| \le e_j \text{ for all } j,\ 1 \le j \le n,$$

where $0 \le e_j$ is some given error bound on the $j^{\underline{th}}$ entry. Of course, I is equivalent to II if $e_1 = e_2 = \ldots = e_n = 0$.

The program given in section 4 is for the more general situation II but, for ease of discussion, we consider case I here. To force the program to do case I, simply set the error vector (E) there equal to 0.

Next, we discuss the meaning of the restrictions on A. When $a_{ij} = 1$, this means x_j was used in the sum to obtain y_i. Of course, $a_{ij} = 0$ means x_j was not used to obtain y_i. The restriction $\sum_{i=1}^{n} a_{ij} \le 1$ is interpreted as x_j can be used at most once in all sums for the y's. Clearly, any x_j should not be used more than once. Allowing x_j not to be used at all makes it possible to search over a larger set of x's than were actually used to produce $\underset{\sim}{y}$.

The most naive algorithm to find possible A's would be to try each subset of $\{x_1, x_2, \ldots, x_m\}$ to obtain each y_j and reject any collections that were inconsistent or failed to yield $\underset{\sim}{y}$. With this algorithm, $(2^m)^n = 2^{mn}$ cases must be considered. For m = n = 10, this amounts to approximately 1.27×10^{30} cases. Clearly, no existing computer can handle this case.

To make a faster algorithm, we now consider only A's satisfying the restrictions $a_{ij} = 0$ or 1 and $\sum_{i=1}^{n} a_{ij} \le 1$ for all j. There are $(n + 1)^m$ such cases. For m = n = 10, $(n + 1)^m = 2.59 \times 10^{10}$, still a large number of cases.

The algorithm we employ makes an important modification of the scheme mentioned in the preceding paragraph. If a candidate A is found where a collection of rows such that the corresponding x sums do not yield the corresponding y values, no other A's which contain these rows will be considered. This procedure, known in computer science as backtracking, greatly speeds up the running time.

Another modification we have failed to make is the elimination of A's where the only difference is permutation of x values that are equal. Frequently, ± 1 and 0 are repeated values of x so that this would be an important improvement. However, we are unable to retain backtracking and include this modification.

3. Example

Sometimes a declared MUF is obtained by adding several intermediate or temporary MUFs kept by production people on the shop floor. If this declared MUF is thought to be the only MUF of interest, the record relating the temporary MUFs to the declared MUF may be destroyed. However, since the temporary MUFs are part of the production records, they are usually still available.

To make these ideas specific, suppose the following information is available from the production people:

Intermediate MUF (grams)	Throughput (kilos)
10	.1
-50	7.0
75	1.2
-15	1.0
-100	.9
20	1.5
5	.1
5	6.0
60	.9
-10	1.4

Each MUF is that declared for the operation of a given process in a given month. The declared MUFs are given below.

Declared MUF (grams)
10
25
-95
60

When examining the declared MUFs, the 60 gram MUF is singled out for further investigation. One part of this investigation is to determine the throughput associated with this MUF. Unfortunately the throughput is not part of the record, and an attempt must be made to reconstruct the events that led to this MUF.

Here m = 10, n = 4,

$$\underset{\sim}{x} = \begin{pmatrix} 10 \\ -50 \\ 75 \\ -15 \\ -100 \\ 20 \\ 5 \\ 5 \\ 60 \\ 10 \end{pmatrix}, \text{ and } \underset{\sim}{y} = \begin{pmatrix} 10 \\ 25 \\ -95 \\ 60 \end{pmatrix}$$

Define the throughput vector $\underset{\sim}{t}$ by

$$\underset{\sim}{t} = \begin{pmatrix} .1 \\ 7.0 \\ 1.2 \\ 1.0 \\ .9 \\ 1.5 \\ .12 \\ 6.0 \\ .9 \\ 1.4 \end{pmatrix}$$

Running our program, we obtain 50 A matrices. That is, there are 50 distinct ways of combining $\underset{\sim}{x}$ to obtain $\underset{\sim}{y}$. If A is a typical matrix, then our interest is in the last component of

$$\underset{\sim}{s} = A\ \underset{\sim}{t} = (s_1, s_2, s_3, s_4).$$

For the first output matrix A^1,

$$\underset{\sim}{s} = A^1\ \underset{\sim}{t} = \begin{pmatrix} 0&0&0&0&0&0&1&1&0&0 \\ 0&1&1&0&0&0&0&0&0&0 \\ 0&0&0&1&1&1&0&0&0&0 \\ 0&0&0&0&0&0&0&0&1&0 \end{pmatrix} \begin{pmatrix} .1 \\ 7.0 \\ 1.2 \\ 1.0 \\ .9 \\ 1.5 \\ .1 \\ 6.0 \\ .9 \\ 1.4 \end{pmatrix}$$

$$= (6.1,\ 8.2,\ 3.4,\ .9).$$

Thus, $s^1_4 = .9$.

Continuing this procedure, we find 14 throughputs of 2.2 kilos and 36 throughputs of .9 kilos. This information can then be given to the group investigating the 60 gram MUF.

4. Program

```
      SUBROUTINE TRACE(X,M,Y,N,E)
      DIMENSION IA(30,30), X(30), Y(30), E(30)
********************************************
*  M X-VALUES ARE SEARCHED TO GIVE SUMS    *
*  EQUAL TO N Y-VALUES WITHIN ERROR E      *
********************************************
      WRITE (5,100)
      WRITE (5,110)((I,X(I)),I=1,M)
      WRITE (5,120)
      WRITE (5,130)((I,Y(I)),I=1,N)
      WRITE (5,140)
      DO 10 I=1,N
      DO 10 J=1,M
   10 IA(I,J)=0
      I=0
   20 I=I+1
      IF (I.EQ.N+1) GO TO 70
   30 CALL ADD (IA,I,IEND,M)
      IF (IEND.EQ.1) GO TO 50
      SS=-Y(I)
      DO 40 J=1,M
   40 SS=SS+X(J)*IA(I,J)
      CHK=ABS(SS)
      IF (CHK.LE.E(I)) GO TO 20
      GO TO 30
   50 IF ((IEND.EQ.1).AND.(I.EQ.1)) GO TO 90
      DO 60 L=I,N
      DO 60 J=1,M
   60 IA(L,J)=0
      I=I-2
      GO TO 20
   70 WRITE (5,150)
      DO 80 L=1,N
   80 WRITE (5,160)(IA(L,J),J=1,M)
      I=N
      GO TO 50
   90 RETURN
C
  100 FORMAT (6X,*LIST OF ALL A SATISFYING*,
     */,16X,*AX=Y*,/,6X,*WHERE*,/)
  110 FORMAT (16X,*X(*,I2,*)=*,F10.5,/)
  120 FORMAT (6X,*AND*,/)
  130 FORMAT (16X,*Y(*,I2,*)=*,F10.5,/)
  140 FORMAT (/,6X,*IF A(I,J)=1,THEN X(J)*,
     **WAS USED TO MAKE Y(I)*)
  150 FORMAT (/,/,/,/,/,6X,***A***)
  160 FORMAT (X,30(X,I1))
      END
      SUBROUTINE ADD(IA,L,IEND,M)
      DIMENSION IA(30,30)
      IEND=0
      J=M+1
   10 J=J-1
      IF (J.EQ.0) IEND=1
      IF (J.EQ.0) GO TO 50
      IT=0
      IF (L.EQ.1) GO TO 30
      LL=L-1
      DO 20 K=1,LL
   20 IT=IT+IA(K,J)
   30 IF (IT.NE.0) GO TO 10
      IF (IA(L,J).EQ.0) GO TO 40
      IA(L,J)=0
      GO TO 10
   40 IA(L,J)=1
   50 RETURN
      END
```

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NUSAC Appoints Klingelhoefer

Dr. **Ralph F. Lumb**, President of NUSAC, Inc. has announced the appointment of **John W. Klingelhoefer** as a Senior Technical Associate in the Security Programs Division. Klingelhoefer's responsibilities will include participating in corporate security audits and in developing document control procedures of securing proprietary information concerning nuclear power generating stations.

Klingelhoefer comes to NUSAC from the U.S. Army where he was project manager for all aspects of security as related to the transportation and storage of weapons grade materials and associated hardware. He holds a B.S. degree in Engineering from the U.S. Military Academy.

NUSAC is an independent consulting firm providing assistance to the nuclear power generating industry. Its services include management audits of quality assurance and physical security programs, auditing of nuclear fuel fabrication, development of material safeguards design and procedures, and the design and implementation of physical security plans and procedures.

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