IN THIS ISSUE

16th Annual Meeting, Institute of Nuclear Materials Management, Hotel Monteleone in the French Quarter, New Orleans, La., June 18-20, 1975.

INMM

NUCLEAR MATERIALS MANAGEMENT

VOL. III, NO. IV

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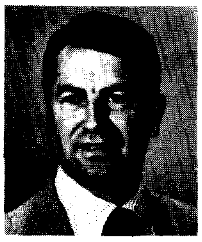

Mr. Soucy

Report of Recent Institute Activities

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

Your Officers and Executive Committee members held their first meeting of the calendar year 1974-1975 on September 22, 1974. At that meeting, plans were formulated for the new year and a number of appointments to standing committees were voted upon. Following is a summary of the results of this meeting together with other INMM developments.

Safeguards Committee

The first major action of the year has been to reactivate the Safeguards Committee. Some of you may recall that under a previous Safeguards Committee the Institute was the first organization to express concern with the transportation of nuclear materials. This concern was outlined in a comprehensive report prepared under the direction of Lou Strom. Dennis Wilson, of the General Electric Company, has accepted the Chairmanship of the reorganized Safeguards Committee. Dennis has already successfully recruited an impressive list of members to assist him. Their first assignment has been to evaluate the proposed Safeguards as discussed in WASH-1327, General Environmental Statement Mixed Oxide Fuel, (GESMO). The results of their evaluation were submitted to the USAEC in a lengthy document on October 30, 1974. It is our view that this committee has great potential and will be a major source of information for the nuclear industry.

Certification

For some years, we have been concerned about the development, acceptance, and overall goals of our Certification Program. Dr. Frederick Forscher, President of Energy Management Consultants Corporation, and a member of the Executive Committee of the Institute, has accepted the responsibility to evaluate our Certification Program. Dr. Forscher reports that he has already had a number of meetings with members of Regulatory Agencies and other professional groups.

A major accomplishment has been the assignment of a Charter by the American National Standards Institute, Inc. to develop a standard for Certification. This standard has been designated as N15.28, **"Standard for Certifying Nuclear Materials Managers."**

Standards

Possibly the most significant accomplishment of the Institute since its incorporation has been the development of standards on Nuclear Materials Control. Our accomplishments in this area were recognized by the American National Standards Institute, Inc. at our Atlanta meeting when a special award was presented to Bob Delnay in recognition of the Institute's work. We are fortunate to have John Jaech of Exxon Nuclear Corp. accept the Chairmanship of N15, now that Bob Delnay has resigned. John is faced with the major problem of developing standards for the security of Special Nuclear Material, a task which has been assigned to the Institute in view of our excellent work in other areas of Nuclear Material Control. John is known as a man of accomplishment in the standards area and he is agressively organizing his sub-committees. He has already succeeded in accelerating progress on a number of standards.

I trust that members who are involved in the development of standards will work diligently to assist John. He would also appreciate offers of assistance from INMM members who wish to participate in standards work.

Annual Technical Meeting

As most of you are now aware, the 16th Annual Meeting of the Institute will be held in New Orleans, Louisiana, on June 18th, 19th and 20th, 1975. The Institute is fortunate to have Dr. G. Robert Keepin accept the Chairmanship of the Technical Program Committee. Bob Keepin has moved quickly to assemble an

(Continued on page 3)

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EDITORIAL

Mr. Higinbotham

Let's Get More Specific

By W.A. Higinbotham
Executive Editor

The word is that the intervenors have turned their attention from reactor safety to safeguards, which puts the ball squarely in our court. Our chairman recently appealed to the membership to join in the public debate. Yes, but that will not be easy. To respond to each misstatement of fact or gross misconception that appears in print or on the airwaves, could employ half of our membership full time.

Correcting misstatements is rather a futile effort, anyway. The damage is done on page one under glaring headlines. The antidote appears in letters to the editor, a page primarily of interest only to those who write letters to the editor. Fortunately, the memory of the casual reader is short.

The important people are those who will be directly or indirectly involved in approving or disapproving a reactor site or rejecting or approving the generic environmental statement on mixed-oxides. These are politicians, writers, members of the League of Women Voters, community leaders and environmentalists. Many of these people still have open minds. But nuclear theft and sabotage are more subjective subjects and less subject to quantitative analysis than, say reactor safety. Different people are bothered in different ways. It is doubtful that one could write a white paper that would be universally or even generally convincing. It begins to look like each individual and each group will want to have answers to his particular set of questions.

Elsewhere in this issue a letter is reprinted from the INMM Safeguards Committee to S.H. Smiley. The AEC issued the GESMO draft in late August with a request for comment within 6 weeks. Members of the committee do not feel very happy with their letter, but say it was the best they could do on such short notice. Actually, it still sounds pretty good to me.

Right now, plutonium-recycle appears to be the focus of attention. GESMO lists a number of unresolved topics in the safeguards field. The Nuclear Regulatory Commission is now trying to resolve these issues in a way that should convince reasonable people that safeguards can be very effective. A lot hangs on this exercise. Perhaps INMM could expand on some of the proposals in our letter. We recognize that there may be weaknesses. Could we be more specific about fixing them?

DUES NOTICE

"There are over 100 members who have not yet paid their FY1975 dues. The Institute must meet its obligations and expects its members to do likewise. Members in arears at the end of the year will be dropped. Please send your dues to the treasurer promptly." — Ralph J. Jones, INMM Treasurer.

Soucy's Report on Institute Activities

(Continued from Inside Front Cover)

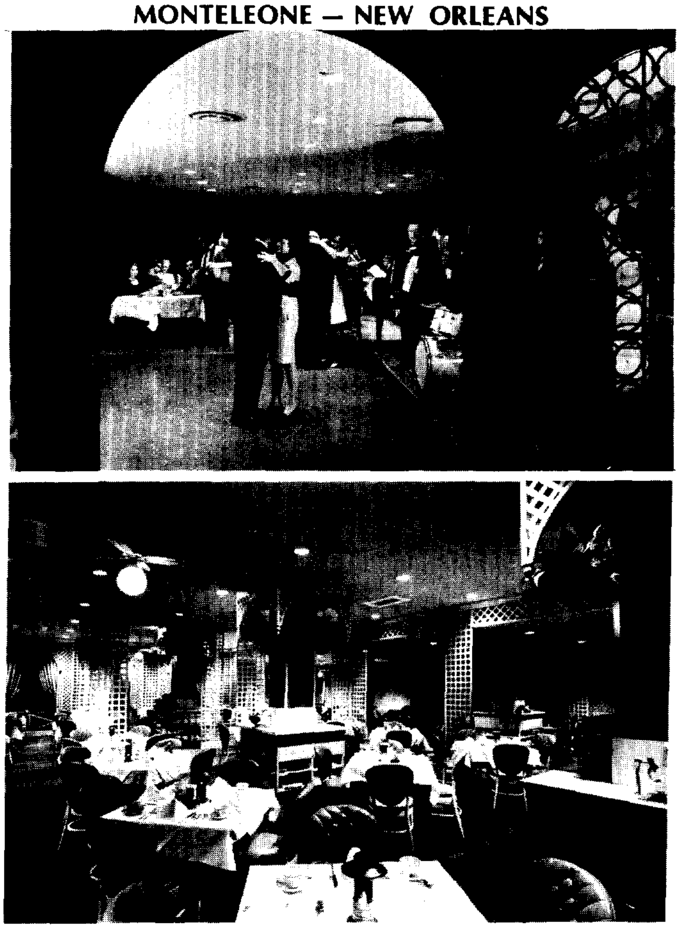
outstanding group of speakers for our New Orleans meeting. An indication of the caliber of participants that we expect to have at the New Orleans meeting is shown by some of the people that Bob has invited to the meeting. Personalities such as R. Rometsch, Inspector General of the International Atomic Energy Agency, the Honorable Henry M. Jackson, and Major General Edward B. Giller, Assistant General Manager for National Security of the AEC. With the continuing rapid developments in the area of Nuclear Materials Safeguards, it is almost imperative that anyone interested in the subject of nuclear materials safeguards should plan to attend the Institute's next Technical meeting.

Education

A logical activity of the Institute is to promote Education on the subject of Nuclear Material Control. During the month of November, the Institute sponsored, for the first time, the Annual Educational courses on Safeguards at the Argonne Center for Educational Affairs, under the direction of Dr. Manuel A. Kanter. Under the prodding of Dr. Kanter, the Officers of the Institute signed a contract with the Argonne center, whereby the Institute agreed to pay all of the expenses of the Argonne program which were estimated to be $15,000. We are pleased to report that the receipts for tuition fees for attendance at the school were substantially above cost of operating the educational sessions. The Institute, therefore, is in the pleasant position of having a substantial surplus in its Education account. We plan to apply these funds to future Educational Programs.

There are, of course, numerous other members of the Institute working to implement our basic objective which is to further the advancement of Nuclear Materials Management in all aspects. Although the techniques of Nuclear Materials Management have advanced, we continue to be particularly concerned over numerous newspaper articles which accentuate the negative aspects of Nuclear Materials. We ask that you attempt to counter some of the misinformation which is given publicity, by writing letters in which you provide the facts. We also again invite you to comment on all aspects of the Institute's business and we are, of course, always receptive to offers of assistance in the work of the Institute.

MONTELEONE — NEW ORLEANS



ANSI N15 REPORT

J.L. Jaech, Staff Consultant, Statistics, Exxon Nuclear Company, Richland, Wash., is shown lecturing this past fall in an INMM-sponsored course at Argonne (Ill.) National Laboratory in Nuclear Materials Control.

TIME TO BE ACTIVE IN WRITING NEEDED STANDARDS

By John L. Jaech
N15 Chairman

In the Spring 1974 issue of this journal, there appeared an article by Bob Delnay, then the Chairman of N15. This article was concerned with standards development.

I refer the reader to this article because it emphasizes that we members of the Institute who are engaged in standards-writing activities are currently struggling through changes in leadership that are affecting our productivity. To be more specific, in addition to my replacing Bob Delnay as N15 Chairman, of the 9 individuals listed as Subcommittee Chairman in the article, 7 are no longer serving in this capacity. The only two individuals who continue as chariman are R.E. Weber (INMM-4) and L.W. Doher (INMM-8). Dick Alto provides continuity as N15 Secretary and he has done a fine job in this capacity.

We are taking steps to fill these vacancies. As of this writing, Dick Schneider has agreed to serve as chairman of INMM-6, and Dennis Bishop is the new INMM-9 chairman. Bill Shelley had previously agreed to chair INMM-10 as reported in the Fall 1974 issue. By the time this appears in print, it is my hope that all the vacancies will have been filled.

With the proliferation of government regulations and guides concerned with nuclear materials safeguards, and with public attention becoming increasingly focused on this phase of our activities, it is clear that now is the time to become especially active in writing needed standards. It is my fond hope that we will collectively meet this challenge and demonstrate that INMM can indeed operate as a responsible secretariat in this important activity.

To the outgoing chairmen and to those who continue to function as chairmen, we express our appreciation to you and to your unnamed committee members for your past efforts. To our new chairmen, welcome aboard, and may you find satisfaction in your labors.

Mr. Patterson

PATTERSON CERTIFIED

Mr. James P. Patterson has been named a certified Nuclear Materials Manager by the Institute of Nuclear Materials Management, according to an announcement by INMM chairman, Armand R. Soucy. Mr. Patterson is a Safe-guards Inspector with the U.S. Atomic Energy Commission's Region III Materials and Plant Protection Branch in Glen Ellyn, Illinois.

The Institute is a technical society of approximately 400 qualified, professional individuals having responsibility for the management and safeguards control of nuclear materials in industry, government and academic institutions. Professional certification is extended only to those individuals who have demonstrated exemplary performance through several years of progressive, responsible experience in the management of nuclear materials and have satisfactorily completed a comprehensive written examination. The distinction is then granted upon the recommendation of the INMM Committee on Professional Standards and Certification.

Mr. Patterson is a graduate of the University of Notre Dame and holds a B.S. in Physical Science. He was employed in 1957 by Argonne National Laboratory and performed duties relative to the control and accountability of nuclear materials utilized in the laboratory complex. In 1968, Mr. Patterson joined the Atomic Energy Commission and was assigned as a Safeguards Inspector in the Division of Nuclear Materials Safeguards District III Office in Berkeley, California.

When the AEC underwent a reorganization in May, 1972, resulting in the creation of the present Materials and Plant Protection Branch in Glen Ellyn, Mr. Patterson volunteered to return to the Chicago area to help staff the new created office. His present responsibilities include inspection of nuclear power plants for compliance with federal regulations pertaining to safeguards of nuclear materials and physical security of the overall facility.

Letter to Editor

WHEN WILL WE EVER LEARN?

Ordinarily I am not a nostalgia buff. I believe, for example, that an antique is something so useless that it never wore out. I do have one collection of memorabilia of sorts, however — newspaper clippings and personal notes of conversations regarding unacceptably large MUFs. It's a disturbing collection, for a number of reasons.

First, the number of companies listed. Or perhaps I should talk about the number of companies that are not listed. Very few major companies are conspicuously absent.

Second, the total dollar value. The usual comparison is with the total dollar value of the inventory or throughput of the facility, or with the quantity needed to make one or more weapons. Despite some occasional scare headlines, I don't think those comparisons are too bad. Try comparing the dollar value of an apparent MUF with the budget of the responsible NMC staff, however. I suggest that in most cases a doubling of the budget of the NMC staff would have been a cheaper alternative.

Third, the failure of one company to learn from the bad experience of another. Most MUF incidents are not publicized, but they are fairly common knowledge among the insiders. Why then do the incidents keep recurring? Why must each company insist on making its own mistakes?

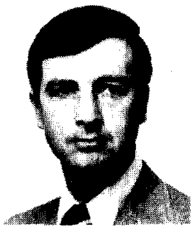
For the record, I personally am satisfied that most or all of these incidents have been resolved. I do not believe that any nuclear material has been diverted. I do believe that too much material has been unnecessarily lost, and that too much money has been spent chasing investigations that would have been unnecessary if there had been adequate material control. Most NMC departments do not need to have their budget doubled in order to be effective. Mainly they need to have their authority doubled.

I have before me two newspaper clippings that are less than a week old. The first adds another company to my scrapbook, and suggests that another million dollars in material is missing. The second suggests that a reinventory resolved the problem. I hope so. Neither article discusses the financial loss to the company in having to take a second inventory on a panic basis, and neither article asks whether any changes have been made to reduce the probability of a recurrence.

When will we ever learn?

James E. Lovett
Vienna, Austria

ADVERTISING INDEX


Mr. Dale

PUBLIC RELATIONS EDITORIAL

OPPORTUNITY IS KNOCKING!

By Larry F. Dale, Chairman
INMM Public Relations Committee

The old cliche "Opportunity only knocks once!" certainly applies to many of our lifetime endeavors. When we fail to take advantage of opportunity, disappointment usually accompanies the realization that we have blown that one and only chance. However, in some instances, opportunity knocks time and time again. How many times did Sherlock Holmes have an opportunity to outwit Moriarity? Perhaps this is somewhat analogous to the situation in which the Institute nows finds itself.

For several years now, we have been seeking public and industry recognition for the Institute. But have we taken advantage of all the opportunities available to us? I think not! How many times has each of us read a newspaper or magazine article indicting the nuclear industry for slipshod practices in nuclear materials control and accountability, and then said to ourselves, "Someone should write that clown and set him straight," while we casually turned to the next page? Our accusers do not pass up an opportunity to present their case and neither should we.

There are several means by which we, as a technical organization or as individuals, can present the Institute's position. Among these are resolutions, position papers, letters to the editor, articles, and public speaking. Presentations on behalf of the Institute can serve two main purposes. First, and foremost, they can inform the public as to the true facts about nuclear materials safeguards. The second purpose is to promote the Institute's public recognition and acceptance, thereby causing it to become an even more formidable vehicle for disseminating factual information.

Several of our members have been individually accepting the challenge and answering opportunity's knock. As an organization we took a giant step forward last year at the 15th Annual Meeting by adopting and making public a resolution detailing our position on the subject of providing nuclear reactors and fuel materials to developing nations. These recent indicators are most encouraging.

The upcoming 16th Annual Meeting in New Orleans may prove to be very critical for the Institute's continued growth. Our attitudes and actions (or inactions) in June may well provide the catalyst to propel the Institute into a position of prominence in the industry, or the lethargy which will relegate it to oblivion. It appears that we have reached a fork in the road, and the direction we choose is a decision that msut be made in the near future. That decision is ours alone to make.

Opportunity Is Knocking! Let us each resolve to approach the New Orleans meeting with an aggressive attitude and a positive plan to answer that knock. If we do any less, then we are not fulfilling the stated objectives of the Institute of Nuclear Materials Management.

One of INMM's most dedicated members is Roy G. Cardwell (left) of the Oak Ridge (Tenn.) National Laboratory. Mr. Cardwell is the current INMM Vice Chairman and served in the important post of Technical Program Committee Chairman for recent annual meetings of the Institute. He is shown here conferring with a registrant at the 15th annual INMM meeting last June in Atlanta, Ga.

INVITATION TO NEW ORLEANS

PREDICTS OUTSTANDING INMM MEETING IN JUNE

By Roy G. Cardwell
INMM Vice Chairman

Committee activities are now in full swing to prepare for the 1975 Annual Meeting in New Orleans at the Hotel Monteleone.

The Monteleone is a charming facility on the edge of the famous French Quarter and within walking distance of many attractions. In the daytime, you can ramble from shop to shop through antiques and curiosities such as you have never seen, have lunch at any one of several world-famous restaurants, and spend the afternoon on the square watching "Brush Magicians" recreate the old city in colorful paintings. After sundown, the quarter blossoms into a mass of dancing pulchritude mixed with large proportions of the famous "SATCHMO" JAZZ to round out your day's entertainment.

Several conversations with Program Chariman Bob Keepin indicate a most attractive speaker lineup for the general sessions. These will be announced as soon as all are confirmed, but we are sure it will be the kind of lineup you won't want to miss.

The call for papers has been out for a few weeks now. If you did not receive one, a note or phone call to Tom Gerdis, our Editor, will get one on its way to you. Remember, the deadline is March 1.

The charm and southern hospitality of old New Orleans awaits you in June!

Mr. DeVito

REPORT ON SEPTEMBER INMM EXECUTIVE MEETING

By V.J. DeVito
Secretary of INMM

An Executive Committee meeting was held on September 22, 1974, in Miami Beach, Florida. Many members of the Executive Committee and the committee Chairman were on hand to attend, during that week, the Fourth International Symposium on Packaging and Transportation of Radioactive Materials.

The financial statements presented by Ralph Jones, Treasurer, showed that for the fiscal year 1974 there was a net gain in the INMM financial balance of $1,602. The cash balance at the end of the fiscal year in the savings and the checking accounts was $19,383. Ralph Jones also reported that the Annual Meeting in Atlanta was a financial success and was attended by 249, of which 160 were members. The attendee affiliation was as follows:

Government	**48**
Government Contractors	**97**
Private Industry	**96**
Foreign	**8**

An operating budget of $23,900 was approved for fiscal year 1975.

Chairmen for the Standing Committees and other appointments were approved as follows:

Program	**Dr. G.R. Keepin** **E.J. Miles**
Public Relations	**L.F. Dale**
Constitution and Bylaws	**L.K. Hurst**
Membership	**J.W. Lee**
Journal	**W.A. Higinbotham** **T.A. Gerdis**
Safeguards	**D.W. Wilson**
N.15 Standards	**J.L. Jaech**
N.15 Standards Secretary	**R.A. Alto**
Education	**M.A. Kanter**
Past Chairman	**B. Gessiness**
Site Selection	**R.E. Lang**
Certification	**F. Forscher**
Awards	**T.B. Bowie**
Nominating	**H.L. Toy**

Armand Soucy noted that the Safeguards Committee had been reactivated and would take a very active public role regarding safeguards in the months ahead.

The Executive Committee approved going ahead with the INMM Safeguards School at Argonne National Lab on the basis of preliminary registrations.

Fred Forscher reported on the activity associated with the development of a proposed charter for a Nuclear Materials Manager certification standard. The current INMM certification program has been suspended pending the possible development of an ANSI standard dealing with the requirements for certifying Nuclear Materials Managers.

The new logo, which is exhibited in the current Journal, will highlight the main aspects of nuclear materials management, i.e., safeguards, reliability, and assurance.

In view of the cost associated with the purchase of new binders, preparation of material, and the dissemination of the INMM Manual, the Executive Committee voted to discontinue manual distribution. Information and items normally associated with the manual will henceforth be distributed through the INMM Journal.

The Site Selection Committee presented for Executive Committee Approval four cities for the 1976 Annual INMM Meeting. These were: Seattle, Albuquerque, Chicago, and Colorado Springs. After evaluating each site, the Executive Committee unanimously selected Seattle, Washington.

The next Annual Meeting will be held during the week of June 15, 1975, at the Monteleone hotel in New Orleans. In keeping with past practices, the Executive Committee will hold its next Executive Committee meeting at that site on February 13 and 14, 1975.

D.W. Wilson

INMM SAFEGUARDS COMMITTEE REPORT

NEW STANDING COMMITTEE ON SAFEGUARDS

By Dennis W. Wilson, Chairman
INMM Safeguards Committee

At the request of the Institute Chairman and with the concurrence of the Institute Executive Committee, a new standing committee has been established. Referred to as the Safeguards Committee, this group has been chartered to provide a mechanism whereby the Institute will examine specific safeguards issues or problems and offer professional opinions, comments and recommendations as appropriate. Specific topics normally will be 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.

The Committee is headed by a Chairman appointed by the Institute Chairman and approved by the Executive Committee. The Committee Chairman selects as many Committee members as deemed necessary and prudent to accomplish the assigned work. 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. In this regard, a number of individuals representing a wide spectrum of experience and backgrounds are currently serving on the Committee. It is anticipated that this participation will provide an avenue for safeguards study and comment in a forum not previously available. For example, it is not expected that Committee activities will duplicate or necessarily be consistent with other safeguards groups outside the Institute (e.g., AIF's Committee on Safeguards Policy). It is important that Committee work truly approach this professional independency.

The Committee is currently chaired by Dennis W. Wilson who is ably assisted by eleven other enthusiastic members. The Committee members with their geographical locations include:

Chairman:
D.W. Wilson (Dennis) — California

Members:
R.J. Adkisson — Oklahoma
R.N. Chanda (Dick) — Colorado
T.J. Collopy (Tom) — Connecticut
C.A. Colvin (Curt) — Washington
R.J. Lumb (Ralph) — Virginia
H.H. McClanahan (Henry) — Virginia
J.S. Murrell (Jon) — Ohio
M.L. Pendergrass (Marshall) — Arkansas
D.C. Pound (Dwight) — California
T.D. Reilly (Doug) — New Mexico
R.A. Schneider (Dick) — Washington

Membership on the Committee is not limited or closed. Primary qualifications are experience in safeguards, sincere interest in promulgating sound safeguards principles, and a willingness to serve. Further information can be obtained from any Committee member. Refer to the INMM directory or any officer for addresses.

The first activity of the Committee was accomplished essentially simultaneous with Committee formation. The subject was to review the Commission's draft report on safeguards included in WASH-1327, "Generic Environmental Statement on Mixed Oxide" (GESMO). The Committee operated under considerable time restraints, so the results may not be representative of future work. However, review results were summarized in a comment letter to the Commission (see the letter published elsewhere in the Journal). The Committee is currently examining a number of topical matters for further examination. In today's stimulating safeguards environment, there is no dearth of material to be worked on. The Committee's main challenges will be to 1) choose wisely its subjects and 2) provide exceptional contribution to nuclear materials management in those areas examined. Committee members are greatly interested in the ideas of others and would appreciate

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BY N.T.I.S.

NEW BOOK RELEASED ON BEHAVIOR OF STAINLESS STEELS

A recent release by the U.S. Atomic Energy Commission is the book **Fatigue, Tensile, and Relaxation Behavior of Stainless Steels** by J.B. Conway, R.H. Stentz, and J.T. Berling of Mar-Test Inc., Cincinnati, Ohio.

The book contains a comprehensive discussion of fatigue, tensile, and relaxation behavior combined with a detailed summarization of data defining these properties for 304, 316, and 348 stainless steels. Methods of data analysis are covered in considerable depth. Prediction techniques are reviewed along with cumulative-damage and creep-fatigue interaction considerations.

Our sales agency is the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161. The book is available as TID-26135; $7.60 ($10.10 foreign), 276 pages, 8 1/2 x 11 inches, paper binding, Library of Congress Catalog Card Number 74-600115.

SOCIAL METABOLISM IS THE KEY

Editor's Note: The following letter from Dr. Frederick Forscher is reprinted from page 10 of the **Pittsburgh Post-Gazette,** *Friday, January 17, 1975. Dr. Forscher is a member of the INMM Executive Committee and chairs the Certification Committee of the Institute.*

I am in agreement with AP writer John Cuniff's analysis entitled "Economists Fail Credibility Test" (Jan. 10) and his emphasis of the effects of poor forecasts. They have "resulted in what many people feel have been inappropriate federal policies, as economic advisors in Washington refuse to permit the facts to overwhelm their assumptions." I would like to suggest some basic reasons for their forecasting failures.

Energy is necessary for the survival of any society, the more industrialized, the more energy is needed. Calories are necessary for the survival of any living organism, the more cells and organs, the more calories are needed. It seems that our economists have not yet learned the simple truth that energy, like calories, follows different laws than the supply-demand economics that apply to natural resources, including fuels.

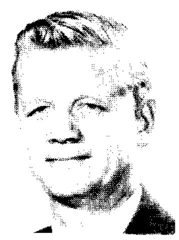
They are confused about the difference between food and calories, between fuel and energy; they don't look at the living organism as a key to the understanding of how energy is used. Biologists have begun to unravel the mysteries of metabolism. Economists have not even begun the study of SOCIAL METABOLISM. But, inevitably, social metabolism contains the key to our social-economic dilemma.

When will our ailing body politic find the appropriate practitioner? To rely on our economists will only lead us deeper into trouble. They recognize the value of a common media of exchange, money and how money—like blood—circulates. They have not yet recognized the importance of energy, and that energy cannot be recycled. Akin to cardiovascular specialists or heart surgeons, they tend to treat all our ailments by concentrating on the blood supply, when what we need are internists' methods.

It is clear that the methodology of social metabolism does not stand by itself. It supplements economics and other management sciences as internal medicine supplements the other medical specialties.

When the patient is as sick as our economy is, no applicable specialty or profession should be overlooked in an effort to cure the ills. The public deserves a better treatment than it is bound to receive from our practicing economists who got us where we are today; obese, disliked and very sick.

FREDERICK FORSCHER, Ph.D.
Pittsburgh



Dr. Keepin

INMM'S 1975 ANNUAL MEETING IN NEW ORLEANS JUNE 18-20

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

A glance at your calendar will show that the Institute's 1975 annual meeting in New Orleans is fast approaching—our big date being Wednesday through Friday, June 18-20. With the spotlight of the antinuclear movement focused on the twin issues of safeguards and safety, all of us in the INMM clearly shoulder a grave responsibility in our professional commitment to effective safeguards and control over nuclear materials which are the lifeblood of the entire nuclear industry. From just reading the newspapers these days, it becomes increasingly clear that the future of the plutonium fuel cycle, if not the very promise of nuclear power itself, could depend in large part on how effectively we are able to safeguard, control and manage strategic nuclear materials, and especially plutonium.

We must make no mistake about it—the opponents of nuclear power are going for the jugular; while much of the mass media seem to be trying to provide objective and honest coverage, clearly they must have factual input from professionals in INMM, and the nuclear community generally, who know and understand the promise—and the problems—of nuclear power and its admittedly unique fuel materials. So today more than ever we must speak out clearly and positively about the many effective SNM control techniques and security systems which do exist here and now; at the same time we must explain to the public as fully and clearly as possible the thrust of modern safeguards technology and its vital role in achieving clean, safe, and safeguarded, nuclear power on a practical and cost-effective basis.

Traditionally the focal point of Institute activities, the INMM Annual Meeting provides the major U.S. professional forum for experienced safeguarders and materials managers to speak out on these key issues and be heard by all sectors of the nuclear community and, via the media, by the public at large.

Our 1975 program will feature distinguished experts from U.S. industry, the Government, ERDA, and NRC, as well as from overseas; the program will cover a wide range of technical topics as outlined in the INMM Call for Papers (printed elsewhere in this issue of the Journal). In one key area—namely plutonium fuels—**Si Smiley,** Director of the NRC Office of Special Studies, has promised us an up-to-date status report on the NRC's intensive special studies on safeguarding of the plutonium fuel cycle. This year, for the first time, the category "International Safeguards and Inspection" has been designated as a separate program topic. Among other reasons, increased export of U.S.-supplied power reactors and nuclear fuel materials to developing nations will mean steadily increasing U.S. interest and concern with effective international safeguards and inspection. **Dr. Rudolf Rometsch**, Inspector General of the International Atomic Energy Agency, expects to be with us to review recent technical developments in international safeguards and to give us his firsthand impressions direct from the five-year NPT Review Conference to be held in Geneva, Switzerland in May 1975.

Another highlight of the New Orleans meeting will be a panel discussion on the crucial and timely topic of "Safeguards, the Press and the Public." Panelists will include distinguished representatives from industry, government and the information media; the panel will provide a unique opportunity for knowledgeable professionals working directly in the safeguards and materials management field to provide authoritative, direct answers to questions posed by established representatives of the press, the concerned public, and informed nuclear critics.

Due to the anticipated large number of papers, the Program Committee is planning again this year to schedule concurrent sessions on the second day of the meeting. Based on its success at the Atlanta meeting in 1974, we also plan to incorporate the American National Standards Institute [ANSI] committee work

(Continued on page 42)


Dr. Kanter

COURSE INTEREST HIGH, APPLICANTS TURNED AWAY

By Manuel A. Kanter, Chairman
INMM Education Committee

The Institute's Education Committee was reactivated about a year ago by Chairman Harley Toy with Armand Soucy, Vincent DeVito, Ralph Jones, Bernard Gessiness, Richard Alto, and Manuel Kanter as members. At that time, its chief function was the investigation of the need for training courses in Nuclear Material Control (NMC) and Safeguards since USAEC dropped its program at Argonne in 1973. They recommended that the Institute contract with the Argonne Center for Educational Affairs to offer a series of four courses in the spring of 1974. However, due to delays in working out contract details it was not possible to offer these courses until this past fall.

As it turned out, there were an insufficient number of applicants for courses in measurements in NMC and in NMC in power reactor operations. However, there were enough for courses in statistics of NMC and in advanced concepts in NMC. In fact, the interest in the course in advanced concepts was so high that about ten interested applicants were turned away. Unfortunately, the applications came so late that there was no time to make any selection according to the need. Several applicants who had a real need for the information had to be turned away.

Thirty-four participants attended the two courses given at Argonne November 4-15, 1974. Six took both courses, six from the staff of the USAEC, nine from AEC contractors, eleven from private nuclear industry, one from a utility, and seven from abroad. John L. Jaech from Exxon and Richard Brouns of Battelle-Northwest presented the course in the applications of statistics which represented a first public presentation of the methods recommended in ANSI Standard N 15-16. The course was well received by those who had had some experience in the field although the one-week presentation was somewhat difficult for those who had not practiced statistics. The course in advanced concepts, concerned with planning for control, new applications to inventory, real time nuclear material control and physical protection, brought together a number of experienced people. In addition, some time was devoted to discussion of new government programs and to a discussion of the role that safeguards "critics" are presently playing. Because the class came from a varied background and experience in nuclear material control, a number of fundamental discussions were added on an ad hoc basis for those who were new to NMC. Sheldon Kops pitched in on a last minute call in this area.

Since the demand for at least some of the courses exceeded capacity, it seems there is still a limited need for additional training in nuclear material control. The committee and the executive board of the Institute will consider additional courses for the future. It seems desirable to offer both fundamental and advanced courses since there seems to be a steady stream of new people in the field as well as for an updating of those already in it. These courses should clearly be keyed to the certification program now under consideration.

There are other training efforts going on. The U.S. Atomic Energy Commission has sponsored a course in portable non-destructive assay in verification at Los Alamos in October of 1974. It was attended by 23 people including three from the staff of IAEA. There are plans for additional courses this spring. IAEA continues training of its own staff. John L. Jaech gave a course in statistics to the staff in Vienna in January and I consulted on a course for orientation of new staff which was given in November 1973 and will probably be given again this spring. EURATOM has given training courses to its own inspectors at the Ispra Center in the spring of 1974 and intends to offer this training to facility staff within the Community sometime in 1975.

One other aspect of training in NMC has been the continued contact which I have had with the faculty of nuclear engineering departments in the development of on-campus courses. In the past year, we presented a one-week course at the University of Arizona in January and gave seminars at Georgia Institute of Technology and the University of Kentucky. The Center has plans for conducting a worskhop in safeguards for university faculty this coming June.

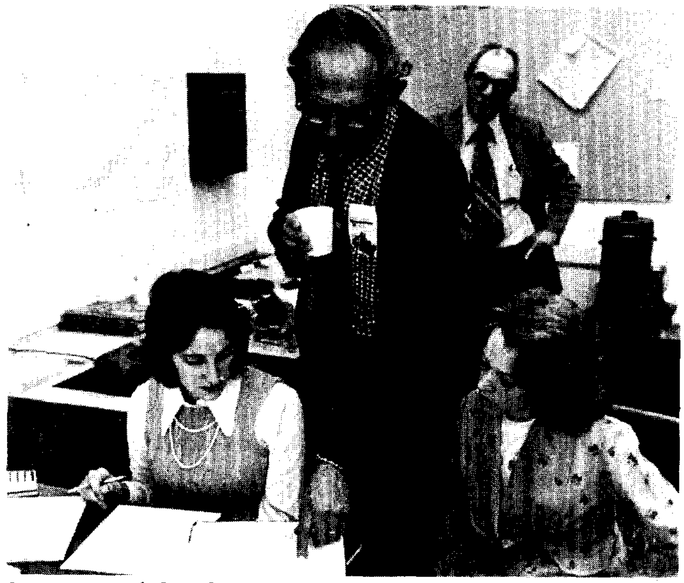
INMM's Education Committee still has an active agenda. It should see that appropriate courses are sponsored. It should take an active role in university relations and it should begin to look into the possibility of providing guidance for in-service training for junior staff at facilities.

PHOTO REPORT
FALL COURSES AT ARGONNE

John Jaech, Exxon, Lee Harkness and Manuel Kanter, ANL enjoying a time out.

Instructor, John L. Jaech, center, helps Guy Cullington, EURATOM and Jimmy Gilbreath, TVA with their homework.

Class in Statistics having a light moment. First row, left to right: Joseph Britschgi, Aerojet; Ryohei Kiyose, University of Tokyo; G. Dan Smith, USAEC; R.T. Shutt, B & W; second row: Emanuel Morgan, USAEC; Deborah Hill, USAEC; Jimmy Gilbreath, TVA; Matthew Suwala, NUMEC; Dennis Bishop, General Electric; Anthony Grandillo, Mound; last row: James Curtis, Union Carbide; Isamu Tsukakoshi, Atomic Energy Bureau, Japan; Lee Harkness, Argonne; Carl Ahlberg, USAEC.



Lecturer Richard Brouns explains a knotty point to Deborah Hill, USAEC and Shirlev Geer, NUMEC.

G.R. Mallett, Kerr-McGee, Joseph Britschgi, Aerojet, Guy Cullington, EURATOM, and Jimmy Gilbreath, TVA argue out a "limit of error."

Deborah Hill, USAEC and Shirley Geer, NUMEC doing their homework.


Dr. Forscher

CERTIFICATION REPORT

NUCLEAR MATERIALS MANAGEMENT AS A PROFESSION

By Dr. Frederick Forscher, Chairman
INMM Certification Committee

Nuclear fuel is now an object of commerce and international trade. Fissile isotopes are a commodity of great economic significance, but with national security implications.

Individuals who, by virtue of their position in government and industry, make decisions about the disposition and utilization of these materials are not only affecting corporate profitability, but also public safety, environmental quality and national security. Such individuals are in fact members of a new profession, and as such should be subject to "certification" or licensing.

The INMM has accepted the challenge of a new profession. It will help to develop the professional aspects of nuclear materials management so that, eventually, it will receive public recognition along with other professions.

Justice Brandeis defined a profession as "an occupation for which the necessary preliminary training is intellectual in character, involving knowledge and to some extent learning, as distinguished from mere skill. . . . is pursued largely for others and not merely for one's self . . . in which the amount of financial return is not the accepted measure of success."

This approach represents a new and enlarged concept of the function and qualifications of a "certified" nuclear materials manager. Consequently, the Certification Committee of the INMM is asking all members to hold their application for certification in abeyance until it can complete the development of criteria and test standards that will meet this enlarged image of the profession.

The Certification Committee, now chaired by Frederick Forscher, has asked the INMM-sponsored Standards Committee, N15, to approve a new subcommittee for this purpose, and has also applied to ANSI's Nuclear Technical Advisory Board (NTAB) for approval of a Project Charter. Both of these requests have been approved.

A new subcommittee (N15.28), known as the "Certification Subcommittee," has been formed, and has held its organizing meeting. The present composition of this subcommittee is as follows:

Frederick Forscher, Chairman
Energy Management Consultant
Lennard Brenner
ERDA—Div. of Materials and Security
Paul F. Gauphran
Security Consultant
Lynn K. Hurst
E.R. Johnson Associates, Inc.
John L. Jaech
Exxon Nuclear Co.; Chairman N15.
William Kenna
NRC—Reg. Operations, Region II
Ralph J. Jones
NRC—Reg. Standards
Joseph A. Prestele
EPRI; Chairman, ANS Stds. Committee
Thomas B. Bowie
Combustion Engineering, Inc.

The NTAB Executive Committee on November 1, 1974 has approved the following Project Charter for N15.28:

This standard presents a program for certifying nuclear materials managers. It defines / the profession of / nuclear materials management and sets forth the specific levels of competence in accountability, quality assurance, and safeguards that are required for "certification" of nuclear materials managers. It also specifies the requirements for qualification test programs and qualification maintenance programs (requalification).

The certification program must be open to all qualified persons, must be based on performance criteria and test results, and must be administered by a recognized body that can meet ANSI's accreditation standards. In addition, the certification program should, if possible, meet IAEA acceptability.

(Coninued on page 42)

INMM SAFEGUARDS COMMITTEE

TRANSMIT COMMENTS ON G.E.S.M.O. TO S.H. SMILEY

Editor's Note: As the first activity, the Institute's newly-formed Safeguards Committee generated comments on the controversial Commission-issued WASH-1327, 'Generic Environmental Statement Mixed Oxide Fuel' (GESMO). These comments were transmitted to the Commission and are reprinted below. From these comments, INMM received an invitation to participate in the upcoming hearings on GESMO. The invitation was declined, primarily because of difficulties encountered in providing time for organized input.

October 30, 1974

Mr. S. H. Smiley, Deputy Director
Fuels and Materials
Directorate of Licensing
United States Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Smiley:

As you are aware, the Institute of Nuclear Materials Management (INMM) is the one professional organization in the United States which is specifically involved with the management of special nuclear material. As such, the Institute is committed to 1) advancement of nuclear materials management in all its aspects, 2) promotion of research in the field of nuclear materials management, 3) establishment of standards for use in nuclear materials management, 4) improvement of the qualifications and usefulness of those engaged in nuclear materials management and 5) the increase and dissemination of nuclear materials management knowledge. The Institute's membership includes experts, both government and private industry, in all fields of nuclear materials management such as accounting, chemistry, physics, engineering, measurement, physical protection, facility operation, government regulation and compliance, transportation, and audit. Among the numerous Institute activities is a standing committee on safeguards. Committee members representing Institute membership examine specific safeguards issues and generate professional opinions, comments and recommendations as appropriate. Results of the Safeguards Committee's work, while representative of INMM membership opinion, do not necessarily provide total membership consensus on study topics. In this light, the Safeguards Committee has made an evaluation of current and proposed safeguards as discussed in WASH-1327, "Generic Environmental Statement Mixed Oxide Fuel" (GESMO). It is to this document that our current comments are addressed.

We consider effective, sound and meaningful safeguards to be a dominant factor in the successful utilization of plutonium in the fuel cycle. We are firm in our belief that this valuable material can be integrated safely with appropriate safeguards controls. In this regard much has been done during the past few years, and GESMO contains a comprehensive summary of current safeguards requirements. These requirements apply to all segments of the fuel cycle, and are currently only in effect on back-fitted facilities. The important aspects of pre-design and subsequent implementation have not been tested for effectiveness. In all probability, however, it will be determined that current requirements do not represent optimized safeguards and responsible society will continue to implement **improved** safeguards. We emphasize the word "improved" and avoid the word "additional" in this connotation since we do not believe that merely adding requirements necessarily betters the resulting system. Additionally, considerations of the degree of vulnerability versus form of plutonium should be addressed. Meaningful safeguards will provide emphasis on the concentrated forms of strategic SNM because physically small quantities are more attractive to the diverter, easier to conceal, and more difficult to detect and recover. These same material quantities contained, for example, in fabricated fuel elements are more difficult to transport and require complex chemical or physical separation processes in order to be used for unauthorized purposes. Therefore, we urge the Commission to consider future requirements in light of a "total safeguards" system and to provide flexibility within the system to attain overall safeguards objectives. This approach appears necessary if provisions are to be made for growth within the framework of a responsible society.

In this light, GESMO describes a number of possible additional safeguards requirements. We suggest that the Commission carefully analyze these concepts in light of the overall system to earnestly seek improved safeguards. For example, an uninformed reader of GESMO may conclude that if it "could be done" it "should be done" in the name of safeguards. We do not feel that this approach is in the best interest of improved safeguards. We do concur, however, that several of the new concepts may be useful in conjunction with a systems approach to safeguards. Each of these has far-reaching impact and should be considered carefully before implementation. We see, for example, significant suggestions of protective measures which go beyond anything ever before attempted in a free society and in interaction between governments and private industry. The necessity of assessing the high reliability of people, providing dedicated armed resistance to would-be thieves and saboteurs, and implementing highly sophisticated and dedicated communications systems will go beyond resources available to private industry. However, we firmly believe that effective and comprehensive safeguards are practical where effective coordination between industry and government is maximized. In this respect, we offer the following comments on proposed additional safeguards.

1. **Co-location of Fuel Cycle Plants**

The concept of locating reprocessing plants next to fuel fabrication plants — and the broader aspect of integrated fuel cycle facilities — has major ramifications on the fuel cycle. The concept has obvious safeguards advantages. At the extreme end, this concept could effectively eliminate the transportation of separated plutonium along with its myriad postulated safeguards difficulties, and could offer the most significant step available in reducing the overall plutonium safeguards problem. For example, it is conceivable that routine production of separated plutonium could be eliminated entirely through development of processing techniques which could leave plutonium diluted (denatured) with uranium throughout the reprocessing-fuel fabrication cycle. Elimination of the availability of separated plutonium could alter considerably the entire safeguards picture. However, safeguards is only one of the many concerns involved. The concept has high impact on a number of areas of public interest including waste management, perpetual land dedication, national security, environmental protection, and the consequences arising from disasters involving radio-toxic materials. Although safeguards is only one of the issues, it is apparent that it could play a major role in justifying the adoption of the co-location concept. On the other hand, prohibiting transport of separated plutonium may create difficulties in utilizing alternate plants and processes; thus available capacities could not be used to economic advantage. This lack of flexibility in the growing industry could stifle competition with adverse effects on economics. Thus, it is important that a thorough and objective evaluation of safeguards be made to determine the ramifications on the fuel cycle.

2. **Additional Transportation Requirements**

While we generally feel that transportation safeguards need improvement, the need for additional transportation requirements should be directly keyed to the final form of plutonium as shipped. For example, if separated plutonium products were excluded from shipment through utilization of co-located plants, the necessity for upgrading current practices should be carefully examined in terms of a cost-benefit evaluation. Since transportation remains the weak link in fuel cycle material protection, we strongly support prudent efforts which provide meaningful improvement to the safeguards system. In this regard, we comment on the GESMO recommendations as follows:

a) Use of massive shipping containers — While this technique offers some increased resistance to access to shipped products, we feel that any immediate benefit may be more than offset by substantially increased difficulties in handling and shipping techniques. Large, heavy shipments tend to slow transport and limit routes; limitations which appear inconsistent with safeguards objectives.

b) Use of special vehicles — Positive support is given for use of special vehicles where design and operation of such vehicles can be shown to be incrementally useful in increasing protection within the established safeguards system.

c) Use of special escorts or convoys — The use of sufficiently armed escorts is considered an appropriate course of supportive safeguards action. However, numbers and techniques of assistance should be carefully evaluated to assure meaningful and direct improvement in the total system.

d) Establish communication system — We are strongly supportive of measures which provide increased assurance that continuous communication is available as required for safeguards in the fuel cycle. Development of such communications measures should not be delayed for the several years necessary for satellite relay communications development. If such delays are inherent with satellite use, acceptable interim measures should be made available.

3. **Additional Hardening of Facilities**

Facilities should be designed to provide considerable resistance to overt or covert acts directed at theft or sabotage of nuclear materials. We recommend that current requirements be carefully evaluated such as by fault tree analysis of postulated design basis incidents to determine adequacy. Arbitrary additional requirements should be avoided. Where additional restraints are determined to be advisable, we generally suggest improved reliability on response and mechanical obstacles which provide delaying measures to lessen the probability of a successful entry and exit. These restraints may include physical barrier and advance admittance systems. We advise caution in considering deterrents which repel or immobilize individuals. Such systems may offer more vulnerability to jeopardizing normal operations through accidental use with subsequent deleterious effects on legitimate operations.

4. **Upgrading of Operating Functions**

We offer support for measures which effectively strengthen operating surveillance functions. Based on current experience, for example, it appears that electronic surveillance offers superior search capability over manual hands-on methods. Such measures are more consistent, more thorough and decidedly less offensive. While there exist differences of opinion within the Institute, we generally support measures which allow screening and federally sponsored clearances for individuals involved in operations involving special nuclear material where such clearances could reduce the necessity of individual searches and could be an effective criterion in improving the overall quality of individuals working within nuclear facilities.

5. **Guard and Police Functions**

The subject of guarding special nuclear material and interaction with law enforcement authorities remains a frustrating and difficult one. On one hand, considerable interest is shown in maintaining control over facility operations which includes administering security functions. On the other hand, significant reservations are evident about the responsibility of private industry to maintain citadels of armed individuals whose charter is to provide hardened resistance to actual or suspected diversion of sabotage. In general, we feel that solutions to the overpowering problems of law enforcement liaison, armed defense of materials and recovery of diverted material are within the purview of federal authorities. Licensee responsibility should include measures to detect, communicate and delay. In this regard, security in transit and security at fixed sites may be the logical separation point. Communication to, liaison with and response by local law enforcement authorities must be strengthened to ensure consistently effective systems. While we prefer techniques which provide for industrial control, we recognize that federal coordination may be required. We urge that immediate effort be initiated to analyze in depth this overall security problem in all its aspects to provide long-term resolution to the armed guard requirements.

6. **Improving Accountability Systems**

We support activities which provide meaningful improvement in measurement systems. Such measurement systems in production facilities become extremely complex, however, and considerable effort must be directed to ensure that improvement emphasis is expanded in areas shown deficient or in areas affording marked improvement. Overall significant measurement improvement is not likely to occur since present, primarily chemical, techniques offer good overall measurement results. However, considerable effort could be directed to replacing many current methods with faster techniques which approach or improve upon current measurement capability and which emphasize on-line accountability rather than physical inventory. In our opinion, Real Time Materials Control (RETIMAC) systems have potential application. However, such systems will need additional development and are not likely to drastically improve the currently available measurement systems.

7. **Use of "Spiked" Plutonium**

The concept of increasing the harm to the diverter by introducing radioactive material is not new. This concept has been considered before in the case of high enriched uranium. Because of the many obvious economic and practical disadvantages, the concept was not seriously considered. In general, we do not regard the adulterating of plutonium with other perhaps more hazardous materials as a reasonable and responsible approach to improving safeguards measures. The obviously severe complications of handling these materials in normal operations would adversely affect economics and technical operations considerably more than any estimated benefit. However, if the concept is to be evaluated again, the safeguards impact and limitations should be considered in detail. Some of these include:

- The level of spike needed to provide a deterrent to diversion as opposed to the level of spike needed to immediately incapacitate a would-be diverter.
- The question of detectability of concealed plutonium versus measurability. Could detectability goals be reached without greatly reducing the exactness of accountability-type measurements?
- The uniformity of application of such a spike concept to other strategic SNM materials such as ^{233}U and high enriched ^{235}U.

As professional nuclear materials managers we are strongly supportive of well-planned measures which offer assurance that special nuclear materials receive protective measures commensurate with their strategic importance and the risk of loss or diversion to unauthorized uses remains acceptably low. We feel measures presently in place, while not optimum, represent useful approaches. Improved systems should be examined in a "total safeguards" approach with flexibility available to provide consistently adequate safeguards. In this regard, we feel that safeguards systems must be an integral part of mixed oxide concept development, and therefore, it does not seem prudent to delay final safeguards systems until one year after issuance of the final GESMO statement. We recommend full evaluation before final decisions are offered. We believe that future safeguards developments will be influenced by Pu recycle and the pattern these set will apply for the later HTGR and LMFBR material flows. For this reason, the Institute of Nuclear Materials Management is vitally interested in safeguards evolution. We stand ready to offer our expertise in important areas.

We appreciate the opportunity to review and comment on the safeguards aspect of GESMO. Although we believe there are issues yet to be resolved in the safeguards system, we are confident that appropriate safeguards are practical. We stand committed to this end.

Very truly yours,
D.W. Wilson, Chairman
Safeguards Committee

BOOK REVIEWS

Nuclear Criticality Safety and Fission, Fusion and the Energy Crisis

With the emergence of the nuclear power industry as a large-scale source of energy in the United States, the field of nuclear criticality safety has become increasingly important and has involved an increasing number of persons. The U.S. Atomic Energy Commission has published the proceedings of a short course on Nuclear Criticality Safety held at the D.H. Lawrence Ranch near Taos, New Mexico, May 7-11, 1973, and sponsored by the University of New Mexico and supported by the American Nuclear Society's Trinity Section and Nuclear Criticality Safety Division. The short course was designed to give persons from industry, national laboratories, government, and universities — all involved in criticality safety — the opportunity to meet together to exchange ideas and to discuss common problems. The publication, **Nuclear Criticality Safety,** introduces the underlying principles and reviews the state of the art of nuclear criticality safety as well as presents discussions and work sessions on topics of current importance and interest. It contains a reasonably comprehensive coverage of the field of nuclear criticality safety. Not intended to be complete coverage, it is a first step.

Nuclear Criticality Safety will be valuable to anyone directly or indirectly responsible for or interested in the criticality safety of facilities in which radioactive materials are handled.

This book is available as TID-26286 for $7.60 ($10.10 foreign) from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 (Library of Congress Catalog Card No. 74-600168, paper bound, 8 1/2 by 11 inches, 181 pages).

Fission, Fusion and the Energy Crisis by S.E. Hunt, Professor of Physics at the University of Aston, Birmingham, England, has been released by Pergamon Press, Inc., Maxwell House, Fairview Park, Elmsford, N.Y. 10523 (Hardcover: $8.75, ISBN 0-08-018102-3 or Paperback: $6.25, ISBN 0-08-018079-5).

Professor Hunt has been associated with the development of both nuclear fission and nuclear fusion programs since the early 1950s. Initially, he was a member of the then Associated Electrical Industries Research Laboratory at Aldermaston where he became Head of the Nuclear Physics Section, and as a result of this work, he was invited to occupy the Visiting Chair of Modern Physics at the University of Algiers in 1958-1959. He is now Head of Physics at the University of Aston in Birmingham.

Since 1945, nuclear power has been associated in the lay mind with the explosion of nuclear weapons and the unfulfilled promise of cheap power "just around the corner." Nuclear power became economically competitive in this country in 1970, and it seems unlikely that the world's major energy crisis will be resolved without a massive expansion in the nuclear power program. It is important in this expansion to choose reactor types which utilize our reserves of uranium efficiently, and which minimize the risk of serious accident and general damage to the environment.

The above remarks are reprinted for the back cover of a desk copy (paperback) received from the publishers. — **Tom Gerdis.**

CONCEPTS OF REAL TIME AND SEMI-REAL TIME MATERIAL CONTROL

By James E. Lovett

INTRODUCTION

The traditional approach to nuclear material control, or safeguards, involves the preparation of one or more closed material balances, each covering either a total facility or some major portion of a facility, called a material balance area (MBA). In principle, all components of the closed material balance are directly measured, such that the resulting material unaccounted for (MUF) consists only of the net result of measurement uncertainties plus any thefts or diversions. The uncertainties are assumed to be known on a probabilistic basis, thus permitting the detection of possible unaccountable losses (thefts or diversions) of significant magnitude.

As has been pointed out many times, the success of the closed material balance depends on the ability to measure all components and on the ability to determine and control measurement uncertainties. For any production-scale facility, controlling measurement uncertainties to within ±5000 grams fissile probably defines the state of the art. Some facilities with generally acceptable measurement procedures might have difficulty keeping their uncertainties within ± 10000 grams fissile. There are also problems of timeliness, since the material balance can only be closed when a physical inventory is taken. Despite efforts to improve inventory techniques, inventories more frequent than quarterly are largely wishful thinking.

Several recent sources have suggested the need for a material accounting system which could reveal an apparent shortage of material that is smaller than that which can be reliably detected by the usual MUF-MBA system, on a time scale that is considerably shorter than even monthly inventories might achieve. There is no real agreement as to the size of the shortage which must be detected or as to the time span within which detection must occur. At one extreme a pessimistic outlook on the potential hazard and a willingness to ignore the probable state of the technology can lead to a detection target of only a few grams, to be detected with essentially zero delay. At the other extreme, some might settle for a detection target as large as perhaps 3-5 kgs, to be detected within a week or ten days. The exact capabilities of the concepts discussed in this paper obviously depend on the applications, and on the willingness of management to modify operating procedures to accommodate safeguards requirements. In most applications, however, the detection capability should be in the range from 100 g to 1 kg, and the detection time should be in the range from perhaps 4 hours to 4 days.

The idea is not completely new. Perpetual inventory control systems were in routine industrial use before the Manhattan Project days. Batch control systems have been used off and on by various AEC contractors, although often the control would be considered crude by today's standards. A continuous process inventory control system for a chemical reprocessing plant was published in IDD-14498, and a *pro forma* based on batch controls was submitted to the AEC for license approval as early as the spring of 1971. These early uses were restricted to some fairly obvious examples, however; it has only been in recent years that the possibility of using short-term material accountancy as a primary material control technique has been suggested.

It is not the intent of this paper to defend or condemn either traditional material balance accounting on an MBA basis or the current suggestions that MBA accounting be abandoned in favour of real time controls. It would seem that the two are complementary rather than mutually exclusive, and that a reasonable balance should be sought. The purpose of this paper, however, is to explore the basic concepts of real time and semi-real time material control, together with some of the major problems that will have to be solved if the idea is to work.

Three specific types of short-term material control* are discussed, as follows:

1. **Storage.** A storage operation is defined as one in which identifiable and measurable quantities of material are stored without being processed in any way that disturbs either the identification or the measured quantity;

* There is, unfortunately, no generally accepted term to refer to the techniques discussed here. The term "real time," used in the title, unfortunately implies advanced computer applications. While a computer may be desirable in specific applications, it is doubtful if EDP is essential. As in most other areas, the rule should be, "Learn how to do it manually, then put it on the computer."

2. **Batch Processing.** A batch process is one in which identifiable batches of material are processed in such a way that batch identity is maintained;
3. **Continuous Processing.** A continuous process is one in which measurable quantities are processed continuously, in a manner in which batch identity is lost.

Other possibilities may exist. The definitions given above may seem overly simplistic; a continuous process obviously is one that operates continuously. In the present state of the technology, however, the success of short-term material controls very likely depends on a careful consideration of these basic definitions. Many processes that look continuous, for example, are only piece-wise continuous. Intermediate storage tanks usually exist, or a particular internal operation may be performed batch-wise. In the present technology short-term material controls can be made to work only if the entire facility can be divided into a series of operations, each of which is pure storage, or pure batch processing, or pure continuous processing. If any part of the facility is not included, the whole system breaks down. If any part of the facility is not covered by short-term material controls, a would-be thief could transfer the material to be stolen into this never-never region and then steal it. The theft might or might not be caught by traditional material balance accounting, but it would not be discovered on the short time-scale desired.

It is fashionable today to speak of contingencies, and to insist that two (or more) contingencies be violated before the system itself is defeated or circumvented. How many contingencies should be required in a safeguards system? The question will not be debated here. However, it will be assumed that two contingencies always exist, as follows:

1. All employees having access to nuclear material have been "cleared," and are reliably believed not to be members of a terrorist organization;
2. An adequate system of physical security exists, such that no one person can remove nuclear material from the facility without the explicit knowledge and consent of a second person.

Thus when this paper speaks of collusion between two employees, it should be understood that both employees are "cleared," and that this collusion is in addition to the collusion (or other violation of security) required to physically remove the material from the facility. In this sense all procedures discussed provide at least a third contingency. Possibilities for fourth or fifth contingencies are also discussed in places.

STORAGE AREA CONTROL

The basic techniques of perpetual inventory control in a storage area have been known for many years. A portion of the facility, ranging anywhere from a vault to a simple fenced area, is arranged such that access can be limited and controlled. Identified and measured containers are placed in the area, and at the same time a record is made of the identity and the quantity. When the item is removed from storage it is deleted from the record; the record thus is a perpetual inventory of the storage area.

If perpetual inventory control is to be of value, the first requirement is measurability. The material quantities placed in storage must be known, based on measurements having some reasonable degree of accuracy. Elaborate physical security precautions applied to unknown quantities give a false sense of security, and in actual fact make the concealment of diversion easier, not harder.

While measurement accuracy is not defined, and for purposes of physical security is not critical, the existence of direct measurements is critical. Estimates based on so-called "by difference data" are of course always forbidden. Estimates based on average factors or experience often are useful in material balance accounting, but they too must be forbidden in perpetual inventory control. The question concerns how much **is** being placed in storage, not how much **should be.** Only directly measured quantities can be allowed.

The second requirement is that there must exist adequate security over the storage area. The word "adequate" is subject to considerable debate, and will not be defined here. Obviously an open area accessible to everyone is not secure. A fenced area, a "vault-like room," a vault, alarms — the reader must draw his own line. For the purpose of the discussion here, the storage area will be **called** a vault, and the persons who have access to it will be called vault custodians.

One point will be made regarding physical security, however. The purpose of the physical security is to keep persons who are not vault custodians out. If it does not do this, it is not adequate. This does not necessarily mean that visitors should not be allowed in, even under escort. It does mean that visitor control procedures should be examined carefully, to be certain that they do not permit the system to be defeated.

The mere placing of identified and measured containers in vault storage does not provide an additional contingency against diversion. The vault custodian can steal any time and any quantity, subject as always to the probable length of time in storage. If he knows from experience that the storage time will be weeks or months, then the mere existence of vault storage does not constitute a short-term material control. (It would constitute a contingency if vault custodians were "cleared" and other employees were not, because it would place the material under the protection of a trusted employee. The assumption, however, is that all employees have been cleared, and that additional contingencies are desired.)

In order for vault storage to be effective in introducing an additional contingency, two additional requirements must be established. The first is that the bridge, from process area to vault storage, and from vault storage to process area, must be documented and controlled. It is essential that every container which is recorded as leaving a process must also be recorded as entering storage. It is essential that every container which is recorded as leaving storage also be recorded as entering a process. Without this duplication the vault custodian can steal, either by failing to record an input or by recording a false output.

The second requirement is that there be constant or frequent checks on the vault inventory, by someone other than the vault custodian. Without these checks the vault custodian still can steal, subject only to the question of probable storage time.

The logical way to satisfy the first requirement is to have the process area data clerk report that he delivered a container for storage, and the vault custodian report that he accepted the container for storage. Some third person (possibly assisted by a computer) matches the data, and investigates any mis-matches. Collusion between at least two of these three (any two) now is required in order to defeat the system. Note that so long as the vault custodian keeps his own records, collusion is not necessary.

To protect against the possibility that the person who measures the quantity placed in storage might falsify his measurement, as well as to protect against theft while the material is in storage, the following procedure might be adopted.

(a) The process area staff seal the container, using seals which are not available to the vault custodian;

(b) The vault custodian measures the contained nuclear material;

(c) The vault custodian's measurement is reported to and used by the process area in its short-time material control procedures;

(d) Someone other than the vault custodian, presumably the third person mentioned earlier, performs periodic inspections of seal integrity.

This system provides considerable protection, and does not duplicate any significant effort. Additional security perhaps could be gained by having the vault custodian repeat a measurement originally performed in the process area, or by supplementing seal inspection with random measurement verification. Unless a fourth person is introduced into the system, however, these additional precautions do not add additional contingencies. Collusion between any two persons could still defeat the sytem.

The extension of the procedures to cover withdrawals from storage should be obvious. The vault custodian reports the withdrawal, the process area data clerk reports both the entry into process and the final seal verification, and some third person checks the data for mis-matches. Collusion between any two persons defeats the system.

It is often proposed that the quantity removed from the storage should be remeasured at the time of withdrawal and that the two measurements should be compared. The idea has merit, and should not be rejected without consideration. Re-measurement does not automatically add information, however. First, the re-measurement must be **in addition to** all procedures previously described. If it substitutes for something, for example for the use of seals during storage, information is lost which the re-measurement does not necessarily replace. In the case of seals, for example, the vault custodian would be left free to juggle quanitites between containers, covering his shortage indefinitely.

Second, the re-measurement must be performed by some fourth person not already a part of the control system. If it is performed by one of the three previously discussed, collusion between that person and one other can defeat the system. The remeasurement may restrict the choice for collusion, but unless it is performed by a fourth person it does not increase the number of conspirators required.

The sequences outlined above provide for measurement after sealing, a sequence that is possible only with non-destructive measurement equipment. There is no easy alternative. If a process area employee is allowed to measure and seal his own container, without the possibility of a measurement verification, then no extra contingency exists. On the other hand, if the vault custodians perform measurements on unsealed containers, and then seal them, the ready access to seals makes it much easier for a vault custodian to conceal a theft without collusion. There is no problem with the process area performing precise measurements by "weigh sample analyse" techniques, followed by an approximate NDA verification by the vault custodian. If no NDA technique at all is available, redundant measurements probably are unavoidable.

BATCH PROCESSING CONTROL

A batch process is one in which one or more identifiable containers of material are used, as a batch, to produce one or more identifiable containers of product. The control technique described is that of preparing a batch material balance for each batch processed. The "batch MUF" usually is not expected to average to zero, because the batch material balance usually is not totally closed. The batch MUF is expected to behave in a rational manner, however; and to be small enough to provide meaningful safeguards information.

The requirements for short-term material control in batch processing operations are as follows:

(a) One or more identified and measured containers of material are transferred from storage or from some other process to the batch process being controlled. These containers are assigned to a batch or blend, and are recorded as inputs to the batch material balance;

(b) Using only the recorded inputs, one or more identified and measured containers of product are produced and transferred either to storage or to some other process operation. These containers are recorded as outputs on the batch material balance;

(c) Within limits, one of the batch inputs may be measured heel or recycle from the previous batch. This heel or recycle is also recorded as an output on the batch material balance from which it came;

(d) At least the more important scrap or waste materials are accumulated and measured on a batch basis, and are recorded as outputs on the batch material balance;

(e) Except for recorded inputs and outputs, the process equipment is "nominally empty" at the start of each batch (and obviously also at the end of each batch), such that there is no significant unmeasured crossover between batches.

As an example consider the conversion of $Pu(NO_3)_4$ solution into PuO_2. One bottle (about 2 kgs Pu) of solution is reacted with oxalic acid, the precipitate is dried and calcined to PuO_2. The batch material balance lists the $Pu(NO_3)_4$ solution as input and the PuO_2 plus measured filtrate "losses" as output. The "batch MUF" represents primarily those miscellaneous losses that presumably will be recovered when the equipment is cleaned more thoroughly.

The immediate objection to the example very likely is that the process really isn't a batch process, and batches of PuO_2 cannot be associated with specific bottles of $Pu(NO_3)_4$ solution. This problem, in fact, is the one major problem in the batch material balance concept of safeguards. **Unless** batches of product can be associated with batches of feed, the technique will not work. Of course there is no particular problem in using, say, three batches of feed to make perhaps seven batches of product, if that is the way the equipment is sized. To a limited extent, one can use 2 1/2 batches of feed to make 6.4 batches of product, transferring the partial batches between data sheets. Control begins to break down in this latter situation, however, and one cannot go too far.

Many processes are in fact operated at least semi-batchwise, and could be converted to true batch processes with varying degrees of effort. Plutonium nitrate is introduced to process batchwise, in ten-litre bottles, and precipitation likewise often occurs batchwise. What remains is to control the process, using specific feed batches to make specific product batches. The pressing of UO_2 pellets usually starts with a blend of powder. Much mixed-oxide work is done batchwise. The fundamental requirements exist in many operations, provided only that detailed operating procedures can be modified to meet short-term material control requirements.

An objection very likely will be raised by production personnel that converting a "more or less" batch process into a true batch process with batch process safeguards will require equipment modifications, or will slow production, or in some other way will cost money. Very likely they are right. Like most other things, safeguards are seldom free. The counter argument must be to examine the alternatives. One is to argue that there is no credible threat, and that therefore short-term material controls are unnecessary. Another is to argue for traditional material balance accounting on weekly inventories. A third is to rely strictly on multiple redundancy physical security. The first alternative is not likely to gain much acceptance, but the second and third are viable alternatives and should not be dismissed lightly. If batch process controls cost more than weekly inventories, then weekly inventories would seem to be the better alternative. Hopefully the decision will be made in this manner, however, and not by default through the refusal of someone who should know better to even consider the relative costs of his alternatives.

If batch inputs and outputs are properly measured and recorded, the batch MUF can be used as a short-term material control indicator. Like all MUFs, the batch MUF contains the net result of all measurement uncertainties, plus any unrecorded discards or losses. In this case usually the latter predominate, and reflect the extent to which the process equipment was not truly clean, or the extent to which various low-level waste materials were removed without measurement. So long as the batch MUF is small and behaves rationally, however, it serves as direct and short-term evidence that significant diversion is not occurring.

Although the measurement uncertainties associated with a batch material balance should be known at least qualitatively, it usually is not worthwhile to perform exact calculations and to evaluate every batch MUF against its combined measurement uncertainty. Most batch MUFs exceed the calculated measurement uncertainty, for the simple reason that there were unmeasured losses or unmeasured inventory quantities. It usually is worthwhile to apply statistical quality control techniques to batch MUF data, however. CUSUM techniques, subtracting out an average MUF, are especially useful.

A. **Process Heels.** It was stated earlier that within limits a batch material balance could include a heel leftover from a previous batch. If the heel is very small, it can sometimes be transferred "by difference" to the next batch. A better procedure, however, usually is to ignore a small process heel, allowing it to disappear into the batch MUF. It usually only affects the first batch processed after a cleanout, or possibly the first few batches. After that an equilibrium is reached. In most cases there is a second control limit, which says that the glove box or process equipment will be cleaned when the cumulative batch MUF exceeds some limit. Where this second control exists the two approaches lead to identical results.

Most process heels, however, not only exceed the control objective, but also vary from batch to batch within fairly wide limits. In this case the only alternative is to measure the heel, recording it as an output from one batch and as an input to the subsequent batch. If the heel is hard to measure, but is controllable and predictable within narrow limits, it may be possible to assume that the heel has some defined value. Individual situations should be examined carefully, however, to be certain that a knowledgeable operator cannot divert quantities in excess of the control objective through careful manipulation of the heel.

B. **Secondary Batch Controls.** The batch MUF control scheme does not require that the process equipment, glove box, etc. be thoroughly cleaned after each batch.

It of course would be cleaned if the control objective were exceeded. To preclude the siphoning-off of small quantities within the detection limits of the batch MUF, however, it is necessary to establish a secondary control over the assumed equipment holdup. This secondary control consists of a cumulative balance or total batch MUF subsequent to the last careful cleanout. The cumulative balance thus is debited with each batch MUF as it occurs, and is credited with the measured quantity in each package of waste removed from the system. When this total exceeds some defined limit, the process is shut down and cleaned, a true MUF is posted to the records, and the procedure starts over.

This secondary control system does not mean that every week or two the equipment must be shut down without warning. First, it is assumed that some routine cleaning efforts proceed every day. If these routine efforts are pursued conscientiously, they should be adequate to keep the residual holdup under the limit almost indefinitely.

Second, there is no reason not to allow the process engineer to see his running balance. In fact there is every reason why he should see it. If the balance continues to climb despite the routine cleaning efforts, the engineer can schedule some non-routine cleaning, with the process still in operation. If this too is not enough, the engineer still has warning, and can schedule the cleaning with some flexibility. The only instance in which an unexpected cleaning would be required is when the primary batch MUF limit is exceeded. If this limit was properly chosen, it will be exceeded only when some clearly unusual event occurs. A malfunction, a spill, or an attempted diversion.

Note that the secondary batch control again assumes measurement. The all too common practice of collecting unidentified and unsegregated scrap and waste materials in large drums without first performing any measurements cannot be permitted. Scrap and waste materials will have to be segregated, both physico-chemically and according to origin, and measured. High precision is not essential; unbiased NDA equipment is the usual answer.

C. **Evaluation of Batch MUF Data.** If the batch process has been properly designed, batch MUF data will behave as a random variable whose mean is the true batch process loss and whose standard deviation is primarily the batch to batch variation in process loss. This being the case, the data is amenable to evaluation by the technique of quality control. CUSUM is particularly useful, being a very powerful technique for the detection of changes in bias. These changes in bias should be investigated, even if only superficially, just to be certain that they have rational causes. An experienced operator, one who knows the process and what the batch control system is doing, is in a good position to attempt to divert within the uncertainty of the system.

The evaluation and investigation of "spikes," sudden totally abnormal batch MUFs, requires little comment. They will occur from time to time, from equipment malfunction, from operator error or carelessness, from accidents such as spills, or simply from the perversity of inanimate objects. Obviously they should be investigated. The details of the investigation depend on the processes and the nature of the spike, and cannot be discussed in general terms. Two comments are in order. First, if the spike indeed represents diversion, it does not in itself get the material out of the plant. Questioning security guards, and other actions to check on physical security, should be undertaken fairly early unless an obvious physical cause is found. If the material is not yet out of the plant, some added alertness may keep it from getting out. A guard may also remember some occurrence which was innocent enough that it was allowed to pass, but which now appears worthy of investigation.

Second, one should beware of the physical cause which only explains part of the spike. Spilling one kilogram, and thereby creating an explainable spike, should not be allowed to conceal the diversion of a second kilogram.

Occasionally when a batch control scheme is first instituted it exhibits no consistent behaviour. Probably some significant sidestream or process heel either isn't being measured or is being measured poorly. If the batch MUF cannot be made to settle down and behave rationally, the batch control scheme should be dropped. Perhaps the process can be re-defined, or some other control scheme can be used. Leaving the batch control scheme in place when it isn't working should not be considered.

D. **Multiple Contingencies.** The mere existence of a batch control scheme does not in itself automatically add any contingencies to the two basic contingencies identified in the introduction. Many batch operations are carried from beginning to end by one operator, and even if they are not, one operator can always falsify his numbers in such a way that the other operators will not detect a shortage. If batch control is to have meaning, cross-checks and audits are required, just as in perpetual inventory control.

For a start, the feed to a batch control system should come from another operation which is controlled by short-term material controls. For simplicity, assume that the feed comes from a perpetual inventory storage area. The output from the storage area **must** be used as the input to the batch data sheet. Someone, preferably someone not directly involved in either area, should audit to be certain that this identity exists.

Similarly, the product from the batch process **must** be used as the input to a storage area, another batch process area, or a continuous process area, and someone must audit that this correspondence exists. If all steps in the process are covered by short-term controls, this crossover of measurement data, and its audit, will occur as a logical part of the system. If some part of the facility is being operated without short-term controls, transfers into (and out of) that "non-controlled" area must nevertheless be audited.

Otherwise the short-term controls do not accomplish their objective.

Subject to the earlier comments about computer processing in general, batch control represents a good area for computer control. Operators can simply record container numbers and measurement data, and the computer can keep all the batch control records. This is especially true where there are measurement delays.

If there are significant sidestreams or process heels, which there usually are, the same restrictions regarding duplication of records, and subsequent audit, still apply. Sidestreams usually will not be a problem; they presumably go into a perpetual inventory control area, and will be controlled by the procedures previously described. Process heels are a more serious problem. It is easy to hypothesize a three-shift operation in which each process heel is measured by the oncoming operator and used to complete the balance for the outgoing operator. In this case a contingency exists. Not many batch operations are so co-operative, however. Even when they are, the process frequently gets off cycle. So long as a process heel is measured by one operator and the data is used by a second operator a contingency exists; the two must collude to conceal diversion. The possibility of accusing the wrong operator of diversion exists, however.

The situation which has to be avoided is the operation where one operator starts and stops all batches. This could be a small facility, which only operates one shift, or it could be a large facility with longer cycle times. If the measurement procedures are complex, such a facility might start and stop all batches on a day shift, using a senior operator to make the measurements, and using junior operators on off shifts as "gauge-readers."

There is no obvious solution. If the cycle time is indeed long, it might not be much of a penalty to insist that process heel measurements be witnessed by some "non-interested" party. Or consideration might be given to having the "measurer" be someone not directly involved in operating the process. Whatever the solution, batch controls do not provide an added contingency if process heels are measured by an operator who has access to the process.

CONTINUOUS PROCESS CONTROLS

The most difficult short-term material control to apply is the continuous process control. Unfortunately, the continuous process also is usually the most economical, especially if it is "big." The concept is simple. A continuous process operating at equilibrium has a certain in-process inventory, plus or minus some normal variations. All inputs and outputs (including sidestream outputs) are measured and recorded, and a running book inventory is maintained. If the book inventory exceeds the limit for normal equilibrium operation, appropriate action is taken to determine why. Likewise an inventory which was too small would also be subject to investigation, although how this might be interpreted as diversion is not clear.

There are several problems. If the process equipment is large-scale, the normal variation in the in-process inventory may be larger than the desired detection limit. The inputs and outputs to a continuous process almost always are made batchwise, and this can cause its problems. The book inventory increases after each batch input, and decreases after each batch output. If the in-process inventory is on the high side of normal and a product withdrawal has not been made, a feed batch may cause the limit to be exceeded, for completely natural reasons. One way to avoid this problem is to define the circumstances under which the book inventory will be calculated, for example immediately after each product withdrawal. Another way is to have a sawtooth set of limits, as a function of the number of feed and product batches since the last cleanout.

Some continuous processes gradually accumulate a holdup inventory. After one day of operation the inventory might logically be 10 ± 1, while after a month it might be 20 ± 3. This complicates the control system, but does not necessarily invalidate it. If the desired detection limit is small, however, the gradual buildup of a process holdup may create difficulties.

By far the most difficult problem is the process that looks continuous, but really isn't. The irradiated fuel reprocessing facility is usually taken as an example of a continuous process. In fact, the operation is far from continuous. The sequence of operations usually is something like this. Chop one or more fuel assemblies and load a dissolver (batch operation). Leach the chopped fuel and transfer the solution to a measurement tank (batch operation). Transfer the measured solution to a feed solution hold tank, and from the feed tank to an extraction cycle (batch feed to a continuous process). Collect the product from the first extraction cycle in a hold tank (batch product withdrawal from a continuous process). Repeat the last two steps for each additional extraction or partition cycle. In addition, at various points the quality of the product is checked, and various possibilities for recycle or special treatment may exist. In other words, the process is a complex mixture of batch and continuous processes that looks like one continuous process because it all takes place in one canyon.

The technology of short-term continuous process control is far from being fully developed. Except for some work at the Idaho Chemical Processing Plant some years ago, there has been little in the way of actual field testing. All that can be done here, accordingly, is to discuss ideas. There are few if any alternatives.

For a small facility, a continuous process control chart conceivably could work on the process as a whole. It was used at the Idaho Chemical Processing Plant some years ago, with reasonable success. Even if there is no hope that the total in-process inventory can be kept within suitable bounds, a total process control should provide useful corroborative data. It will also aid in defining what improvements are required if the design objective is to be met.

If a process looks continuous but isn't because there are intermediate hold tanks, the calculation of the running in-process book inventory should exclude these tanks. They may be in the process area, but they are not truly in process. From a short-term diversion control viewpoint, they are potential "diversion-hiders." A tank that is assumed to be full when in fact it is empty provides an excellent concealment for a true shortage somewhere else in the system.

The exact means of excluding hold tanks from the in-process inventory depends largely on the ability to measure their contents. Where the necessary measurement capability exists the tanks can be inventoried, perhaps daily, perhaps only weekly, depending on the design objective in terms of timely detection. They can then be subtracted from the apparent in-process inventory to yield the true material in process.

Note that this is not the same as daily or weekly physical inventories. No attempt is made to clean anything out, or to minimize any particular quantity, and no attempt is made to measure the content of extraction columns or other truly continuous processes. Those materials which were temporarily static were measured, with no special effort to acheive high precision, and the balance was assumed to be the in-process inventory. It is the statistical control of this in-process inventory that provides the short-term material control, not any attempt to define MUF.

Even where no measurement capability exists in the usual sense of that term, it may be possible to perform some sort of a measurement that will be adequate for the purpose at hand. In a continuous process, for example, solution in intermediate hold tanks must have some approximate concentration, the only question being whether the tank is full, half full, or empty. For the purposes of the short-term material control, a volume measurement times an estimated concentration based on solution density, or perhaps times just an estimated concentration based on prior special studies, may be adequate.

This question of measurement uncertainty is an important one. The philosophy that a measurement which cannot be performed well should not be performed at all is prevalent. In traditional material balance accounting the philosophy may have some merit. In short-term material control, however, the philosophy must be that any measurement is better than none at all. (Even in traditional material balance accounting an accurate but imprecise measurement is preferable to none at all.) The object of short-term material control is to prepare material balances quickly, over relatively small portions of a total facility. In order to do so, precision and accuracy must be sacrificed.

Extraction columns are a special case which may be worth discussing. In theory these columns are brought to an equilibrium condition and can then be operated indefinitely at equilibrium. Where this is the case, a running book inventory control to see that the quantity of nuclear material which appears to be in the system remains within statistical limits should provide a good short-term safeguard. In practice, however, extraction columns seldom remain at equilibrium for sustained periods. An emulsion starts to form, the decontamination factor drops, the nature of the feed changes, these and dozens of other factors lead to changes in the operational regimen, and equilibrium shifts or even is temporarily lost.

The answer again is to look for quick inventory procedures which are accurate enough to permit the preparation of a material balance to within an uncertainty defined by the detection limit. The total volume of the extraction system should be determinable. (For good material control, it should already be known). The approximate location of aqueous-organic interfaces should also be known. From these two parameters the total system can be divided into regions, each of which can, to a first approximation, be assumed to have some determinable average concentration. The result, in a sense, is a "quick and dirty" dynamic inventory. It does not prove, with 95 percent statistical confidence, that all of the material which should be present is physically present. It does demonstrate that the quantity of material in process is within the range expected for the status of the operations, so that there is no reason to suspect that an unauthorized removal might have occurred.

CONCLUDING REMARKS

First of all, short-term material controls are necessary if today's protection requirements are to be met. Physical security is also essential, but physical security gives little or no assurance that the system has not been circumvented. The exact requirements of a short-term material control system have not been clearly defined, and probably cannot be. Considering the present technology, it may be necessary in some cases to modify the requirements to conform to what can be achieved. A goal of 5000 grams fissile, to be detected in no more than one week, would appear to be feasible for most facilities handling plutonium or highly enriched uranium. At the truly large facilities where 5000 grams is not feasible, it should still be possible to subdivide the facility in such a way that a limit of 5000 grams or less can be applied to each subdivision. For storage areas and batch processes, smaller quantities and shorter times should be possible.

Considerable developmental work remains to be done. None of the concepts has been proven in any general sense, although individual pieces have been tested at various facilities. Ingenuity will be needed to adapt the concepts to specific facilities. Most important, co-operation from those involved in production operations is essential. If any inconvenience, delay, or cost to production, no matter how slight, is forbidden, then short-term material controls are out of the question. Properly designed, their effect on costs should be acceptably small. It cannot be zero.

MATERIALS AND PLANT PROTECTION STANDARDS: REVISITED

By James A. Powers and LeRoy R. Norderhaug

INTRODUCTION

Approximately a year and half ago (**Journal of Nuclear Materials Management,** Spring, 1973) I described the Atomic Energy Commission's program for enhancing the protection of licensee plants and the material contained therein. Regulatory issues standard specifications, performance criteria and voluntary guides the latter of which identify acceptable means for the implementation of requirements of AEC rules, regulations and orders. Shortly before the Spring 1973 article was written, Regulatory had published a number of proposed, comprehensive changes to Title 10 Part 50, 70, and 73 of the Code of Federal Regulations. These proposed amendments were to make sweeping changes to the required protection of licensed nuclear plants from acts of sabotage and the protection of special nuclear materials both at fixed sites and in transit from acts of theft. The amendments also established standard specifications for the frequency and quality of physical inventories taken to verify the validity of material accounting records. In November of 1973 these proposed rules were issued as effective amendments. While the organization and the provisions of the effective amendments and, in some cases, the detailed requirements, were modified to reflect public comments, the concepts embodied in the original proposed rules essentially were unchanged in the final effective rule.

Since November of 1973, no less than six additional amendments and approximately twenty-five guides have been issued to further assure that plants and materials are protected against saboteurs or thieves whose misdeeds could endanger the health and safety or the common defense and security of the American people.

We recognize that the sweeping changes made to improve the protection of nuclear material can, if not properly guarded against, result in a situation where conditions and stipulations applied to individual licensees could become increasingly more stringent as both the Regulatory staff and the Industry become familiar with the state-of-the-art of security devices and the license reviewers seek to establish a new "plateau of acceptability." This situation is often referred to by the industry as ratcheting, i.e., tightening of the requirements from one license application to the next. The potential for such a situation to develop in a rapidly changing technology led the Materials and Plant Protection Standards Branch to seek funds to develop a systematic basis against which the adequacy of licensees' programs for the protection of special nuclear material and the facilities containing those materials can be evaluated. The approach planned is to use both fault tree and event tree analysis of plant protection systems, incorporating recent historical data and best judgment, to derive a single, comprehensive basis against which to evaluate both plant design and security procedures.

REGULATION AMENDMENTS: PROPOSED AND EFFECTIVE

Fixed-Site Physical Protection

Under the new physical protection amendments issued as effective rules in November of 1973 all physical protection requirements for plants and special nuclear materials are contained in Part 73 with appropriate references in Parts 50 and 70.

Operators of fuel reprocessing plants and other licensees, such as operators of fuel fabrication plants, who use highly enriched uranium, uranium-233 or plutonium, alone or in combinations exceeding 5000 grams, are required to: (1) equip and train guards and watchmen to protect against industrial sabotage; (2) establish a "protected area" enclosed by a physical barrier; (3) provide for control of access by individuals, vehicles, and packages to the protected area; (4) install lighting along the perimeter of the area; (5) develop a response capability to intrusion; (6) establish liaison with law enforcement authorities for assistance when necessary; and (7) establish an emergency, two-way communication link with law enforcement authorities.

The most significant changes made in these amendments as compared to the proposed amendments of February 1973 include: (1) elimination of the requirement to search vehicles and all packages being transported in the vehicles prior to entry to a "protected area"; (2) exemption of employees who possess an AEC clearance from routine search at the "protected area" boundary; and (3) specification of the maximum amount of fissionable material which can be stored other than in a material access area.

In-Transit Physical Protection

When cargo aircraft are used, the number of enroute transfers must be minimized and the transfers must be observed by armed monitoring personnel. Unarmed escorts must accompany air and sea movements from the last terminal in the United States to the point where the shipment is unloaded at a foreign terminal. Shipments of all but very small quantities of these materials on passenger aircraft were banned in February 1973.

Truck or trailer shipments must be accompanied by an armed escort traveling in a separate vehicle unless trucks or trailers specially designed to protect against theft are used. In addition, shipments will be made on a point-to-point basis with no loading or unloading of other cargo between these points. Additional measures to help assure prompt detection of an actual or attempted theft include the use of radiotelephone calls or conventional telephone calls at least every two hours between the truck and the licensee or his agent. Where radiotelephone coverage or conventional telephones along the planned route are not available, conventional telephone calls must be made at least every five hours. Trucks are to be marked on the top and sides with identifying letters or numbers.

Other safeguard measures include use of preferential routing to avoid trouble areas; continuous surveillance of the truck containing special nuclear material of the material itself at transfer points; and preplanning shipments to assure delivery at a time when the receiver is available to accept the material.

When rail transportation is used, the shipment must be escorted by two armed individuals, in the shipment car or an escort car of the train, who keep the shipment cars under observation and detrain at stops when practicable in order to guard the shipment cars and check car or container locks and seals. Radiotelephone communications are required to be maintained with a licensee or his agent every two hours or less and at scheduled stops in the event that radiotelephone coverage was not available in the last five hours before the stop.

For sea shipments, ship-to-ship transfers are not permitted. Transfer at domestic ports from other modes of transportation also must be observed by armed monitors. To provide the same protection for import shipments, importers are required to protect shipments from time of their arrival in this country.

The major changes made as the result of comments on the proposed rule changes include: (1) an extension in time for telephone reports, when radiotelephone coverage or a conventional telephone along the planned route is not available, from two to five hours; (2) safeguards for shipment by sea have been added; (3) in order to be consistent with truck and trailer shipments, the requirement that all monitors be armed has been added; (4) the requirement that truck or trailer shipments take the most direct route has been deleted; and (5) Part 70 of AEC Regulations has been amended to require that existing licensees, as well as all new licensees, submit a plan which outlines the procedures that will be used to meet the transportation requirements of the new amendments to Part 73.

Material Control and Accounting

With regard to inventory frequency and quality, those licensees authorized to possess more than one effective kilogram of plutonium, uranium-233, or uranium enriched to more than 20 percent in the U-235 isotope must take an inventory every two months in accordance with specific criteria in the new rules.

In addition, low-enriched uranium and plutonium-238 in quantities above one effective kilogram must be inventoried every six months in accordance with the specified criteria. All licensees must maintain strict control of records associated with control and inventory programs and must keep the record on file for five years.

The most important changes made in the proposed amendments include: (1) changing the control and accounting requirements for plutonium containing 80 percent or more by weight of the plutonium-238 isotope to be the same as those for low-enriched uranium; (2) a change in the required frequency of plutonium inventories from one month to two months; and (3) provision for consideration by the AEC of alternate limits of error on a material balance — at the request of the licensee and subject to approval only if the licensee has a program to upgrade his control system.

Approximately a year ago the Commission published a proposed amendment to 10 CFR Part 70 specifying the "fundamental material controls" to be described in the license application for the protection of special nuclear material. Previously, the AEC had required certain major special nuclear material licensees to submit, as a part of a license application, a description of the procedures for the control of and accounting for special nuclear material. They also were required to identify and maintain fundamental controls essential to adequately safeguard the material.

During the several years these requirements were in effect, they were implemented by a series of license conditions. Now these license conditions have been standardized and were recently included as part of the regulations. This will eliminate the need for each license applicant to identify and to state these controls in his license application.

Also, within the last few months the AEC issued a proposed regulation change which underlines the AEC's interest in high quality in design, construction **and operation** of plants and processes related to licensed activities potentially affecting the welfare of the public.

The proposed amendments identify requirements for planning, establishing, and maintaining a measurement control program. The program would include organizational controls for the management of measurement quality, training and performance qualification requirements, a standards and calibration system, a quality testing system for the determination and control of systematic and random errors, a records evaluation system for the collection and statistical analysis of the data, and a system of management audits and reviews.

REGULATORY GUIDES

Commensurate with the AEC's greater interest in physical protection measures and industrial standardization of means of implementing regulatory requirements, the AEC has initiated a number of actions in an effort to quantify and improve both current practice and the state-of-technology. The AEC has stepped up both its activity in industrial standards writing efforts and its effort to review the provisions of established industry standards for incorporation into regulatory guides. As each industrial standard (ANSI or ASTM or other) is issued, the AEC reviews the provisions of that standard for adequacy in meeting specific requirements of Regulation. Approximately forty materials and plant protection guides were issued in 1973 and 1974 (Table 1). In these guides more than twenty-five different industrial standards have been referenced and/or specifically endorsed.

The participation in writing groups and the utilization of published industrial standards are but two approaches that the AEC uses to assure the practicability of the provisions of its guides. Since June of 1974 the Regulatory guides have provided specifically for a public comment period after which comments (including constructive criticism) are reviewed and incorporated into a revised guide, if warranted.

Also, each Regulatory guide now includes a section which indicates how quickly the Regulatory staff feels that the guide could be implemented if a licensee should choose to do so. In any case implementation of a Regulatory guide continues to be voluntary as far as the industry is concerned but is binding upon the AEC's own Regulatory process in terms of specifying acceptable means of meeting the requirements of Regulation.

INDUSTRIAL STANDARDS: SAFEGUARDS AND NON-SAFEGUARDS

To develop a comprehensive, adequate, and yet practicable approach to the protection of special nuclear materials and nuclear plants containing those materials, the AEC must rely heavily on the standards writing efforts of others. However, the performance of industrial standards writing groups for safeguards-related standards is, overall, very poor when compared with the total performance for other interests. Figure No. 1 reflects the subject area of industry standards published in the last 5 years. While the number of safeguards-related approved industrial standards increased significantly from 1971 to 1972, a continued increase in 1973 commensurate with the increased number of non-safeguards-related standards issued did not materialize. Nineteen seventy-four appears to be even more dismal.

Of the ten highest priority standards efforts identified by Regulatory Standards more than two years ago (Table 2), only two have been even marginally productive.

Several analytical procedures have been expeditiously standardized by the ASTM C-26 Committee and just as quickly reviewed and endorsed as Regulatory guides. In the application of statistics to licensee data only one standard, ASTM E178-74, has been issued. The N-15 working group responsible for this effort, however, has provided valuable advice on the identification and quantification of random and systematic error of SNM measurement (particularly non-destructive assay) systems which has been incorporated into other guides.

At the other end of the performance spectrum, automated material handling, response to attempted sabotage or theft, and performance of physical protection devices have received no significant attention whatsoever. Only two standards have been issued in the entire nuclear security area. The provisions of ANSI N18.17, "Industrial Security for Nuclear Power Plants," was endorsed by Regulatory Guide 1.17 (June 1973) even before the standard had been formally issued. ANSI N18.7, "Administrative Controls for Nuclear Power Plants," only alludes to the need for emergency plans to cope with "civil disturbance."

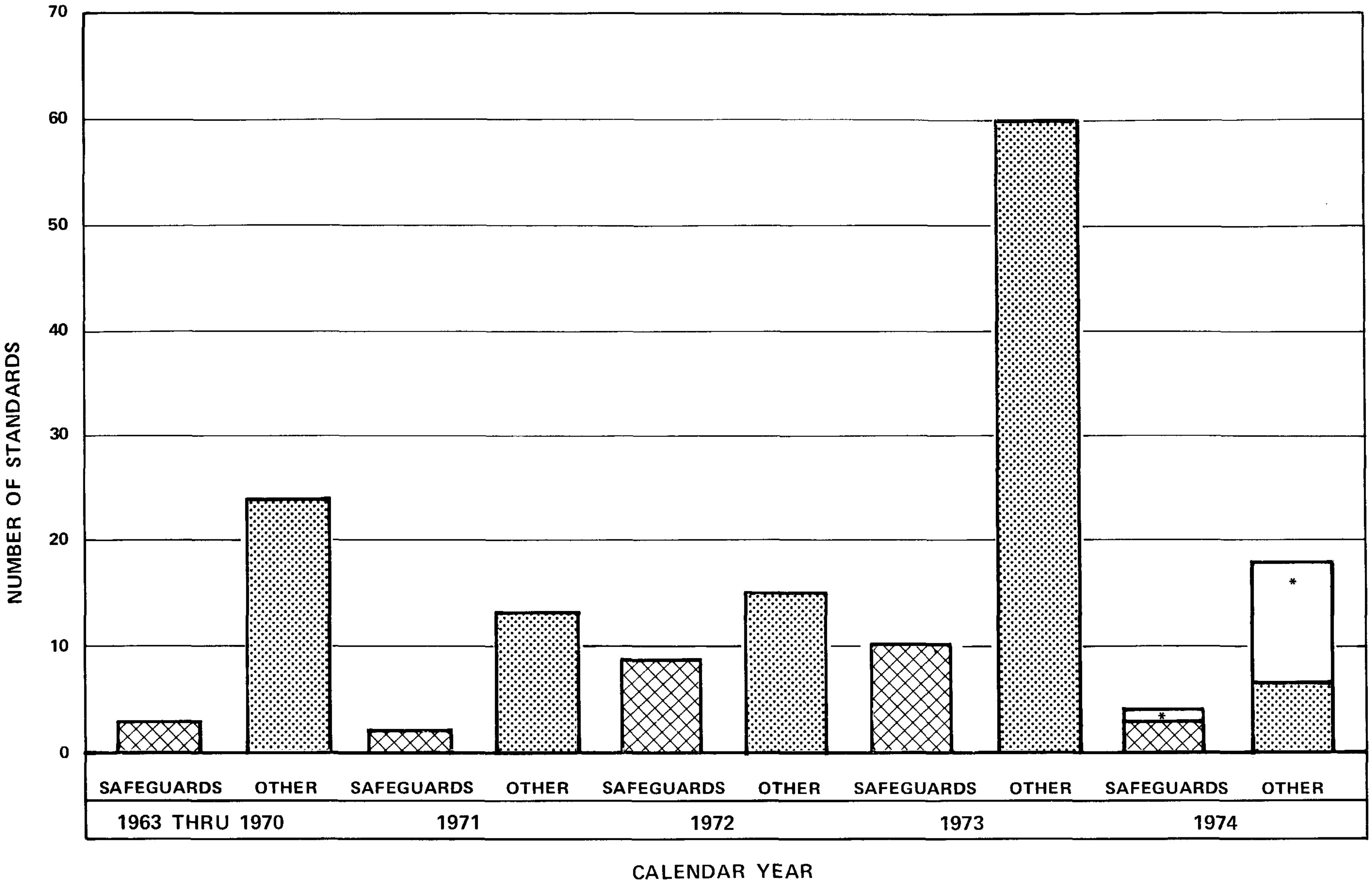
Indeed, a number of potentially endorsable industrial standards are in some stage of development, but the AEC must forge ahead. It is for this reason that the policy of a specific comment period on Regualtory guides was implemented.

CONCLUSION

The increasing awareness of both the potential threats and the shortfall of the AEC's past **ad hoc** approach to evaluating licensee security programs and the need for a systematic application of new technology through industry and AEC standardization calls for a redoubled effort on the part of the industry to improve its performance in the development of safeguards-related standards. While the industry standards efforts overall have significantly expanded in the last two years, the safeguards-related efforts have not reflected that expansion to the degree warranted either by public, congressional, or management interest.

We all recognize the need for standardization in the safeguards area and can appreciate the benefits of such an approach. The question then is, how can these needs be met and the benefits reaped? Some immediate short-term measures that can be taken include: expeditious appointment of a full-time chairman of the INMM Standard Committee N-15, expanded industry com-

ANSI STANDARDS
(Nuclear Only)



*Approved by Board of Standards Review as of 09-05-74 mitment to standards writing efforts, industry utilization of the comment period for new Regulatory guides and continued diligence in streamlining the ANSI standards approval chain. The AEC, for its part, will continue to participate in standards writing efforts of industrial groups and will promptly review new industrial standards and comments on new Regulatory guides to assure timely incorporation into the regulatory process. Only with a concerted and diligent effort of both the AEC and the industry can we assure that nuclear power can play its role in providing a significant contribution to the President's goal of energy independence for the United States without subjecting the American public to unwarranted dangers of nuclear blackmail or deliberate radiological contamination.

TABLE 1
DIVISION 5 REGULATORY GUIDES
MATERIALS AND PLANT PROTECTION

Number	Title
	(1972)
5.1	Serial Numbering of Light-Water Power Reactor Fuel Assemblies (ANSI N18.3-1972)
5.2	Classification of Unirradiated Plutonium and Uranium Scrap (ANSI N15.1-1970 and ANSI N15.10-1972)
	(1973)
5.3	Statistical Terminology and Notation for Special Nuclear Materials Control Accountability (ANSI N15.5-1972)
5.4	Standard Analytical Methods for the Measurement of Uranium Tetrafluoride (UF4) and Uranium Hexafluoride (UF6) (ANSI N15.6-1972 and ANSI N15.7-1972)
5.5	Standard Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets (ASTM C696-72)
5.6	Standard Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Plutonium Dioxide Powders and Pellets and Nuclear-Grade Mixed Oxides ([U, Pu]O2) (ASTM C697-72, ASTM C698-72a)
5.7	Control of Personnel Access to Protected Areas, Vital Areas, and Material Access Areas
5.8	Design Considerations for Minimizing Residual Holdup of Special Nuclear Material in Drying and Fluidized Bed Operations
5.9	Specifications of Ge(Li) Spectroscopy Systems for Material Protection Measurements — Part 1: Data Acquisition (IEEE Std 301-1969 and IEEE Std 325-1971)
5.10	Selection and Use of Pressure-Sensitive Seals on Containers for Onsite Storage of Special Nuclear Materials (ASTM D2860-70, ASTM D543-67, and Pressure-Sensitive Tape Council Standard PSTC-5)
5.11	Nondestructive Assay of Special Nuclear Material Contained in Scrap and Waste (ANSI N15 — in preparation)
5.12	General Use of Locks in the Protection and Control of Facilities and Special Nuclear Materials (Underwriters Laboratories UL-768 and UL-437)
5.13	Conduct of Nuclear Material Physical Inventories
5.14	Visual Surveillance of Individuals in Material Access Areas (ANSI A11.1-1973)
5.15	Security Seals for the Protection and Control of Special Nuclear Material
	(1974)
5.16	Standard Methods for Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Nitrate Solutions and Plutonium Metal (ASTM C759-73 and ASTM C758-73)
5.17	Truck Identification Markings
5.18	Limit of Error Concepts and Principles of Calculation in Nuclear Materials Control (ANSI N15.16 — draft)
5.19	Methods for the Accountability of Plutonium Nitrate Solutions
5.20	Training, Equipping, and Qualifying of Guards and Watchmen (National Rifle Association Official Rules and Regulations)
5.21	Nondestructive Uranium-235 Enrichment Assay by Gamma Ray Spectrometry
5.22	Assessment of the Assumption of Normality (Employing Individual Observed Values) (ANSI N15.15-1973)
5.23	In situ Assay of Plutonium Residual Holdup
5.24	Analysis and Use of Process Data for the Protection of Special Nuclear Material
5.25	Minimization of Residual Holdup in Wet Process Operations
5.26	Material Balance Areas and Item Control Areas
5.27	Doorway Monitors.
5.28	Evaluation of Shipper-Receiver Differences in the Transfer of Special Nuclear Material (ANSI N15.16-1974 and ANSI N15.17 — draft)
5.29	Nuclear Material Control Systems for Nuclear Power Plants (ANSI N15.18 — draft)
5.30	Materials Protection Contingency Measures for Uranium and Plutonium Fuel Manufacturing Plants (IEEE Std 279-1971)
5.31	Specially Designed Vehicle with Armed Guards for Road Shipments of Special Nuclear Material
5.32	Communication with Transport Vehicles
5.33	Statistical Evaluation of Material Unaccounted for
5.34	Nondestructive Assay of Plutonium in Scrap by Spontaneous Fission Detection

(Continued on page 42)

SOME THOUGHTS ON RANDOM ERRORS, SYSTEMATIC ERRORS, AND BIASES

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Introduction

An error of measurement may be defined as the "magnitude and the sign of the difference between the measured value and the 'true' value" [1]. The subject of measurement errors is of great importance in the area of special nuclear materials (SNM) accountability. Key quantities that measure the level of SNM accountability performance, material unaccounted for (MUF) and shipper-receiver difference (S/RD), are influenced by measurement errors, and much effort is expended in evaluating the sizes of reported MUF's and S/RD's relative to the combined effect of errors of measurement. In these applications, individual measurement errors may be quite large, and their effects cannot be ignored. Further, there are many sources of error that contribute to an overall index of performance such as MUF, and the problem of how to combine their effects is a very important one.

In this field of application, the ultimate aim of taking all the measurements needed in SNM accountability is to arrive at the "true" value of some index, i.e., one not influenced by measurement errors. In attempting to arrive at "the truth," careful distinction must be made among the various kinds of errors that can be committed. In particular, the terms random error, systematic error, and bias are frequently used in this connection. One statement that the readers of this paper can universally agree on is that there has been and continues to be considerable confusion and some disagreement on the definitions of the various measurement errors just cited, and how to treat their effects statistically. The purpose of this paper is to try to clear up the confusion such that a more distinct picture of the various viewpoints will develop.

In a sense, this paper might be regarded as a defense of the terminology and methods of error propagation used by the author in a recently published TID publication [2]. The contrary opinions that have surfaced as a result of this book is one factor that has convinced me of the need for this paper. Further, various ANSI standards under preparation seem to offer conflicting viewpoints on this general subject. Finally, I am aware of different positions put forward in the international safeguards arena on this subject and I think it is time an attempt is made to begin clearing the air by trying to create a better understanding of the various viewpoints.

It is my hope that this paper will prompt others to communicate on this subject through the avenues available to members of the INMM. I will also welcome personal correspondence on the subject.

The reader will note a paucity of references. It is a hopeless task to perform a comprehensive literature search on the subject of random and systematic errors, and biases. Every author of a statistics application book must touch on this subject, and there are many such books available. Further, the number of journal articles and unpublished papers that discuss this subject is very large.

Rather than attempt to perform even a nominal literature search, therefore, I believe it more instructive to make this paper largely self-contained, with references to other literature held to a minimum. Nevertheless, there are two general references that I should like to cite because of their importance relative to this topic. These are Mandel's book relating to the analysis of experimental data [3], and especially Chapter 6 of this book, and an NBS publication on measurement and calibration comprised of a number of papers on this subject [4].

Scope of Paper

My original intent was to discuss mathematical models, estimation of the parameters, and propagation of errors. After considerable thought, however, I have decided to concentrate on modeling and error propagation in this paper, and avoid problems of estimation for the present.

There are a number of reasons behind this decision. First, it is my opinion that even in the very simple measurement situation in which repeated measurements are made on the same standard, the problem of when to make bias corrections, for example, has not been studied in sufficient depth from an applications viewpoint, and since this is basic to the estimation problem, I would rather avoid the subject for the moment. Secondly, discussions on estimation of biases are generally limited to the simple situation just discussed, i.e., when making repeated measurements on the same standard. This tends to create the impression that biases or systematic errors that may affect a statistical index such as MUF are rather simple in origin and can be evaluated rather easily. This is far from true (see, for example, the discussion in Section 3.2 of Reference 2). Thus, discussing error parameter estimation for the case of known standards only scratches the surface of a very complex subject, one of which cannot be explained in depth is a paper of this scope. Finally, I do not wish to detract from the main point of this paper which deals with error propagation.

In avoiding the subject of estimating error parameters, I do not imply that the subject is unimportant. On the contrary, the topic is of utmost importance. I would suggest that application papers on this subject would be of great use to the nuclear industry.

Historical Comments on Terminology

Before proceeding further, some comments on terminology are appropriate. Most practitioners in the field of SNM accountability with whom I have been in contact over the past several years have used the term systematic error variance in the sense in which I have used it in [2], and will use it in this paper. At least this has been my understanding of their usage. Although other terminology might be preferred by some readers, I believe it preferable to stick with common usage unless the term itself creats confusion. In my opinion, systematic error variance is properly descriptive of the idea I wish to convey, and I see no reason for discarding it in my communications on this subject.

Mathematical Models

Mathematical models of increasing complexity are discussed. In each case, x_i is the observed value of some random variable for the i-th item. For simplicity in presentation, additive models are assumed.

Model I

$$x_i = \mu + \varepsilon_i \qquad (1)$$

The parameter μ is some constant. Assume that ε_i is a random variable with mean 0 and variance σ_ε^2 for all i, written $E(\varepsilon_i) = 0$, and $\sigma_{\varepsilon i}^2 = \sigma_\varepsilon^2$ respectively. Further assume that ε_i and ε_j are uncorrelated for all i and j, written $E(\varepsilon_i\varepsilon_j) = 0$. In this model, ε_i is called a random error and σ_ε^2 may be called the random error variance.

This model would apply, for example, if a number of measurements were made on the same item. Here, μ is the true value of the item characteristic in question, and ε_i is the error introduced by the i-th measurement on that item. The measured or observed value, x_i, is the algebraic sum of μ and ε_i. The expected value, or mean, of x_i is μ, and its variance is σ_ε^2.

Model II

$$x_i = \mu + \varepsilon_i + \eta_i \qquad (2)$$

Make the same assumptions about μ and ε_i as in Model I and further assume that η_i is a second random error with $E(\eta_i) = 0$, $\sigma^2_{\eta i} = \sigma^2_\eta$, $E(\eta_i\eta_j) = 0$, and $E(\varepsilon_i\eta_j) = 0$ for all i, j.

This is a model in which there are two random errors, and in this case, the variance of x_i is the sum

$$\sigma^2_{x_i} = \sigma^2_\varepsilon + \sigma^2_\eta \tag{3}$$

Formula (3) is called an error propagation formula.

As an example of application, in determining the net weight of UO_2 powder in a container ε_i might represent the random error introduced by the gross weight determination and $-\eta_i$ the random error introduced by the tare weight determination. The observed net weight, x_i, is affected by both random errors. If σ^2_ε and σ^2_η are assigned values, the variance of x_i can be found using equation (3). This provide a measure of the uncertainty* in a reported net weight. Alternatively, it describes how a number of measured net weights of the same item will be expected to vary.

Model II can easily be extended to include m different errors; $\varepsilon_{1i}, \varepsilon_{2i}, \ldots, \varepsilon_{mi}$ in which case

$$\sigma^2_{x_i} = \sigma^2_{\varepsilon_1} + \sigma^2_{\varepsilon_2} + \ldots + \sigma^2_{\varepsilon_m} \tag{4}$$

provides the error propagation formula.

Model III

$$x_i = \mu + \theta + \varepsilon_1 \tag{5}$$

For Models I and II, the results are straightforward and there is agreement on the error propagation formulas. With Model III, this is not always the case. The problem centers around θ. Since it has no subscript, θ is the same for all observations and hence, affects all observations in the same way.

Consider two situations, as follows:

Case (1)

θ is a constant whose value is not known. In this case, θ is called a measurement bias by the author.

Case (2)

θ is randomly selected from a population that has zero mean and variance denoted by σ^2_θ. In this case, θ is called a systematic error by the author, and σ^2_θ is called a systematic error variance. Note that θ differs from a random error only in the sense that the same value of θ applies to all observations in question, whereas ε_i is different for all i.

In the literature on this subject, bias and systematic error are generally regarded as being one and the same. In fact, this is indeed the case from point of view of the effect on an observation. Whether Case (1) or Case (2) applies, it is clear that the net effect is to cause all observations, x_i, to be θ units offset from the true value, μ. In addition, the ε_i component introduces a second error that is not the same for all i.

If bias and systematic error are the same with regard to their effect, what then is the distinction made by the author? This distinction is tied in with describing this effect. The two cases, with θ a bias and θ a systematic error, are discussed separately.

Case (1): θ a bias.

In this case, the expected value of x_i is $(\mu + \theta)$ and its variance is σ^2_ε. Say that the problem is to find some way of expressing the total uncertainty in x_i. The value of θ is known with high probability to be smaller in absolute value than some value θ_0. In describing the uncertainty in x_i, it is reasonable to make two separate statements of the following sort:

- The random error standard deviation is σ_ε.
- The bias is less than θ_0 in absolute value.

The use of two statements of this form serve the purpose of providing a good description of the total uncertainty in x_i. However, it falls short when it is necessary to make an overall statement on the uncertainty in x_i in order to help make some judgement about the size of μ given an observed x_i. The two statements must be combined somehow in a total uncertainty statement. This can be of the form:

$$\text{total uncertainty in } x_i = k\,\sigma_\varepsilon + \theta_0 \tag{6}$$

Case (2): θ a systematic error

We now turn to the case in which θ is regarded as a systematic error, sampled at random from a population with mean 0, and variance σ^2_θ. Then, the expected value of x_i is μ and its variance is $\sigma^2_\varepsilon + \sigma^2_\theta$. This expression for the variance of x_i provides the required statement of uncertainty. Of course, as with Case (1), separate statements can be made, with σ_ε the random error standard deviation as in Case (1). The systematic error standard deviation, σ_θ, is then used to describe the systematic error.

As an aside, it is pointed out that a systematic error, and also a bias, is only meaningful when applied to a given set of conditions. When the conditions change, so does the value of the systematic error. Thus, over a material balance period, say, there may be several sets of conditions applicable to a given measurement. The concept of a short-term systematic error may be applied in this instance [2].

A comment might be helpful to those readers familiar with the analysis of variance. In an analysis of variance, a distinction is made between a fixed and a random effect, even though the model is written the same in both cases. By analogy, I think of bias as being a fixed effect and a systematic error as representing a random effect. In this sense, then, the systematic error variance σ^2_θ is equivalent to a component of variance in the terminology of the analysis of variance.

Model IV

Model IV is the model of real interest in SNM accountability, with Models I, II, and III introduced to lead into this more complicated model. In SNM accountability applications, the analyst is frequently confronted with a random variable affected by many sources of error. The model may be written

$$x_i = \mu + (\theta_1 + \theta_2 + \ldots + \theta_m) + (\varepsilon_{1i} + \varepsilon_{2i} + \ldots \varepsilon_{mi}) \tag{7}$$

where the θ_j are biases or systematic errors, and the ε_{ji} are random errors. Assume in the following discussion that all the parameters identified are known, i.e., have assigned values. The emphasis is on the error propagation formulas.

For ease in exposition, first consider the case in which the θ_j are regarded as systematic errors, drawn from populations having zero means and variances $\sigma^2_{\theta_j}$. Then, the error propagation is straightforward.

$$\sigma^2_{xi} = (\sigma^2_{\theta_1} + \sigma^2_{\theta_2} + \ldots + \sigma^2_{\theta m}) + (\sigma^2_{\varepsilon_1} + \sigma^2_{\varepsilon_2} + \ldots + \sigma^2_{\varepsilon m}) \tag{8}$$

where it is assumed that the various errors are uncorrelated.

Now regard the θ_j as biases. Following the line of reasoning of Model III, these biases are characterized by θ_{jo} values such that, for each j,

$$|\theta_j| < \theta_{jo}, \text{ with high probability}$$

With this approach, how is the error in x_i to be propagated? This is where disagreements arise. There are those who advocate that the combined effects of the biases be characterized by summing the θ_{jo} values and asserting that the total bias is less in absolute value than $\sum_{j=1}^{m} \theta_{jo}$ with high probability. The random error variances are then propagated in the standard way and the total uncertainty in x_i is expressed as in Model III, Case (1) (see equation (6)) with θ_0 replaced by

$$\sum_{j=1}^{m} \theta_{jo} \quad \text{and } \sigma_\varepsilon \text{ by } \sqrt{\sum_{j=1}^{m} \sigma^2_{\varepsilon_j}}$$

In support of this approach, it is true that if any given $|\theta_j|$ is less than θ_{jo} with high probability, then $|\sum_{j=1}^{m} \theta_j|$ is also less than $\sum_{j=1}^{m} \theta_{jo}$ with high probability. My objection to this approach is not that the method of error propagation is theoretically not supportable, but rather, that it may be unrealistically conservative in given applications. This is especially true if there are several biases as is the case in many SNM accountability applications. The

*This term is used as defined in [1]. In some circles, the term is gaining acceptance as the generic term to express the limits of error in measurement.

degree of conservatism is large because the implicit assumption is made that not only are all of the m biases in the same direction, but each tends to be close to θ_{jo} in value. No allowance is made for any cancellation of biases that have opposite sign.

What is an alternative? One is to characterize the uncertainty in each bias by some quantity denoted by $\sigma_{\theta j}$ rather than by θ_{jo}, where $\sigma_{\theta j}$ is descriptive of the interval in which a given bias will be expected to occur, just as θ_{jo} provides the limits on this interval. As an example, if the bias θ_j is judged to be equally likely to fall anywhere between $-\theta_{jo}$ and $+\theta_{jo}$, it can be regarded as having the same effect as if it were a uniformly distributed random variable with range $2\theta_{jo}$.* In this case, since the standard deviation of the uniformly distributed random variable is $2\theta_{jo}/\sqrt{12}$, $\sigma_{\theta j}$ may be equated to $2\theta_{jo}/\sqrt{12}$. As another example, if it is known or judged that θ_j will "almost surely" fall between $-\theta_{jo}$ and $+\theta_{jo}$, but will more likely be much smaller, then it is not unreasonable to regard the bias θ_j as being a normally distributed random variable with zero mean and a standard deviation, say, of $\theta_{jo}/3$ or, more conservatively, of $\theta_{jo}/2$.

In effect, then, with several biases affecting x_i, each constant bias θ_j, although not a random variable, may be regarded as one with variance $\sigma^2_{\theta j}$, i.e., θ_j may be treated as a systematic error for error-propagation purposes. If there is concern that some or all of the biases may tend to be in one direction, this can be taken into account by introducing a positive covariance between such biases, still regarding them as systematic errors.

It is the author's contention that this latter approach to error propagation is generally the realistic approach when several biases or systematic errors are involved. Although careful consideration should be given to each application, the general recommendation is that in many SNM accountability applications, and in particular, when finding the variance of MUF, biases be treated as systematic errors when propagating errors. This leads to what is commonly called the "root-mean'square" approach to propagating errors.

Limit of Error

Thus far we have restricted our attention to finding the variance of some random variable. The reader is aware, of course, that in application, and in particular when assigning the uncertainty to MUF, this variance must be translated to a limit of error (LE). This translation is very simple when the approach recommended in the previous section is followed, and when the principles for the calculation of LE given in the appropriate ANSI standard (5) are adopted. The solution is to describe the bias or systematic error in terms of $\sigma_{\theta j}$, apply equation (8) to find the variance of x_i (or MUF in a particular example), extract the square root of the result, and multiply by two.

It is pointed out that this approach can lead to a result that is identical to the quadrature approach in which systematic errors are described by setting limits on them, $|\theta_j| < L_j$, and propagating the total effects of these systematic errors by $\sqrt{\Sigma L^2}$. This is equivalent to regarding L_j as a $2\sigma_{\theta j}$ value, and finding the LE (for systematic errors only) by

$$LE = 2\sqrt{\Sigma\sigma^2_{\theta j}} = 2\sqrt{\Sigma L_j^2/4} \quad \sqrt{\Sigma L_j^2} \qquad (9)$$

*Critics of this approach are disturbed that θ_j is treated as a random variable, and that the distribution of this random variable may be based partly on judgement as to what range of values θ_j may take on. The situation is analagous to the assignment of a prior distribution in Bayesian statistics, or to subjective probability in general.

Concluding Remarks

It should be kept in mind that there is no "right" way to treat the combined effect of systematic errors or biases. There is a certain degree of arbitrariness involved with any approach and this is why there are disagreements. The choice then should be made on the basis of what is meaningful in a particular application. In advocating the root-mean-square approach in this application, I am influenced by the familiar central limit theorem of mathematical statistics that implies to me that the systematic errors that will affect a reported MUF, say, will tend to cancel out.

Many have argued that it is advisable to make separate statements about the effects of random and systematic errors. I have no quarrel with that viewpoint, and, in fact advise it. But to carry that idea one step further and forbid that the effects of such different errors be combined into a total uncertainty is not acceptable in this field of application. Judgements are required on the significance of reported MUF's and S/RD's. To make such judgements, it is necessary that the total uncertainty be expressed in some way.

Acknowledgements

I submitted the first draft of this paper to a number of individuals for review and comment. I was heartened by the response, not that all the reviewers are in complete agreement with me, or with each other, because this is not the case, but rather that so many reviewers obviously devoted a considerable amount of effort to the paper. It is further evidence to me that those working in this area, most of whom are members of INMM, have a real professional interest in approaching the very important problems of SNM safeguards. No one supplied me with superficial comments; all were well-reasoned and the products of extensive thought.

Although I would like to take this opportunity to acknowledge the contributions of the reviewers by name, I do not wish to imply by either the inclusion or exclusion of certain individuals that they support or are in conflict with the thoughts expressed in this paper. Therefore, I shall extend by thanks to them as a group for the attention given this important subject and leave it to them as individuals to express their thoughts on the subject.

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SOME THOUGHTS ON 'SOME THOUGHTS ON RANDOM ERRORS, SYSTEMATIC ERRORS, AND BIASES' BY JOHN L. JAECH

By Roger H. Moore
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INTRODUCTION

At the Fourteenth Annual Meeting of the INMM we presented a paper "An approach to determining a system of routine inspection efforts and timing for fabrication plants" developed in 1971. This System consisting mainly of the analysis of time-series data of MUF originating in each fuel fabrication facility was able to determine reasonable routine inspection efforts for each individual facility. But, as stated in the paragraph 81 of INFCIRC/153 (or The Agreement), actual routine inspection efforts should be determined taking, not only the analysis of MUF and so on, but also various other factors in fuel cycle into consideration. Therefore, in 1972 we evaluated those criteria listed in the said paragraph 81, that is, (a) the form of nuclear material (b) the effectiveness of the State's accounting and control system (c) characteristics of the State's nuclear fuel cycle (d) international interdependence (e) technical developments in the field of safeguards, in view of their influence on routine inspection efforts, and including the System developed in 1971 developed a complete System which can determine actual routine inspection efforts for any facility effectively. The outline of this complete System is shown below.

BASIC IDEA

First, "the fuel fabrication facility" (or Facility) studied in this paper shall mean such facility that processes uranium hexafluoride (UF_6) with enrichment less than 5 percent and produces UO_2 powder or fuel assemblies. This corresponds to the facility defined in the paragraph 80 (c) in the Agreement and "the inspection efforts" cited here shall mean annual routine inspection efforts.

Secondly, in regard to the way of thinking about inspection we followed such idea mentioned in PART I of the Agreement as "BASIC UNDERTAKING" and considered "all source or special fissionable material in all peaceful nuclear activities" as the object of safeguards.

SYSTEM DEVELOPMENT TO CALCULATE INSPECTION EFFORTS

Structure of the System

Overall structure of the System including correlation with the System developed in 1971 is shown below.

$$F = f_1 \text{ (law factor) } \times f_2 \text{ (plant factor)}$$
$$= a \times \text{MRIE} \times f_2 \text{ (plant factor)} \quad \text{------------- (1)}$$

where

F : Annual routine inspection efforts (man-day)
$a(\leq 1)$: This factor, being the main object of this study, is to be derived in consideration of the criteria listed in the paragraph 81 (a) ∿ (e) of the Agreement
MRIE (Maximum Routine Inspection Effort); Maximum routine inspection effort for the Facility, defined in the paragraph 80 of the Agreement
f_2 : A function to be derived in consideration of the accountability of each individual Facility and developed by us in 1971

Basic Idea of Quantifying the Criteria

From the standpoint of inspection the distance between any nuclear facility and a nuclear weapon comes into question. In other words, the problem is how long it will take for nuclear material in certain chemical form in any nuclear facility to reach the nuclear weapon. In this study, however, we considered certain quantity of both metallic Pu and metallic ^{235}U to be equivalent with the nuclear weapon and defined them as Risk Material (RM) and also defined fast critical mass of both metallic Pu and metallic ^{235}U, namely 8 kg and 25 kg respectively, as Significant Quantity (SQ).

That is:

$$\varepsilon(8 \text{ kg Pu metal}) = \varepsilon(25 \text{ kg } ^{235}U \text{ metal}) = 1 \text{ SQ} \quad \text{--- (2)}$$

where ε = SQ function

Now, observing the movement of nuclear material which leads to RM paying special attention to the change of its chemical form it is understood that any nuclear material in certain chemical form will reach RM along possible routes being changed in its chemical form as it passes nuclear facilities. Thus, expressing chemical forms of various nuclear materials and moving directions of nuclear material towards RM with NODEs and ARCs respectively, we can make a network (RM Cycle) consisting of NODEs and ARCs. Of course, each route on the RM Cycle does not always coincide with that on the ordinary fuel cycle (Peaceful Use Cycle).

It is observed that any nuclear facility will give nuclear material in it such working operation which will cause one of the following changes, namely, (a) chemical form ("c" factor) (b) enrichment ("e" factor) (c) composition ("m" factor) (d) burnup ("b" factor). Therefore, it follows that if we can express minimum time (Critical Time : Tc) in which just SQ of any nuclear material starting from any NODE on the RM Cycle reaches the RM NODE being given any one of the said four changes by each nuclear facility and consequently being changed in its chemical form, using such factors contained in the criteria (a) ∿ (e) in the paragraph 81 of the Agreement, then we will be able to obtain a measure equivalent to the above-mentioned distance between nuclear material and RM. In the following section we will show our mathematical model which can calculate "a" in Eq. (1) using Risk Degree (RD) concept that shows the relative status of nuclear material or a facility in fuel cycle.

Mathematical Model

In this study we introduced a concept of Risk Degree (RD) concerning nuclear material on any (material) NODE in order to formulate "a" and then to calculate reasonable F in Eq. (1). RD at NODE "i" is defined in Eq. (3)

$$RDi = \frac{\dfrac{1}{Q_i^{RM} \cdot Tc_i}}{\sum\limits_{k \varepsilon Ri} \dfrac{1}{Q_k^{RM} \cdot Tc_k}} \qquad \text{------------------------} \quad (3)$$

where

Q_i^{RM} equals ε (Quantity of RM contained in nuclear material at NODE "i") on the condition that Q_i^{RM} becomes SQ at RM NODE. As mentioned before Tc_i means minimum time in which just SQ of nuclear material intentionally diverted from the NODE "i" reaches RM NODE.

The denominator of Eq. (3) is the sum of all $1/Q^{RM}$. Tcs from NODE "i" to RM NODE along all the possible routes on RM Cycle.

Thus, RD of any facility can be obtained by replacing the numerator of Eq. (3) with the sum of $1/Q^{RM}$. Tc corresponding with all the NODEs which belong to the facility.

Namely,

$$RD = \frac{\sum\limits_{i \varepsilon F} \dfrac{1}{Q_i^{RM} \cdot Tc_i}}{\sum\limits_{k \varepsilon R} \dfrac{1}{Q_k^{RM} \cdot Tc_k}} \qquad \text{------------------------} \quad (4)$$

Then, let us consider the realtion between "a" and RD. Considering the effect of the NODEs located on the routes from NODE "i" to RM NODE, it is understood that increasing number of the NODEs will also increase the potential possibility that nuclear material will divert from any NODE towards RM NODE along any of the routes. So, we adopted following Eq. (5) taking this effect of the NODE number into consideration.

$$a = \sqrt[n]{RD} \qquad \text{------------------------} \quad (5)$$

"n" shall mean the number of the unduplicated NODEs which are located along the routes that lead to RM NODE starting from such NODE(s) belonging to any facility. F is calculated by replacing "a" in Eq. (1) with Eq. (5).

Now, Tc_i in Eq. (3) and Eq. (4) can be obtained by quantifying four factors, "c", "e", "m" and "b", and the basic idea of this quantification will be shown below.

. Quantification of "c" factor

This quantification is to be done by calculating the time in which certain amount of nuclear material corresponding to loss rate "1" to be reported as Design Information is first accumulated every year in a facility until total sum will reach SQ and then processed in the facility containing that nuclear material

. Quantification of "e" factor

This quantification is done by calculating the time in which uranium with loss rate "1" and enrichment "E" is first accumulated and then enriched to produce SQ of highly enriched uranium (≥90 %).

. Quantification of "m" factor

This is done by calculating both the accumulating time and the processing time of such amount of U-Pu blend equivalent to SQ in the facility which performs blending of U and Pu.

. Quantification of "b" factor

"b" factor is considered about various nuclear reactors. In this case quantification is done by calculating the time in whish SQ will be accumulated assuming that nuclear material can be diverted within calculation error α_R to be applied to the discharged fuel from reactors.

SIMULATION-CALCULATION OF INSPECTION EFFORTS

Taking, as examples, Facilities with capacities ranging from 100 to 500 TU per year and assuming various cases in the situation of fuel cycle in Japan, we applied our System to the Facilities and calculated inspection efforts for them. We had following results which are naturally to be affected more or less by the situation of those factors contained in the System developed in 1971 as accountability, confidence level and so on of the Facilities.

According to our results annual inspection efforts for any Facility will be a few man-days, that is, one inspection per year in the present fuel cycle of Japan, in which neither an enriching plant nor a reprocessing plant is present. In case of the fuel cycle after five years from now (1972), in which one reprocessing plant will be in operation and quite a few light water reactors will appear, annual inspection efforts for a Facility was calculated to be 15 - 30 man-days. Finally, in the complete fuel cycle, namely, all the nuclear facilities which are needed to provide complete fuel cycle including enriching plants and reprocessing plants will be present in Japan, we obtained annual inspection efforts which range from 20 to 35 man-days.

FRED FORSCHER'S INMM CERTIFICATION REPORT

(Continued from page 19)

The nuclear community is expected to employ "certified" individuals in various positions. On the industrial side, they may be in supervisory positions under plant operation, traffic (dispatcher), security, finance (audit), quality assurance, production control, accountability, inventory (stores), etc. On the regulatory side they may be with state or Federal inspection agencies, or — eventually — with the IAEA (NPT inspectors). They may also be employed in vendor audits by utilities and in insurance inspections.

The certification program should not be associated with a specific job description. Industry and Government will place a certified nuclear materials manager where his or her proficiency is best utilized within a given organizational framework.

The current public concern with safeguards, the fissioning of the AEC, the status of the Draft GESMO report, and other events, all impact on the deliberations of the certification subcommittee. Timely action toward the establishment of a 'profession' is called for. The committee faces many tough questions, most of non-technical nature, before the first draft can circulate for informal review. None the less, the certification committee hopes to present a meaningful status report to the INMM membership during the next annual meeting in New Orleans.

Comments, suggestions, and views from INMM members are most welcome and should be sent to Frederick Forscher, Chairman, INMM Certification Committee, 6580 Beacon Street, Pittsburgh, Pennsylvania 15217.

1975 TECHNICAL PROGRAM

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into our preliminary program on Monday and Tuesday, June 16-17, again this year.

In addition to our full technical program, there are, needless to say, many after-hour attractions in the picturesque, historic city of New Orleans. And to top it off, our headquarters will be the charming Monteleone Hotel on Rue Royale overlooking New Orleans' famed French Quarter. All in all it looks like our 1975 annual meeting promises to be the most informative and significant in the history of the Institute. Hope to see y'all "way down yonder in New Orleans."

STANDARDS: REVISITED

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5.35 Calorimetric Assay for Plutonium (ANSI N15.22-1974)

5.36 Recommended Practice for Dealing with Outlying Observations (ASTM E178-74)

5.37 In-situ Assay of Enriched Uranium Residual Holdup

5.38 Nondestructive Assay of High-Enrichment Uranium Fuel Plated by Gamma Ray Spectroscopy (ANSI N15.20 — draft)

TABLE 2

High Priority Standards; Materials Protection*

1. Standard for the use of Fuel Rod Scanners for Measurements of Nuclear Material Content of Fuel Rods
2. Standard for the Application of Statistics to Licensee Data
3. Standard for Recordkeeping and Reporting of Licensee Inventory Data
4. Standard for the Use of Automated Materials Handling Systems in Fuel Conversion and Fabrication Facilities
5. Standard for Measuring Material in Process Equipment
6. Standard for Materials Protection Considerations in High Enriched Uranium Scrap Recovery
7. Standard for Material Protection Considerations in Plutonium Scrap Recovery
8. Standard for Response to Overt Sabotage or Diversion Attempt
9. Standards for the Measurement of Special Nuclear Material
10. Standard for Performance of Physical Protection Devices

* Taken from the AEC Directorate of Regulatory Standards Report to NTAB, October 3, 1972.

INMM SAFEGUARDS REPORT

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receiving comments or suggestions from other Institute members.

The Institute leadership is showing strong interest in increasing the Institute's stature and contribution in all areas of nuclear materials management. The Safeguards Committee is an example of new avenues seen for such increased participation. The goal is to be heard, seen and recognized as the competent experts the Institute claims to have. 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. Whatever success the Committee may have will depend on overall support of Institute membership so that Committee results will truly represent the sound policies of the professional nuclear materials manager.

J.L. Jaech

J.E. Lovett

R.H. Moore

L.R. Norderhaug

J.A. Powers

ABOUT THE AUTHORS

John L. Jaech (M.S., Mathematical Statistics, University of Washington) is a Staff Consultant in statistics for the Exxon Nuclear Company, Richland, Wash. This year he became Chairman of the ANSI N-15 Standards Committee of the INMM. A statistical consultant in the nuclear field for more than 20 years, Jaech had been Chairman of the INMM-sponsored ANSI Subcommittee on Statistics. He has authored 16 open literature publications on statistical methods and applications in various journals.

James E. Lovett (B.S., Chemistry, University of Kansas) is currently with the International Atomic Energy Agency, Vienna, Austria. Formerly Manager of Nuclear Materials Control for six and a half years at Nuclear Equipment and Materials Corp., Apollo, Pa., Lovett is a Past Chairman (1970-1972) of INMM. Prior to joining NUMEC, Lovett has been with the U.S. Atomic Energy Commission for 10 years in Washington, D.C., and two years in Albuquerque, N.Mex. Prior to that, he was with the Rocky Flats Division, Dow Chemical Company, Golden, Colo. He is the author of the book, **Nuclear Materials: Accountability Management Safeguards,** published in 1974 by the American Nuclear Society.

Roger H. Moore (Ph.D., Statistics, Oklahoma State University) is the Director of the Applied Statistics Group of the newly-formed U.S. Nuclear Regulatory Commission, Bethesda, Md. He had been with Los Alamos Scientific Laboratory for 21 years as a Research Assistant, Staff Member, and Alternate Group Leader of Statistical Services. His interest in applying statistics to real problems has resulted in a number of publications in a wide variety of disciplines. He is a member of the ANSI Subcommittee INMM-3 of N-15 on Methods of Nuclear Material Control.

LeRoy R. Norderhaug (M.S., Physics, Idaho State University, 1964) is an Operations Analyst with the U.S. Nuclear Regulatory Commission, Office of Standards Development. From 1964-1965, Mr. Norderhaug attended the Oak Ridge School of Reactor Technology. He joined the USAEC in 1964 starting out as a Nuclear Engineer Trainee with the Idaho Operations Office at Idaho Falls. Then he transferred to the Division of Nuclear Materials Management as a Reactor Technologist. Mr. Norderhaug continued in that role with the Office of Safeguards and Materials Management. In 1971, he joined the USAEC Office of Regulation in his present position.

James A. Powers (Ph.D., Nuclear Chemistry, Purdue University) is Task Leader for the Special Safeguards Study for the Office of Special Studies in the U.S. Nuclear Regulatory Commission. From May 1972 until this winter, Powers was Chief of the Materials Protection Standards Branch, Directorate of Regulatory Standards, USAEC Regulation. Dr. Powers joined the AEC in 1966. Prior to becoming associated with the nuclear materials safeguards program, he worked for ten years in the isotope power program.