# INMM

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**18th Annual Meeting, Institute of Nuclear Materials Management, Inc. Washington, D.C., June 29-30, July 1, 1977, Stouffer's National Center Hotel.**

# NUCLEAR MATERIALS MANAGEMENT


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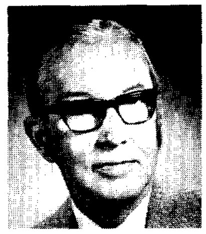

Dr. Higinbotham

## EDITORIAL

# International vs. Domestic Safeguards

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

The close relationship of nuclear power to proliferation of nuclear weapons was recognized during development of the atomic bomb in World War II. In 1946 the U.S. proposed establishment of an international atomic development authority to operate all nuclear facilities which might contribute to production of nuclear weapons. Those UN discussions stalled.

Thirty years later there are five nuclear weapon powers and explosion of the Indian device has refocussed attention on the relationship of world-wide development of nuclear power to nuclear weapon proliferation. The domestic issues of GESMO, of the cost-benefit factors involved in plutonium recycle, are dwarfed by the concern about what policies the U.S. should adopt to contain proliferation and about the international impact of domestic nuclear programs. The importance of understanding domestic safeguards objectives and the means to attain them has not diminished. But additionally, defining the needs for and designing international safeguards, has taken on great urgency.

This belated recognition of an old problem has generated a lot of papers and proposals, many of them hastily prepared. With the new Administration, this subject will receive a thorough review. Some of the more significant documents on the subject are the following:

1. "Three Steps Toward Nuclear Responsibility" by **Jimmy Carter,** October 1976 issue of **The Bulletin of The Atomic Scientists.** The three steps are: "(1) action to meet the energy needs of all countries while limiting reliance on nuclear energy, (2) action to limit the spread of nuclear weapons, and (3) action to make the spread of nuclear power less dangerous."

2. Statement by **President Gerald Ford** on U.S. nuclear energy policy, Oct. 28, 1976 (text available from the U.S. Arms Control and Disarmament Agency, D.C. 20451). The major policy departure is stated: "I have decided that the United States should no longer regard reprocessing of used nuclear fuel to produce plutonium as a necessary and inevitable step in the nuclear fuel cycle and that we should pursue reprocessing and recycling in the future only if they are found to be consistent with our international objectives." In support, ERDA is directed to adapt to the new policy, Congress is asked to support expansion of U.S. enrichment capacity, The Secretary of State is directed to "pursue, vigorously, discussions," new criteria are to be applied to export policies, and ERDA is instructed to, "investigate the feasibility of recovering the energy value from used nuclear fuel without separating out plutonium."

3. "Assessment of U.S. and International Controls over the Peaceful Uses of Nuclear Energy," a report to Congress by the Controller General, ID-76-60, Sept. 14, 1976. This describes U.S. agreements for cooperation, international safeguards programs, U.S. export controls, and future U.S. strategy options. Each chapter contains an assessment of the implications for proliferation, suggestions for Congressional actions, and

(Continued on Page 48)

## THE INMM CHAIRMAN SPEAKS

Roy & Barbara Cardwell, A.R. Soucy . . .

# GRAB HOLD AND PULL!

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

It is most encouraging to have seen the sound defeat of all but one nuclear safety initiative in November following the same action by the people of California last June. Fortunately, the American people seem to have decided that we have a place in the power community; but they are looking to us for answers to serious and often reasonable questions raised by the anti-nuclear forces.

I sincerely feel that INMM, with it's wide diversity of technical and management expertise, can make a significant contribution to the progress and eventual establishment of an accepted nuclear community. Unfortunately our wide diversity sometimes works against us and we fail to come to an understanding of each others particular problems.

In this regard I particularly appeal to our common sense of logic in the desire for a successful nationwide nuclear program and ask for an open-minded attitude as we try to go forward. Make no mistake about it. In this business we all win or we all go down the tube together.

This year I intend to emphasize our public information program and particularly our speaker's bureau organization. What we need is a strike force . . . to hit back hard and quickly . . . against unfair and unjust anti-nuclear claims and statements as well as incidents poorly reported and blown all out of proportion by the press. We lack not for ability in this regard . . . only for organization; and I ask that all of you give your utmost cooperation to **Dick Parks** as the New Chairman of our public information effort.

I have also long believed that INMM belongs in the business of basic and advanced education opportunities for its members. After a good start under **Manny Kanter**, I expect to see this program now extensively expanded under Chairman **Harley Toy.**

I was very disappointed, as were many of you, that the certification standard failed to fly in Seattle and I sincerely hope that this program will find its way to a most important, active place in our society. I find very few members against the concept of certification . . . only the method and procedure. We must, without fail, find a vehicle by which our profession can have the recognition it deserves. Being recognized only by ourselves is friendly but not very encouraging.

We are delighted that petitions have now been received for two regional chapters . . . one in Japan and one in Europe. Since this is a first, negotiations are underway with the petitioners to establish the rules and guides of our new relationship. We look forward to this exciting new dimension in our activities.

Finally, I am most encouraged that INMM is finally beginning to take its place of recognition among the better known technical and management societies. The acronym is, in fact, becoming a relatively common word quite frequently referred to by those outside of our membership. Our potential and opportunities are at their highest point in our near twenty-year history, and our mission is clear. We need your help. Grab hold and pull!

Mr. Gerdis

# Thanksgiving and The New Year

By **Tom Gerdis, Editor**
Nuclear Materials Management
Journal of INMM

November 25—This issue of Nuclear Materials Management, the still new and emerging quarterly journal of this Institute, represents the fourth and final one of the first five years of its existence. This is the 20th issue of the journal. The first one came out in April, 1972.

On this Thanksgiving Day, I am reminded to be thankful for the opportunity to be a member of the Institute, participate in its activities, and serve as Editor of this Journal which will this spring begin its 6th year of publication. I am particularly thankful to those who have given me the opportunity to serve as editor of the publication. Three past chairmen of the Institute—**Jim Lovett, Harley Toy** and **Armand Soucy**—and the current chairman, **Roy Cardwell**—have all been nothing less than a delight to work with and for.

I am also grateful to **Curt Chezem** of New Orleans, Louisiana where he is employed as director of the nuclear activities department of Middle South Services, Inc. It was Curt who invited me to help found the Journal back in the fall of 1971. Curt served as the first Executive Editor of the publication and he was so important to me personally in getting a handle on what should and might be included in the journal. When he left K-State in July, 1972, to join Middle South, he continued to serve for nearly another year.

Then a little more than two years ago, **William A. (Willy) Higinbotham** came on the scene at the suggestion of Harley Toy and others. And what a rich addition to the Journal staff he has been. Willy is a man blessed with immense talent and ability who has been unselfish as Technical Editor of the publication. A veteran safeguards man, Willy Higinbotham of Brookhaven National Laboratory helped this writer by arranging to have regular article contributions from several active safeguards professionals.

Without a doubt, **John Jaech** of Exxon Nuclear Co., Inc., has been the most faithful contributor to this Journal with his articles on statistical topics. There have not been many issues without an article from Mr. Jaech who is a member on the INMM Executive Committee and who for the past two years has chaired the INMM Standards Committee.

In the last year or so, **Norman Beyer** (now of IAEA) and **George Winslow** of Argonne National Laboratory, **John Stewart** of GE-Wilmington, and **Bob Keepin** of Los Alamos Scientific Laboratory have taken it upon themselves to supply at least one technical article per issue. This has been so helpful in moving toward a journal of higher quality and increasing significance in the safeguards field.

And now Mr. Higinbotham has been successful in increasing the size of the Editorial Advisory Committee as a further move to improve the quality and scope of articles appearing in this Journal.

Do you have any constructive suggestions for the content and operation of the Journal? They are welcomed. Let me hear from you soon.—T.G.

Gary Molen of Allied General Nuclear Services, Barnwell, S.C., and INMM Technical Program Chairman, recently visited the Nuclear Safeguards R & D Laboratory at Los Alamos to discuss safeguards in implementation in fuel cycle facilities. With safeguards design document "at the ready", Molen (left) shares a moment of levity with Bob Keepin, LASL Safeguards Program Director, and INMM Vice Chairman, and with INMM member, Ed Schelonka, of the LASL Safeguards staff.

# Safeguards and The Promise of Nuclear Power

**Dr. G. Robert Keepin, Vice Chairman**
Institute of Nuclear Materials Management, Inc.

It has indeed been a very eventful fall and winter for nuclear power, and many key issues still remain to be addressed (and hopefully many resolved by the new Administration and the 95th Congress. Anti-nuclear initiatives in six states were soundly defeated last November 2 by over six million U.S. voters. Including the June 8 California vote, Americans in seven states that contain about 20% of the total U.S. population have had an opportunity to vote on the need for nuclear energy and they have endorsed it by a two-to-one margin. Moreover, according to a November 29th nationwide Harris Poll, Americans favor the building of more nuclear plants by a still greater margin of 61% to 22%. Thus, as Einstein had predicted over 25 years ago, the acceptability of nuclear power has been taken to the Village Square, and has received the approbation of the American voter.

We in INMM must do all we can, both individually and collectively, to ensure that the government decision-makers in Congress and in the new Carter Administration are fully aware of these impressive votes of confidence and their significance. In this connection, it is reassuring that **Jimmy Carter** has recently stated (in a late-November televised discussion on nuclear power with CBS-TV newsman **Walter Cronkite**), "I would not favor any sort of nationwide moratorium on the construction of atomic power plants. I think we've got to have them . . . As President I'd be glad to assume the responsibility to reassure the American people that when atomic power plants are built, they are safe and located properly."

All this heartening reassurance certainly does not mean that the public considers nuclear energy problem free; indeed many Americans, while generally supporting the need for nuclear power, have at the same time made that support conditional upon the timely achievement of significant further progress in the areas of waste management, nuclear safeguards reactor safety.

Apparently due to the poll results and initiative votes, nuclear critics are now, according to several recent news reports, planning to place more emphasis on economics and the fuel cycle, particularly plutonium, safeguards and waste rather than so much on reactor safety issues.

The safeguards issue has, in fact, emerged as a pivotal factor in the future development of nuclear power, in international nuclear trade and export policy, and in rising concern about nuclear proliferation. The issue of proliferation has been described by Congressman **John B. Anderson,** of Illinois, as "an issue of transcedent importance" which must be resolved "even at the risk of offending competitive sensibilities." A strong U.S. Nuclear non-proliferation policy is expected to be proposed by the Carter Administration and strongly endorsed and supported by the 95th Congress. At the same time it is abundantly clear that the United States must vigorously pursue the development of nuclear power domestically while also continuing our support (under adequate international safeguards) of peaceful nuclear developments overseas. To withdraw our support from the latter "would nullify whatever moderating influence the U.S. can hope to exercise through continued leadership and cooperation" (cf. Committee on Economic Development, CED report

# The Energy Controversy

The Energy Controversy: The Fight Over Nuclear Power, by Fred H. Schmidt and David Bodansky, Albion Publishing Co., San Francisco (1976), 150 pp., paperback, $4.95.

**Fred Schmidt** and **David Bodansky** teach physics at the University of Washington. Critics will note that some of the funding for their study came from AEC and ERDA funding. So, also, did some of the support for the studies of Drs. Goffman and Tamplin which took the AEC to task for lax regulation of radioactive emissions. Unlike some physics professors that I have known, Schmidt and Bodansky have tried to make science meaningful to undergraduate students. In consequence, they have not only studied the voluminous and confusing technical literature pertaining to energy sources in general and to nuclear energy in particular, but have presented this most important subject in a mere 150 pages and in basic English, with illustrations that any layman should comprehend.

It is conceivable to me that nuclear power involves problems which could be too difficult for society to handle. It is equally conceivable to me that a heavy dependence on the use of coal or solar cells and windmills will involve similarly difficult problems to cope with. All too often, the question put to a voter is whether or not to have a nuclear power plant built nearby. The only sensible way to decide what to do about nuclear plants or LNG tankers or strip-mining for coal, is to consider the whole societal energy subject, U.S. and international. This is the approach that the authors have taken.

There is no way that one or two individuals can read and digest all of the flood of technical documents and the criticisms being published on the subject of nuclear energy, much less, energy all told. Unlike **Barry Commoner** who wrote three long, provocative and Olympian articles on energy for the New Yorker, authors Schmidt and Bodansky are more modest. They studied what they could digest, wrote their summary for the layman and had their drafts reviewed again and again for insurance. In my opinion, they were overly consciencious. This book would have been more useful a year and a half-ago, than it will be now. The short-comings that it had then were not important, and some still exist. Safeguards and Security take up only 5 pages and nuclear proliferation occupies 2½. The authors rely on Bernie Cohen's calculations of the radiological hazards which a number of other experts believe to be on the low side.

Still, it seems to me that the emphasis is in the right place. The number one question is how to plan for energy for society. Pollution and resources, environment and nuclear warfare are all involved. It probably doesn't make much difference whether you use Cohen's or Tamplin's values for plutonium toxicity. In any case, we have to control plutonium and who knows what are the health impacts of burning coal or oil?

This is a book that you can recommend to your local school board, League of Women Voters and environmentalists.

**W.A. Higinbotham**
Brookhaven National Laboratory

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**"Nuclear Energy and National Security"**; see also Chemical and Engineering News, p. 8-9, Oct. 1976 **"Nuclear Isolationism: A Warning for the U.S."**)

Looking toward the implementation of U.S. leadership in this vital area, ERDA is preparing to undertake major programs designed to support the development of nuclear power under an effective system of international non-proliferation controls and to formulate U.S. domestic nuclear policies in support of the same objectives. Since so much reliance is being placed on effective safeguards inspection and verification techniques as an argument in support of the future use of nuclear energy, greatly increased attention is being focused on the field of safeguards technology and implementation, e.g., by the Congress and by various government agencies (such as the GAO and the OMB). Moreover, a new round of Congressional hearings—this time specifically on Safeguards R & D—now appears to be in prospect for the new 95th Congress.

Though admittedly only part of the overall political-economic-technical solution to effective international control of nuclear weapons proliferation, modern safeguards technology seems clearly destined to play a key role in achieving stringent and effective safeguards in all major types of facilities throughout the nuclear fuel cycle.

Mr. Jaech

## N15 REPORT

# Lull in Productivity

By John L. Jaech, Chairman

If one were to judge the recent accomplishments of N15 writing groups by the numbers of standards just published or awaiting pulication, of draft standards undergoing the balloting process, or of drafts out for final review just prior to balloting, the record would be unimpressive. I hope that this is simply the lull before the storm for at this writing, there are many drafts in various stages of completion. Hopefully, by the time of our June meetings in Washington, I will be able to give a glowing report of visible progress.

For the benefit of those INMM members who have a special interest in a given subject and would be willing to provide informal reviews of drafts as they come along, here is a listing of proposed standards currently being written. Title changes may occur in some of these before final publication.

N15.5 —Statistical Terminology and Notation for Nuclear Materials Management (complete revision).

N15.24—Standard for the Recordkeeping and Reporting of License Inventory Data.

N15.25—Standard for Measuring Material in Process Equipment.

N15.29—Procedures for Correcting Measurement Data for Bias.

N15.33—Categorization of SNM for NDA.

N15.34—Standardized Containers for NDA.

N15.35—NDA Physical Standards.

N15.36—NDA Measurement Control and Assurance.

N15.37—Automated NDA Data Acquisition and Analysis.

Unassigned—Auditing Measurement Control Programs.

Unassigned—Auditing Plant Inventories.

Unassigned—Generic Auditing Standard for Nuclear Materials Safeguards.

If I've overlooked any, my apologies to the Subcommittee Chairman.

This list of standards under development is impressive. Unfortunately, some of the above have been on this for many months, outlasting the lives of the original chairman and, in some instances, his replacements. These delays are further evidence of the work pressures under which many INMM members operate. However, standards writing can proceed apace if each writing group chairman and member will set a reasonable deadline for action, resolve to set aside the few hours needed to meet that deadline, and then conscientiously attempt to do this. There is a tendency for a writing group to proceed at a pace equal to that of the slowest member, so it's essential that **each** member do his part in a timely and responsible manner.

For those uninvolved INMM members, if you would like to assist in furthering the development of one or more of the above proposed standards, let me know and I'll get you in touch with proper party. My phone number is (509) 943-8423.

## Advertising Index

Dr. Forscher

# Hopes For New Draft of Standard

**By Dr. Frederick Forscher, Chairman**
INMM Certification Committee

Irrespective of which Safeguards, domestically and worldwide, are finally agreed upon by the various national and international regulatory bodies, all depend, in the final analysis, on the competence, expertise, and motivation of the individuals in industry and government who are charged with implementing Safeguards. The importance to society of accurate measurement and secure protection of SNM elevates such individual activities to a profession.

**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, and in which the amount of financial return is not the accepted measure of success." Nuclear Materials Managers meet this, and other definitions of a professional. Like most specialists they have banded together in a professional organization with international membership; our INMM. At the 17th annual meeting of the INMM (Seattle, June 1976) Representative **Mike McCormack** stressed repeatedly the importance of this profession. "The future of plutonium recycle, the fast breeder reactor, and thus the long-term promise of nuclear power itself, could depend in large part on how effectively we are able to safeguard, to control, and to manage strategic nuclear materials. This means, in turn, that the nation must depend upon professionals sucn as those in the INMM to provide the expertise and practical know-how to achieve these essential goals."

"Certification" or "Licensing" of these professionals would provide proper public recognition, add a quality control step to admission to the profession, and help the public acceptance problem by lending credibility to safeguards measurements and security verifications. Unfortunately, such public recognition of the profession is not yet established.

Your Certification Committee prepared a document (ANSI-N15.28) that defines the requirements for certification, but further revisions of this document are necessary, and implementation of a professional certification program sponsored by the INMM is still in the future. It is conceivable that, because of the present intense concern with nuclear proliferation, the appropriate agencies may insist on "licensing" nuclear materials managers, with or without a professional certification program. Such a step, in my opinion, would be detrimental to our professional unity, to public confidence in Safeguards, and to international efforts to equalize the capabilities in materials measurements and protection.

ANSI's Nuclear Standards Management Board (NSMB) is now considering the question of accreditation of our certification program and similar programs in other nuclear industry connected professional societies. The outcome will decide whether professional quality, in contrast to product or service quality, can be defined by an ANSI standard. We would also like to know from ANSI what is the proper overseeing or accreditating agency. In the meantime, we hope that a formal trainings program for nuclear materials managers could be established someplace, the graduates of which should qualify for certification, like graduates of accredited accounting courses qualify for C.P.A.'s.

Your Certification Committee is keeping abreast of these and related developments in the field of materials measurement and protection. We hope that by mid-year, and before our next annual meeting in Washington D.C., the situation will have clarified to the extent that a new, and final, draft of N15.28 can be attempted.

# Mishima Studies NDA Techniques At LASL

Tsuyoshi Mishima

**Editor's Note:** The following article was supplied to us by Dr. **G. Robert Keepin,** Vice Chairman of INMM, of Los Alamos Scientific Laboratory. It appeared on page 8 of the November-December 1976 issue of **The Atom.** Mr. Mishima is an INMM member.

**Tsuyoshi Mishima** came to Los Alamos Scientific Laboratory more than a year ago to study LASL's techniques for nondestructive measurement of plutonium and to exchange information on nuclear materials controls.

The Japanese engineer and his wife, Noriko, and son, Yutaka, and daughter, Misuzu, recently returned to Japan, and Mishima resumed his duties in a plutonium fuel fabrication laboratory of the Power Reactor and Nuclear Fuel Development Corporation (PNC).

"One year is not long enough to learn everything, but I learned much basic information," he said, adding that he hopes to make other, probably brief, trips to the United States to study nuclear materials control.

Mishima said he is one of a small number of scientists and engineers in the PNC, which develops a wide range of nuclear engineering techniques for the Japanese government, who have a background in plutonium measurement and materials control.

One motivation for Mishima's coming to LASL is the Laboratory's dynamic materials control (DYMAC) concept, a system which permits accurate and rapid measurement of nuclear materials at key points throughout a nuclear plant.

Coupled with a plant-wide surveillance system, DYMAC incorporates:

(1) an in-line and at-line measurement system relying heavily on nondestructive analysis (NDA) instruments to provide quantitative assay data at key measurement points;

(2) direct, automated transfer of data from the plant floor into a central computer via terminals at selective measurement stations; and

(3) an automated accountancy system that rapidly gives the status on material balances for smaller segments of a plant.

Mishima was interested in DYMAC to see how it can be applied to the needs of the PNC.

"We have a great deal of knowledge about nuclear fuel fabrication in Japan," he noted, "but my visit here was arranged so I could observe nondestructive assay techniques and the DYMAC concept."

Nondestructive assaying of a nuclear material for plutonium content with a radiation detection instrument allows a sample of the material to be taken and measured without destroying the sample in the process.

Mishima said he and other engineers have been working on designs for a new nuclear fuel fabrication facility for about 2 years, "and some of the information I've received on my visit here may be incorporated into techniques for future facilities in Japan."

He said Japan is becoming increasingly conscious of concerns for safety in manufacturing and use of nuclear materials, and said a concept similar to DYMAC is needed and must be adopted for Japan.

Mishima explained that about 15 years ago in Japan there were many nuclear research laboratories, most of them operating independently with their own goals and programs. The government realized that coordination of effort was needed, and the PNC was created with facilities throughout the country.

He said the Japanese have much experience in fuel fabrication and nuclear engineering, but as environmental concerns increase, nuclear safeguards are becoming vital.

The Laboratory's nuclear safeguards research group (R-1) provided Mishima with work space, and assited him in his research, which also included some work in gamma-ray spectroscopy.

He and his family found time for some recreation and sightseeing, and he stated they "enjoyed the area and are hoping for an opportunity to return."

BOOK REVIEW

# Would Rather Be Right

Weinstock

**By Eugene V. Weinstock**
Brookhaven National Laboratory

Review of "The Nuclear Power Controversy," **Arthur W. Murphy,** Editor (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1976).

**Anthony Trollope,** in his novel "The Warden," says of his protagonist, who had become engulfed in a swirling controversy, "He was not so anxious to prove himself right as to be so." In other words it was more important for him to know the truth and act in accordance with it than to "score" with sharp argument and debaters' points. What fitter guideline for those engulfed in the present nuclear controversy, as they try to draw some sensible conclusions from the ever-increasing torrent of books and articles that has become a major by-product of nuclear energy?

One of the best of these is a collection of background papers, entitled "The Nuclear Power Controversy," prepared for the Fifteenth American Assembly and edited by Professor **Arthur W. Murphy,** of the Columbia University Law School. An affiliate of Columbia University, the American Assembly meets at least twice each year to consider issues of great public importance. Its delegates are drawn from leaders in diverse fields; indeed, the list of attendees at the nuclear energy meeting reads like a "Who's Who" in the professions most concerned, directly or indirectly, with nuclear energy and its effects.

The six chapters, each of a different authorship, cover the entire spectrum of issues raised by nuclear energy: its safety, economics, regulation, relationship with government and industry, and impact on the proliferation of nuclear weapons. The expositions, intended for the educated layman, are exceptionally lucid and thought-provoking, and provide an excellent introduction to the subject.

The first paper, by two physicists at the University of Washington, **David Bodansky** and **Fred H. Schmidt,** covers in 47 pages the health effects of radiation, the normal radiation hazards of power reactors, reactor accidents and safety, the disposal of radioactive wastes, and nuclear theft and sabotage. The treatment of the waste problem and of reactor safety is especially good. However, the discussion of nuclear terrorism struck me as somewhat superficial and Pollyanna-ish, for example in stating that only a "very large" heavily armed band of men could successfully seize a nuclear shipment, a claim not supported by a perusal of the **present** regulations governing the protection of nuclear shipments. Elsewhere, the impression is given that all shipments of nuclear material are protected by a system that, in fact, is used only for nuclear weapons and other government-owned material. These, together with an annoying lack of references, are only minor flaws, however, in an otherwise admirable treatment.

The economics of nuclear power are examined in the next chapter, by **R. Michael Murray, Jr.,** through a comparison of the cost of nuclear- and coal-generated electricity, both at present and, by projection, in 1984. Nationwide, nuclear has an average advantage of 17% now and 19% in 1984, but in some areas coal is cheaper, in others the two are equal, and in still others nuclear's advantage is larger, which illustrates the danger of thinking in "global" terms that neglect regional differences. Moreover, a sensitivity analysis reveals that nuclear's advantage could be wiped out by a 10% increase in the cost of nuclear plants together with a 10-point increase in the capacity factor of coal-fired plants. Major factors affecting the price of coal-generated electricity and contributing to its uncertainty are the cost of transportation of the coal and that of removing $SO_2$.

In Chapter 3, **Fritz F. Heimann,** of General Electric, reviews the historical ups and downs of the nuclear industry. He attributes the rapid increase in power plant costs during the late 1960's and early 1970's to three factors: the inflation and shortages caused by the Vietnam war, the emergence of a strong environmental movement, resulting in a great increase in regulation, and the concomitant conversion of the licensing process from a technical to an adversary proceeding, with its costly and interminable delays. To get the industry moving once again he recommends a strong national commitment to nuclear energy as part of a basic energy policy, a rapid expansion of enrichment capacity and development of the "tail end" of the fuel cycle by the government, and "more realistic methods of doing business" for the private sector of the industry.

The regulation and licensing of nuclear power are reviewed in a contribution by Editor Murphy, with particular attention to the causes of delays and to public participation in the licensing process. He explores the unavoidable tension between safety and economics and is led thereby to a consideration of risk, in the process providing the most enlightening analysis of the Price-Anderson Act I have seen. He points out that, contrary to the charges of its critics, the Act actually provides more protection to the public than the latter would get in its absence.

Ex-AEC Commissioner **John Palfrey** gets to the real heart of the nuclear controversy, nuclear weapons proliferation, in the chapter entitled "Nuclear Exports and Nonproliferation Strategy," addressing the central question of how best to delay (everyone seems to have given up on **preventing**) the international spread of

## TECHNICAL PROGRAM REPORT

Molen

# Safeguarding Plutonium Fuel Cycle

**By Gary F. Molen, Committee Chairman**
Allied-General Nuclear Services
Barnwell, S.C.

The Institute's Eighteenth Annual Meeting will open in Washington, D.C. on Wednesday, June 29, 1977, with a Plenary Session of prominent invited speakers from government and industry. We are planning to have somebody from the White House (hopefully the new Energy Advisor) as the keynote speaker. He will be followed by speakers from both congress and industry, as well as NRC, ERDA, and IAEA. We also are planning to invite one or two nuclear critics (those whose criticism has been reasonably responsible) to offer their viewpoints on both national and international safeguards issues.

On Wednesday afternoon (June 29, 1977), we are planning a special panel discussion. The panel members (representatives of congress, industry, ERDA, NRC, and ACDA) will each make a brief statement, followed by questions from a team of three reporters (hopefully representatives of the National Observer, New York Times, and the Washington Post). The discussions will be moderated by our own **Bob Keepin,** who will serve as the Panel Moderator.

For the concurrent sessions (Wednesday and Thursday, June 29-30, 1977), we are planning sessions on safeguards status reports, materials control, national safeguards, system studies, international safeguards, and physical security. Each session will begin with an invited paper highlighting the theme of that session. We expect to have at least seven contributed papers for each session. If the number and quality of contributed papers warrant, we are considering reducing the time allotted for each paper so that more speakers can be accommodated for each session.

Our general theme for the meeting, particularly the panel discussion, is "Safeguarding the Plutonium Fuel Cycle." We are asking the speakers to use this as a thread of continuity in their individual remarks. We are also structuring the meeting so that both national and international issues will be addressed.

I think you will agree with me that this next annual meeting should be an exciting one. We hope so, and we hope that you will plan to attend. See you in Washington, D.C. June 29-30-July 1, 1977.

**TECHNICAL PROGRAM COMMITTEE**
**G.F. Molen,** Chairman **J.H. Menzel**
**R.N. Chanda** **T.E. Shea**

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nuclear arms. Arguing persuasively against unilateral arm twisting by the U.S., he nevertheless identifies two major steps by which we can have a major influence on the course of other nations: deferral of domestic licensing of plutonium until it is needed for the breeder reactor, meanwhile demonstrating its processing and use as a "hedge" against shortages in enriched uranium, and a major expansion of uranium exploration, extraction, and enrichment capacity, to establish the U.S. as a reliable supplier of slightly enriched uranium.

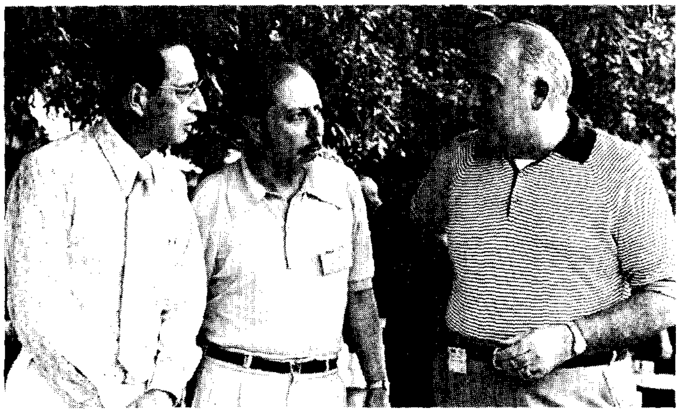
To a nuclear proponent, the most provocative chapter in the book is the last one, written by an avowed nuclear skeptic, ex-Presidential science advisor (to Eisenhower) **George Kistiakowsky.** His tone is moderate, responsible, and free of the hysteria and gross misrepresentation that mars so much of the anti-nuclear criticism. He is also refreshingly candid about not knowing all the answers; many of his objections to nuclear power are admittedly based on "gut feelings" rather than on rigorous technical argument. Thus, as an explosives expert he questions a key conclusion in the Rasmussen report concerning the behavior of a molten reactor core, namely that it would seal itself into the subsoil. More likely, in his view, would be a violent reaction with "thermally unstable components" in the ground water, such as carbonates, resulting in a blow-out that would spew fission products and plutonium downwind.

Although he is caustic about the history of waste disposal by the A.E.C., he thinks this problem will eventually be solved satisfactorily—in the U.S., at least, where stable underground formations exist. He is far less sanguine about the problems of nuclear theft and weapons proliferation, particularly the latter, fear of which is his principal motive in opposing nuclear power.

His opposition, though, is not total: he would allow present plants to continue operating and would complete plants now under construction, but would add new plants only when absolutely necessary and, preferably, only in locations remote from populated areas.

One of the most fascinating aspects of this book is the different conclusions drawn from the same data by Kistiakowsky, on the one hand, and by Bodansky and Schmidt, on the other. The leaks of radioactive waste at Hanford, the vulnerability of the industry to terrorists, the Browns Ferry fire and the data on reactor safety—all these lead to almost diametrically opposite conclusions in the two chapters, an indication of the large role played by subjective judgment in this whole controversy, and also of the extent to which nuclear power has been transformed from a technical into a political issue. As a cure for smug certitude, the first chapter in particular should be read by all nuclear critics, and the last by ardent advocates. And the whole book should be read by all those who, like Trollope's perplexed hero, would rather be right than "prove" themselves so.

**Eugene V. Weinstock**
Brookhaven National Laboratory



NEW NATCO GENERAL MANAGER—Lynn K. Hurst (left), a past Chairman of INMM, Inc., has been named General Manager of Nuclear Audit and Testing Company, Inc. He is pictured with two other past INMM chairmen—Bernie Gessiness (center) and Tom Bowie.

## Lynn K. Hurst, Former INMM Chairman, New Natco General Manager

Nuclear Audit and Testing Company, Inc., Vienna, Va., announced today the appointment of Mr. **Lynn K. Hurst** as General Manager. He succeeds Dr. **Russell P. Wischow** who recently left the firm to join Pacific Gas and Electric Company.

Mr. Hurst joined Nuclear Audit and Testing Company, Inc. in 1972 as Manager, Quality Assurance, and was elected a Vice President in 1974. Prior to that time he was Director of the Argonne National Laboratory's Special Materials and Services Division where he developed and directed the programs for safeguards, safety in storage and transport, quantity and quality measurement, quality assurance, and material management as they were applied to special nuclear materials, precious metals, and specialized nuclear reactor materials.

In announcing the appointment, Mr. **E.R. Johnson,** Chairman of the Board of Nuclear Audit and Testing Company, Inc., said the Company will continue to serve the nuclear industry as it has so ably done in the past under the combined efforts of Dr. Wischow and Mr. Hurst.



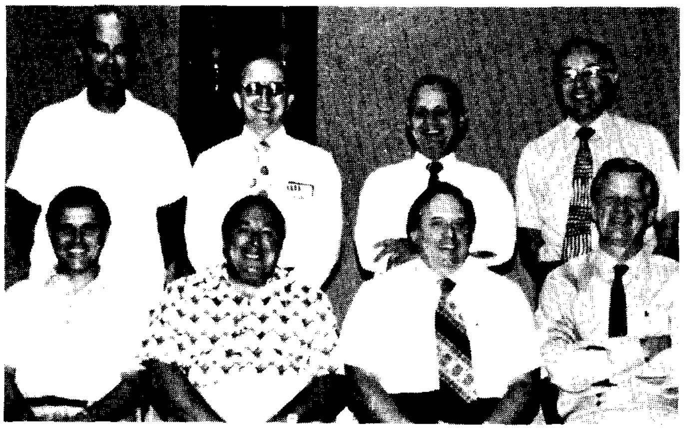
## David Schofield To NUSAC

Schofield

McLean, Va.—Dr. **Ralph F. Lumb,** President of NUSAC, Inc., has announced the appointment of **David G. Schofield** as Manager, Security Programs Division. In his new position Schofield will be responsible for NUSAC's inudstrial security planning services for plant and material protection. Formerly a Senior Technical Associate, Schofield succeeds **Kenneth D. Cohen** who recently left the firm to join the U.S. Nuclear Regulatory Commission.

In another appointment **David Wright,** formerly Assistant Director, Inspection and Appraisal, Division of Safeguards and Security, ERDA, has joined NUSAC as a Senior Technical Associate in the firm's Security Programs Division. Wright's responsibilities will include the conducting of threat analyses, audits, inspections and assessments of physical security and materials safeguards.

NUSAC is an independent consulting firm providing advice and assistance in the areas of nuclear fuel quality assurance and the safeguarding of nuclear materials and facilities.



All four officers and four of the five other Executive Committee Members attend the September meeting in Cincinnati as guest of Bernie Gessiness of National Lead, a past Chairman of INMM. Seated (From left)—Bob Curl, Treasurer (Argonne West); Vince DeVito, Secretary (Goodyear Atomic); Roy Cardwell, Chairman (ORNL); and Bob Keepin, Vice Chairman (LASL). Standing (from left); Ralph Jones, NRC; Gary Molen, AGNS; John Ladesich, Southern Cal Edison; and John Jaech, Exxon Nuclear. (Photo by Dick Parks, Olympic Engineering).



## COMMENT

Mr. Parks

# No Clean Bill of Health

**By Richard E. Parks, Chairman**
INMM Public Information Committee

In the November election, voters in several states mandated to the nuclear industry that they were two to one in favor of nuclear power. Unfortunately, although most of the anti-nuclear initiatives were defeated by a very deciding vote, the nuclear industry still dows not have a clean bill of health.

A recent article in the **Seattle Times** reported findings of the Washington Public Disclosure Commission. The article stated that $982,681 were expended to defeat the nuclear safeguards initiative, that almost 84 per cent came from business-related sources and the heaviest contributors in the group were the various electric utilities in the state.

It inferred that since the initiative would have "increased safeguards for nuclear plants" that the utilities as major contributors were not in favor of nuclear safeguards. The article further stated that only $118,809 were used in an effort to pass the initiative, but did not state the source of these funds.

The nuclear industry continues to suffer from one-sided journalism. The industry has tried diligently to present the facts. Unfortunately, some are still not willing to listen to fact and choose to dwell more on the sensational issues which stir emotions.

Perhaps the credibility of the industry may not be in its safety records, safeguards or technology. We have been trying to prove its credibility with these for some time, with only limited success. An alternate approach to gain credibility may be in order.

Dr. Fred **Fred Forscher's** article in the last issue presented an interesting alternative to indirectly gaining greater acceptance. His hypothesis that energy is to society as food is to people, provides the basis for that argument. To survive as a nation and as individuals, we must have energy. Energy is essential to the production of food.

The argument, then becomes one of determining the best and most efficient use of various forms of fuels available to produce the energy. Our survival is severely constrained when we are dependent on the whims of OPEC. Our coastlines are continually jeopardized by oil tankers and crews. Our balance of trade this past year was not in our favor. Solar-powered farm machinery is not presently available.

Energy is a complex and frustrating problem. We need to continue to extol the virtues of nuclear power as a safe, reliable form of energy. I suggest that it may be of additional benefit to argue nuclear energy with the context of other alternatives, rather than solely on the basis of safety, safeguards, and technology. Perhaps then we can convince the media to provide a more equitable prospective when writing on the subject of nuclear energy.

Mr. McKinney

# Nuclear Power 'Most Practical'

Much is being said, printed, charged and counter-charged these days about the federal government's policy—or lack of policy, depending on one's point of view—toward developing a national program to cope with the existing energy crisis.

For the last several years the public has been urged to use less electricity, less gasoline, less fuel oil, and former President Richard Nixon declared a program designed to make the United States energy self-sufficient in 10 years.

Neither of those two efforts has proved effective.

Motorists found their neighborhood filling stations short of gasoline a couple of summers ago, but since then the symptoms of that problem have not re-appeared. The price of gasoline has continued to increase, but not as drastically, so far, as once was predicted.

The search for alternative energy sources, to prevent our having to import more than half our oil needs from the Middle East have so far been fruitless. We are now importing more petroleum than when President Nixon made his declaration.

Meanwhile, serious environmental problems have plagued the effort to develop substitute energy sources. Opponents to atomic power plants say disposition of radioactive waste materials is an unsurmountable problem and that the possibility of an accident in a nuclear power plant is such a terrible threat to massive destruction of human life that further nuclear development must stop.

The nuclear threat is a dramatic one, and without question, a real one. Should there be a nuclear accident, the results, indeed, might be disastrous. It is easy for lay people to imagine that huge, horrible mushroom shaped cloud of an atomic explosion, burning everything in its path to a cinder and sending a shower of radioactive fallout over the world.

But prospect of using other sources of energy is plagued with problems, too. Coal is recommended as substitute fuel for power production instead of atomic energy. But one estimate holds that to do so would require in the next few years 10 times the amount of coal we are burning now in steam plants to produce the needed electricity. It boggles the mind to imagine the smoke, the sludge from the scrubbers, the environmental disaster caused by mining that much coal, and other related problems.

Environmentalists enjoy advocating solar energy as being clean, free, and plentiful. All those descriptions are, of course, true, but the prospect of man being able to utilize the sun for his energy needs in the forseeable future is nil. Of course solar energy research should continue—full steam. And so should efforts to find ways to utilize the enormous power in the tides, in underground steam, the wind, and other natural energy sources.

No doubt someday techniques will be developed to make efficient use of those energy sources, but they do not offer a practical solution to energy needs in the next 10 to 25 to 50 years.

Nor is it a practical solution to say we must use less energy. The need for energy will continue to grow and the only practical approach is to find ways to meet that need. Conservation, of course, must be practiced and price increases will, no doubt, encourage that.

Obviously we don't have the scientific credentials to make a calculated judgment on the advisability of going ahead with nuclear development, but after all, it is the lay public which, is the last analysis, will make that judgment through adopting or not adopting laws to promote or restrict nuclear power growth. And it seems to us that nuclear power, including the Liquid Metal Fast Breeder Reactor, offers the most practical immediate solution to the energy problem. We think the scientists and technicians should be given the money and the green light to develop the technology both for power and for safety and to harvest the benefits available from nuclear power.

—**Vernon McKinney**

**Vernon L. McKinney,** 48, has been editor and publisher of **The Lenoir City News** since 1961. McKinney is a personal friend of Mr. Roy G. Cardwell, INMM Chairman. McKinney was president of the Tennessee Press Association in 1972 and earned bachelor's degrees at Tennessee Wesleyan College (1949) and the University of Tennessee, Knoxville (1955, Journalism). He is a member of the UTK Publications Council, an advisory and policy-making board for student publications of the University.

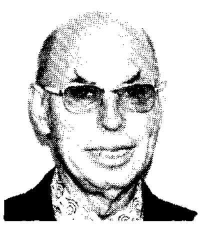
## LETTER TO THE EDITOR

Mr. Vernon L. McKinney
The Lenoir City News

Dear Vernon:

Your recent editorial "Nuclear Power Most Practical" was welcome reading after seeing most of the anti-nuclear material that has appeared in the media these last few months. I must say that your reasoning concern-

(Continued on Page 20)



Mr. Lee

# New Member Count Stands at 51

**By James W. Lee, Chairman**
INMM Membership Committee

It is always nice to be able to report Progress, and thanks to the fine efforts and cooperation of all of you members and officers who have been actively boosting INMM membership, we are pleased to be able to tell you that the new member count stands at 51, a larger number of new memberships than the Institute gained in the same period of time last year.

The Institute is not the only group that can boast of increasing its membership, for the INMM Membership Committee has swelled its ranks to four. Your Membership Committee now consists of **Vince DeVito, Bob Curl,** our new member **Jim Patterson,** and the writer.

Much of the credit for the increasing interest in INMM, and the more frequent requests for membership information, belongs to a spreading awareness of the many active programs now being carried on by the Institute. This interest and awareness now has become international in scope as demonstrated by the presentation of a petition from overseas members of the nuclear industry to the recent Executive Committee requesting the Institute to establish a European Chapter.

INMM is fortunate to have an active number of members working in other countries, including past Chairman **Jim Lovett,** whose articulate and experienced sponsorship of discussions explaining the value of INMM membership and participation in its work, have done much to stimulate interest within the foreign nuclear industry.

Through the dedicated efforts of Vice Chairman, **Bob Keepin, Ryohei Kiyose,** and others, a strong movement in the direction of the formation of a Far Eastern chapter also is underway.

In recognition of the tremendous support and help it receives from many interested members, the Membership Committee is publishing the following HONOR ROLL of members who have submitted names of new prospects or sponsored new members' applications during the 1976-1977 fiscal year to date.

**C.A. COLVIN** earned a listing of his name in capital letters for furnishing the greatest number of prospect names received from any one person this year.

HONOR ROLL
Membership Committee

The following members have submitted names of membership prospects or sponsored new members during the 1976-1977 fiscal year to date:

CURTIS A COLVIN
Tom Gerdis
Jimmy Gilbreath
G. Robert Keepin
John Jaech
Gordon Haugh
Yvonne Ferris
Dennis Bishop
Tom Collopy
A.W. DeMershman
Ralph J. Jones
Sheldon Kops
Orval Jones
Jay Durst
Charles Bean

Carlos Buchler
James Lovett
Willie Higinbotham
Charles R. Condon
Richard E. Parks
Roy Cardwell
Larry Kull
John Glancy
T. Atwell
J.W. Jordan
Russell A. Brown
Rodney Martin
Fred H. Tingey
Roy Roberts
Leo Hansen

R.B. Walton
L.W. Doher
J.R. Barkman
Bob Scott
V.J. Schaubert
Stephen Lawroski
L.F. Wirfs
J.J. Britschgi
Dave Hause
Victor Lowe
Roger Moore
John F. Lemming
Walter W. Strohm
A.R. Anderson
H.A. Hughes

Ed Eckfield
S.C.T. McDowell
Vince DeVito
James E. Rushton
K.C. Duffy
B.F. Disselhorst
Joseph Ryden
Darryl Smith
M.A. Kanter
James P. Patterson
John A. Hind
R.V. Curl
D.D. Scott
Glenn A. Hammond

## New Members

The following 30 individuals have been accepted for INMM membership as of Dec. 22, 1976. To each, the INMM Executive Committee extend its congratulations.

New members not mentioned in this issue will be listed in the Spring 1977 (Vol. VI, No. 1) issue to be sent out late in April.

**Mohammad Yahya Ansari,** 63 Uxbridge Avenue, Toronto, Ont., Canada M6N 2Y1.

**James L. Belanger,** 25713 (4) Winchester Circle East, Warrenville, IL 60555.

**Ronald H. Augustson,** 89 Encino, Los Alamos, NM 87544.

**Carleton D. Bingham,** 34 Sullivan Way, East Brunswick, NJ 08816.

**Joseph L. Brennan,** Project Engineer, Fluor Engineers & Constructors, Inc., 1001 East Ball Road, Anaheim, CA 92805.

**Frederick Brown,** Safeguards Advisor, Department of Energy, Safeguards Office, Atomic Energy Division, Thames House South, Millbank, London, England.

**William H. Chambers,** Group Leader, Los Alamos Scientific Laboratory, Los Alamos, NM 87545.

**Donald D. Cobb,** Los Alamos Scientific Laboratory, MS 540, Los Alamos, NM 87545.

**Elizabeth L. Collins,** Argonne National Laboratory West, P.O. Box 2528, Idaho Falls, ID 83401.

**John E. Ellingsen,** Assistant Advisor, Safeguards, Atomic Energy Division, Department of Energy, Thames House South, Millbank, London, England.

**Francis X. Haas, Jr.,** Senior Development Physicist, Mound Laboratory, Monsanto Research Corp., Miamisburg, OH 45342.

**Clarence F. Hanley,** Manager of Transportation and Handling, Boeing Engineering & Construction, P.O. Box 3707, M/S 8K-39, Seattle, WA 98146.

**Roland Jorn Steven Harry,** Project Leader, Safeguards, Netherlands Energy Development Agency, Petten, Netherlands.

**G.B. Hart,** Manager of Management Services, British Nuclear Fuels Ltd., Capenhurst Works, Nr. Chester England CH1 6ER.

**John E. Hennessey,** 4408 Morgal St., Rockville, MD 20853.

**Allen A. Madson,** Westinghouse Hanford Co., Box 1970, Richland, WA 99352.

**Richard J. Newmaker,** Senior Technical Analyst, Olympic Engineering Corp., 1214 John St., Seattle, WA 98109.

Mrs. **Sanda Onnen,** I.A.E.A., Box 645, A-1011 Vienna, Austria.

**J.T. Owens,** Chief Nuclear Fuels Engineer, Fuel Supply Department, Portland General Electric Co., 621 S.W. Alder St., Portland, OR 97205.

**Everett L. Quimby,** General Atomic Co., P.O. Box 81608, San Diego, CA 92138.

**George L. Ragan,** Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, TN 37830.

**Michael H. Raudenbush,** Senior Staff Member, S.M. Stoller Corp., 1919-14th Street, Boulder, CO 80302.

**Charles K. Rosnick,** Manager, Technical Information Systems, Atlantic Richfield Hanford Co., P.O. Box 250, Richland, WA 99352.

**Maurice R. Smith,** Technical Records Manager, British Nuclear Fuels Ltd., Windscale Works, Sellafield, Cumbria, England.

**James P. Steelman,** Baltimore Gas & Electric Co., Calvert Cliffs Nuclear Power Plant, Lusby Post Office, Lusby, MD 20657.

**Willard L. Talbert, Jr.,** Los Alamos Scientific Laboratory, MS 540, Los Alamos, NM 87545.

**John L. Telford,** Engineer, General Electric, Vallecitos Nuclear Center, Pleasanton, CA 94566.

**Joseph A. (Joe) Weilang,** P.M.A.A.A., Allied Chemical Corp., 550-2nd St., Idaho Falls, ID 83401.

**Howell E. White, Jr.,** Senior Engineer, Alabama Power Co., P.O. Box 2641, Birmingham, AL 35291.

**Norman S. Wing,** Manager, Analytical Laboratories, Exxon Nuclear Co., Inc., 2101 Horn Rapids Rd., Richland, WA 99352.

## ADDRESS CHANGES

The following three changes of address have been received as of Dec. 22, 1976, by the INMM Publications Office at Kansas State University, Manhattan.

**Y.M. Ferris,** c/o International Atomic Energy Agency, P.O. Box 645, A-1011 Viennia, Austria.

**Frank W. Graham,** Atomic Industrial Forum, Inc., 7101 Wisconsin Ave., Washington, D.C. 20014. (Res.: 6 Esworthy Terr., Gaithersburg, MD 20760).

**H. Thomas Yolken,** National Bureau of Standards, Building 221, Room B318, Washington, D.C. 20234.

# Free Bibliographies Available

Energy and habitat—topics of major international concern—are covered in two free bibliographies just issued by Unipub. Some 200 publications produced by the United Nations system and other organizations are described.

Subjects covered in the bibliographies include:

**ENERGY**—resource exploration and exploitation; environmental impact; economic and regulatory aspects; power production; nuclear energy; earth science maps; statistics and other reference data.

**HABITAT**—urban planning; climate and environment; housing; building and construction; land use and development; architecture; human settlements; population; conservation of cultural property.

The free bibliographies are available from Unipub, central source in the United States for publications of the United Nations system and other international information publishers.

Write to: UNIPUB, Box 433, Murray Hill Station, New York, NY 10016.

## Distinguished Scientist Award to G. A. Cowan

LOS ALAMOS, N.M.—Dr. **George A. Cowan,** head of the Chemistry and Nuclear Chemistry Division at the Los Alamos Scientific Laboratory, has received the Distinguished Scientist Award from the New Mexico Academy of Science.

The award was presented Oct. 1 during the Academy's fall meeting at New Mexico State University.

**Richard J. Bohl,** president of the Academy and a LASL staff member, cited Dr. Cowan for his "investigations into the synthesis of elements by multiple neutron capture and into nuclear reaction mechanisms and for his analytical insight shown in examination of data related to a natural fission reactor."

The latter work refers to Dr. Cowan's study of an open-pit uranium mine at Oklo in the Gabon Republic in Africa. From isotopic analyses of uranium taken from this mine, Dr. Cowan concluded that conditions in Precambrian times were favorable for a naturally occurring vein of uranium to begin operating as a nuclear reactor with the consequent depletion of uranium-235.

"Although this work is interesting in its own right," Bohl said, "the results may also find direct application in safe waste disposal methods for radioactive materials."

Dr. Cowan, who joined LASL in 1949, received his D.Sc. degree in chemistry from the Carnegie Institute of Technology in 1949. He received the Atomic Energy Commission's **Ernest O. Lawrence** Award in 1965.

## *Baranowski Retires From ERDA, Served 30 Years*

**Baranowski**

**Frank P. Baranowski,** an invited speaker at several recent INMM annual meetings, retired Dec. 31 after 30 years of government service. He was director of U.S. ERDA's Division of Nuclear Fuel Cycle and Production, a post he assumed in 1961 under the AEC's former Division of Production and Materials Management.

He became associated with the Nation's nuclear energy program when he was assigned as a U.S. Army Lieutenant to the Manhattan Engineer District at Oak Ridge, Tennessee, in April 1945. On leaving the military in December of 1946, he joined the AEC staff at Oak Ridge as a chemical engineer. From 1948 to 1950 he worked for Union Carbide at the Oak Ridge National Laboratory. He rejoined the AEC at Oak Ridge and was assigned in 1951 to AEC Headquarters where he served in the Division of Production as Process Engineer, Industrial Engineer, Chief of the Isotopes Separations Branch and Chief of the Chemical Processing Branch. He was appointed Deputy Director of the Division in 1960 and Director in October 1961.

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(Continued from Page 17)

ing nuclear versus coal and solar accurately reflects the thoughts and fears of concerned scientists and engineers throughout the world and shows that you have done your homework well in considering all the facts before us.

In contrast, many of your colleagues have listened to and amplified only the **Ralph Naders** and the **Tom Cochrans** who cry only "gloom and doom" where nuclear energy is concerned. None of these media men have apparently taken the trouble to ask **Alvin Weinberg, Edward Teller**, or even a prominent scientific journalist like **Ted Taylor** for an opinion.

What the public isn't told by these prophets of nuclear doom is that solar is practically useless for large public application and that the cost of cleaning up coal fired plants to neet environmental requirements will be so costly that we will again find ourselves in the pre TVA era of not being able to afford to burn a 40 watt light bulb to read the News by each week.

Yes, nuclear is hazardous. We do not deny that. So is driving your car down the main street of Lenoir City. But in contrast to the 38,000 plus deaths per year from automobiles not ONE SINGLE FATALITY has occurred from the production of power in the United States by nuclear means since the first plant went on line in the early 1960's. The nuclear industry is not running down a blind alley. They are constantly applying and upgrading their safeguards toward prevention of even the smallest incident. And, as an inspiration to their greater efforts, the Nuclear Regulatory Commission is applying tougher and tougher regulations each year.

Some in industry accuse the NRC of yielding unduly to the pressure of the Naders and the Cochrans to the extent of being extremely unreasonable. And therein lies an even bigger danger. An executive of a major electric company that produces nuclear power reactors told me just last month that he was seriously looking for another position because the company had not taken an order for a reactor in TWO YEARS.

What does this indicate? That the electric utilities are backing away from nuclear because of the extensive pressure from those whose greatest expertise in nuclear energy is how to scare people by innuendoes and half-facts. Result? . . . electric utilities are turning back to oil fired generators and putting the Arabs in an even better position to choke this country out of existence!

Clean energy sources like specially processed coal and fusion will not be creating electric power in significant quantities until after the year 2000. The only suitable bridge is nuclear. I am convinced that the public will eventually accept nuclear as a prime producer of power once they know the true facts. My real concern is that it will not be accepted until we walk in, flip the light switch on the wall, and nothing happens. If we come to that (Heaven help us), then all the "doom and gloomers" will be tossed out the nearest window. Trouble is, we may have to wait five years for the lights to come back on if we are unable to continue our present research and increase production of energy by nuclear means **now.**

Let's hope the public, congress, and state legislatures can come to a period of enlightened reason before the lights go out.—**Roy Cardwell**, Chairman, Institute of Nuclear Materials Management.

# A MODULAR ENRICHMENT MEASUREMENT SYSTEM FOR IN-SITU ENRICHMENT ASSAY

**By John P. Stewart**
General Electric Co.
Wilmington, North Carolina

**ABSTRACT**

A modular enrichment measurement system has been designed and is in operation within General Electric's Nuclear Fuel Fabrication Facility for the in-situ enrichment assay of uranium-bearing materials in process containers. This enrichment assay system, which is based on the "enrichment meter" concept, is an integral part of the site's enrichment control program and is used in the in-situ assay of the enrichment of uranium dioxide ($UO_2$) powder in process containers (five gallon pails). The assay system utilizes a commercially-available modular counting system and a collimnator designed for compatability with process container transport lines and ease of operator access. The system has been upgraded to include a microprocessor-based controller to perform system operation functions and to provide data acquisition and processing functions. Standards have been fabricated and qualified for the enrichment assay of several types of uranium-bearing materials, including $UO_2$ powders. The assay system has performed in excess of 20,000 enrichment verification measurements annually and has significantly contributed to the Facility's enrichment control program.

## I. INTRODUCTION

U-235 enrichment control at all process phases is essential for a multi-enrichment processing fuel fabrication facility such as General Electric's Nuclear Fuel Fabrication Facility, located near Wilmington, North Carolina. Enrichment control at the process container level is essential to avoid the subsequent processing of improperly mixed UO2 powders. Such improper mixing has significant impact to both the product quality and the accountability areas. Thus, at-line enrichment assay of UO2 powder in process containers—without the opening and sampling of the contained material followed by time-consuming, costly laboratory analysis significantly enhances enrichment control in both the product quality and accountability areas. The following discussion outlines one such system which is currently in operation within the above-mentioned fuel fabrication facility.

## II. ENRICHMENT METER SYSTEMS

The guidelines for the application of enrichment meter measurements have been detailed by L. Kull and R. Ginaven (Reference 1) and include the following criteria which must be applied when considering the design, fabrication, and application of a gamma-ray spectroscopic measurement of U-235 enrichment in-situ; i.e., enrichment measurements;

1. The effective thickness of the sample should be comparable to or exceed that amount of material (UO2 powder) required to produce strong attenuation (99% or greater) of the 185.7 kev gamma-ray from the decay of U-235.

2. The container wall (or bottom in the application under discussion) effect should be small or constant over the range of process container materials to be measured.

3. The uranium material matrix should be homogeneous within the container and constant over the range of sample materials.

4. The background effects caused by either high energy gamma-rays causing Compton effects or by overlapping gamma-ray peaks close to the 185.7 kev peak should be quantified and their effects removed from the measurement. This includes ambient background effects produced either by natural causes or other radioactive materials within the immediate vicinity of the measurement device.

These four main criteria must guide the designer of gamma-ray spectroscopy systems which will be used for the measurement of U-235 enrichment per the enrichment meter principle.

The limitations of in-situ enrichment assay systems are evident from the above four criteria. For example, the effective 99%+ attenuation of the 185.7 kev gamma-ray is a function of the composition of the uranium-matrix. As shown in Reference 1, the most significant inaccuracies in the measurement of U-235 enrichment

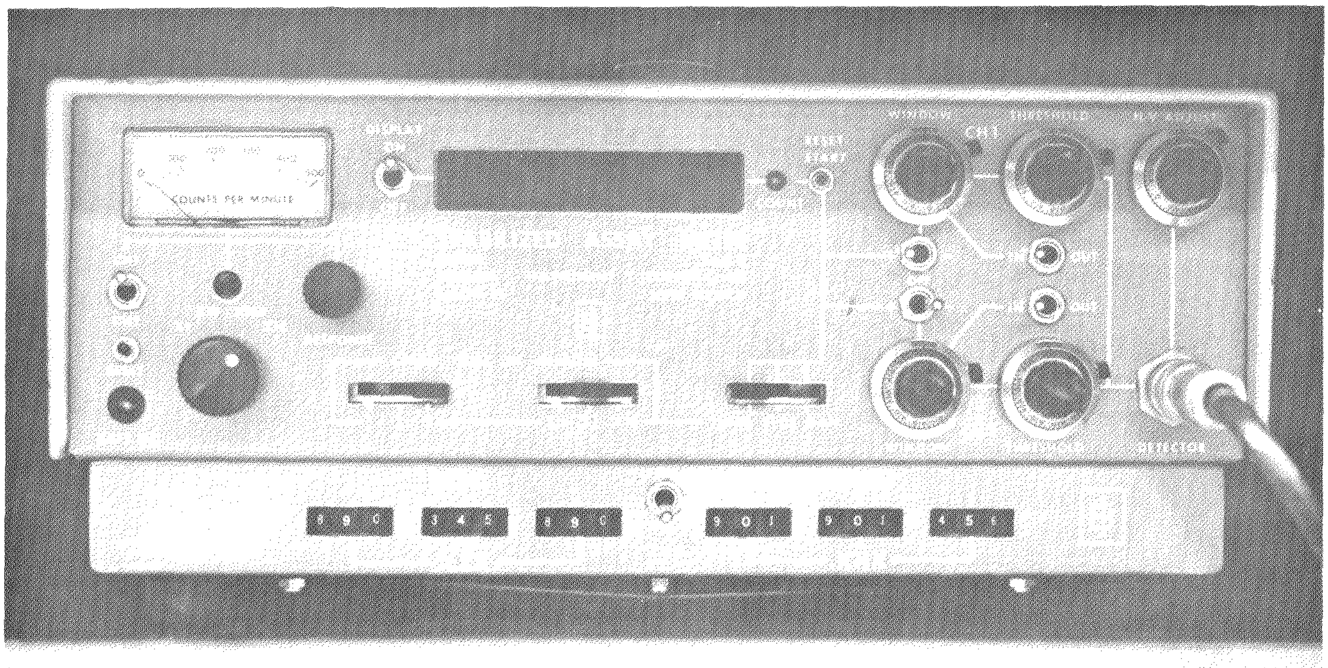


**Figure A**
**Wilmington Enrichment Meter "Sam 2"**

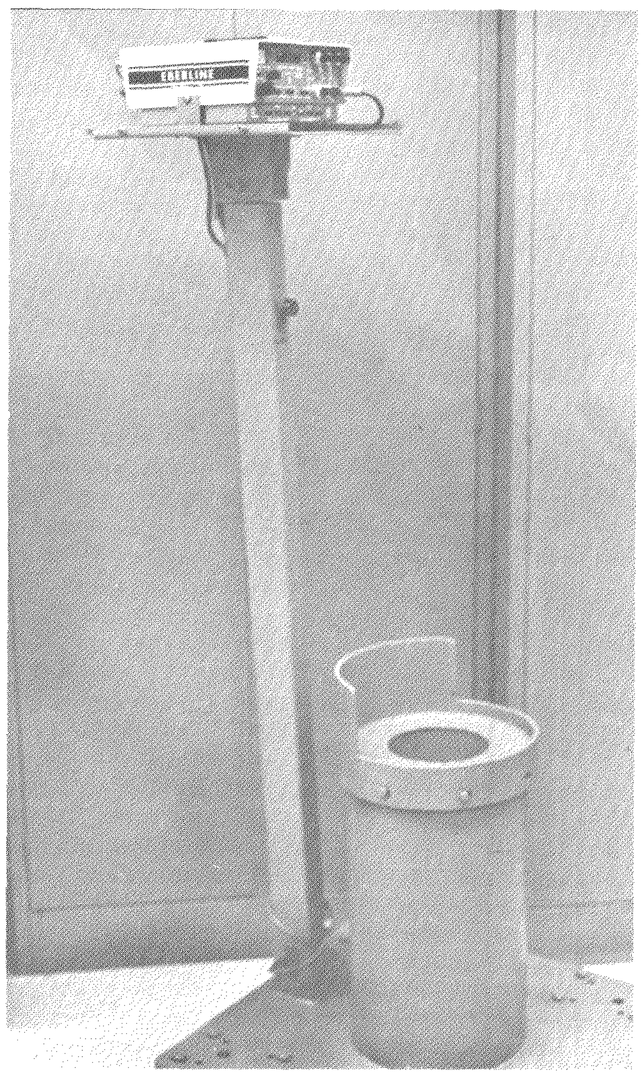


**Figure B**
**Measurement Configuration**

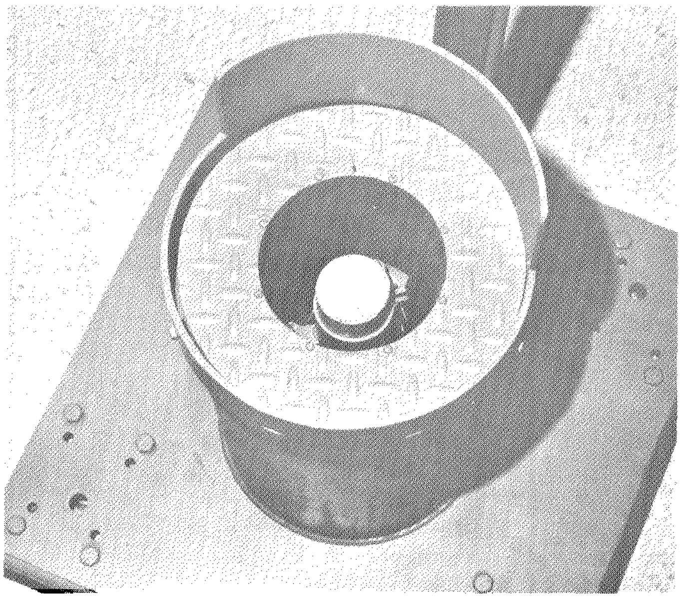

**Figure C**
**Detector Mounting**

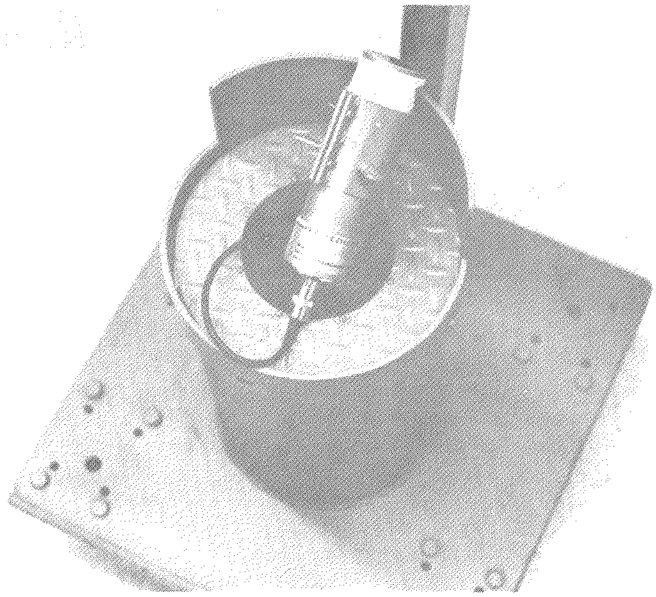

**Figure D**
**Detector Shockmount**

via the enrichment meter method occur when either the uranium matrix or the U-235 enrichment vary within the container being measured. Thus, care must be exercised by both the designer and the end user of the enrichment assay system to only use it where the aforementioned four criteria are satisfied.

The enrichment assay system used at General Electric's Nuclear Fuel Fabrication Facility is based on the Hybrid Assay System developed by T. Reilly, et al, of Group A-1, Los Alamos Scientific Laboratory (Reference 2). The Hybrid Assay System employed, in addition to an enrichment meter system, a passive neutron detector system to produce, when combined properly, a simultaneous measurement of uranium and U-235 content and enrichment of UO2 powders in either five gallon pails or fiber-pack shipping containers. This system, while never employed in a routine assay situation, did produce the basic collimnator design for the Wilmington enrichment meter system, called the "Sam 2" (Eberline Instruments).

Other reported applications of the enrichment meter principle have included one in Germany (Reference 3) and another by D. Sasaki of the Japan Nuclear Fuel Company (Reference 4). The former application, reported at the recent IAEA Safeguards Symposium, involved the in-situ measurement of the U-235 enrichment of UO2 powders in pellet press feed hoppers. The latter application utilizes the Eberline Instruments Sam 2/RD-19 Electronics Detector System in a shielded collimnator/mask assembly for the enrichment assay of unfired UO2 pellets. It is important to note that all the above applications of the enrichment meter principle have one common point. That is, the measurement is used for the verification of UO2 powder enrichment and does not replace an overcheck measurement of U-235 enrichment by traditional means. Indeed, an overcheck measurement is critical to the application of the enrichment meter principle to detect matrix and/or material changes which do not meet the criteria listed above.

## III. THE "SAM 2" ENRICHMENT METER

The initial demonstration of the enrichment meter concept at Wilmington was conducted using a prototype collimnator similar in dimension and detector-to-can geometry to that of the LASL Hybrid Scanner. The Wilmington device used the Eberline Instruments Sam 2 counting electronics and the RD-19 Amercium-241 seeded Sodium-Iodide detector and successfully demonstrated the enrichment meter principle in the measurement of the U-235 enrichment of UO2 powders in five gallon metal cans. Subsequently, a design (see Figure A) was implemented which employed all the aspects of the enrichment meter principle coupled to the Wilmington Facility's process flow. The design considerations were (1) portability, (2) modular electronics system, (3) ease of maintainability, (4) ease of system adaptation to several locations within the manufacturing process, and (5) the possibility of upgrading the system with the application of a microprocessor based controller.

Initial testing of the system included verification that the uranium matrix variations inherent in the uranium powder type to be assayed were well within acceptable limits to allow useful measurements. Also, studies of the variation of the container bottom thickness and the verification of the absence of background-causing radioactive materials were conducted. All testing procedures and results were documented for future reference.

The final design of the Wilmington enrichment meter system is shown in Figure A. The process container to be assayed is placed on the collimnator directly above the detector assembly (see Figure B). The detector is usually shielded from dust, etc., by the application of a multi-layer of metallic tape over the mouth of the collimnator. The Eberline Instruments Sam 2 counting electronics are contained in a metal chassis mounted on a stand which is welded to the collimnator base plate. In practice, the electronics and the settings of the system are protected from both temperature variation and unauthorized adjustment by a thick plexiglass covering over the open face of the metal chassis. The reset/start switch is located on the stand for easy operator access. For at-line usage, a skid plate is mounted between the can conveyor and the collimnator to facilitate movement of the can from the conveyor to the measurement position. The measurement position of the can is fixed by the use of a measurement jig to position the can over the detector assembly in a reproducible manner.

Gamma-ray shielding is provided by a two-inch layer of lead within a six to eight inch annular ring around the detector. This annular ring also provides the mechanical support for the powder can. The Eberline RD-19 detector is mounted in the axial center of the collimnator (see Figure C) in a shock-mounted attachment (see Figure D). The detector face is, for most measurement situations, located a nominal four inches from the can bottom.

A microprocessor-based controller has been developed at Wilmington to control the counting cycle and to provide data reduction in the following manner for a typical measurements situation:

(1) The operator positions the can and initiates the scanning sequence via the reset/start switch located on the stand.

(2) The controller reset/starts the Sam 2 and allows one to three measurements to be made (the number of measurements being selectable). The measured values are stored within the controller memory after each reading and the Sam 2 is restarted.

(3) The controller computes the average of the required number of readings, compares the readings to an upper and lower control limit, actuates an accept/reject panel light, and, when required, transmits the aforementioned data, including the measurement station identification, to the central data acquisition and control system.

At Wilmington, the enrichment meter has been applied to many enrichment verification situations. The most successful application has been in the enrichment verification of in-process material for either powder blending or the pellet pressing operations. The Sam 2 system has also been applied to the at-line determination of powder blend enrichment homogeneity. The system has also been applied to the enrichment verification of the uranium powder for off-site shipment and to the enrichment verification of uranium powder prior to the pellet pressing operation.

As in any application of nondestructive assay instrumentation, the standardization of the measurement is of paramount importance. The standards used for the Sam 2 enrichment verification system were selected from process materials to both characterize and span the range of material enrichments available within the facility. Each can was extensively sampled per a tumbling and sampling process and the samples submitted to the site laboratory for enrichment analysis. The resultant standards are periodically verified to assure the validity of the enrichment value and have been tampersafed to prevent unauthorized processing of the powder. The standards are stored in protected locations near the enrichment measurement station and are painted a bright yellow color to further distinguish them from the process containers which are painted black. Standards are replaced when either the uranium matrix of the sample containers or the enrichment range of process materials changes sufficiently to require the fabrication and qualification of new replacement standards.

## IV. PERFORMANCE HISTORY

The application history of the Sam 2 enrichment verification system has been in the enrichment verification of process materials in process containers. Process materials are subject to Sam 2 enrichment verification measurements, including enrichment verification prior to being processed. This inspection is overchecked by a sampling/laboratory analysis plan to further assure the validity of the Sam 2 enrichment measurement. The Sam 2 enrichment meter also is utilized to provide a powder blend homogeneity verification measurement. Individual powder blends are subject to individual can assay via Sam 2 enrichment assay and, after the scanning data is statistically pooled, powder blends are accepted or rejected for enrichment homogeneity. In this application of the Sam 2 system, as in any application of nondestructive assay systems, standards are periodically scanned to both assure the validity of the calibration and to provide standard data for bias correction purposes, if needed or required.

Further application of the Sam 2 system has been in the enrichment verification of UO2 powder for offsite shipment and the enrichment assay of UO2 prior to the powder dump-pellet pressing operations. This latter application will be coupled with a microcontroller for system operation and control.

The Sam 2 enrichment verification system in-toto performs in excess of 20,000 enrichment verification measurements per year. This is a significant cost savings for the facility annually as opposed to the performance of as many isotopic measurements by the site laboratory per year. Further cost savings have been achieved with the application of the system to offsite powder shipment and powder dump-pellet pressing operations.

The above measurements have been evaluated statistically against the overcheck system and the average measurement history is as follows:

Average Bias = plus or minus 0.007 w/o U-235

Precision of the Bias = plus or minus 0.0115 w/o U-235

This performance history is comparable to most isotopic assay system capabilities and includes such variabilities as can bottom thickness variations and uranium matrix variations. The above accuracy and precision statements have also become the qualification and requalification criteria for any replacement Sam 2 system.

## V. FUTURE SYSTEM IMPROVEMENTS

The Sam 2 electronics and stabilization methods have been under investigation as part of a general system upgrade program. The electronics have, in general, been replaced by units which are less temperature sensitive and which are easier to maintain and modify, if needed. The stabilization method, which uses internally implanted Americium-241 source seed within the 2 by 0.5 inch Sodium-Iodide crystal will soon be replaced by an external AM-241 source for gain stabilization purposes. This improvement will reduce the inherent temperature variability of the internal seed and was suggested by the Matussek and Ottmar paper (Reference 3).

## VI. CONCLUSION

The Sam 2 enrichment verification system has had significant cost and measurement impact in both the product quality and safeguards programs of General Electric's Nuclear Fuel Fabrication Facility. The system has provided and will continue to provide an important level of overcheck measurements for enrichment verification purposes at a low level of cost per measurement. The further expansion of the Sam 2 system into the production process to assure enrichment validity on-line will further enhance its role in the site's product quality and safeguard programs.

## VII. ACKNOWLEDGEMENTS

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# NRC RESPONDS TO LOW-ENRICHED URANIUM REPORT

The Nuclear Regulatory Commission has responded to INMM concerning their receipt of the special Safeguards Committee report "Assessment of Domestic Safeguards for Low-Enriched Uranium".

**Kenneth R. Chapman,** Director of the Office of Nuclear Material Safety and Safeguards, made the following comments in a letter to INMM Chairman **Roy Cardwell.**

"I, too, share your concern that regulations for special nuclear material take realistic account of the risks involved while continuing to assure adequate protection to the public. It was for this reason that the NRC commissioned the Brookhaven National Laboratory to conduct a review of the regulations concerning the control and accounting of nuclear material. Following the issuance of that report, the NRC formed a working group to analyze the issues related to the regulation of low enriched uranium, including international implications, and to prepare a staff analysis on restructuring the safeguards regulations concerning low enriched uranium. The report which you submitted with your November 10 letter has been useful in the efforts of this group."

The report was prepared by a special task group under Safeguards Chairman **Dennis W. Wilson.**

# A Problem Related to Grubbs Technique: The Distribution of Method Variance Estimates For Known Product Variance

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Abstract

The distribution of estimates of measurement method variance made by subtracting a known product variance from the total variance in a finite number of observations can be shown to be the non-central chi-square. Probabilities of finding that estimate to be negative or zero have been calculated for various numbers of observations and ratios of product variance to method variance, as well as the probability of finding the estimate in a range of twice its expected standard deviation centered on its expected value. Results are compared with those to be expected from an ordinary regression analysis.

## Introduction

The separation of method variances from product variances by using two or more methods to make measurements on a series of items each of which has a different expected value has been discussed in this journal, and elsewhere, by Jaech [1,2,3]. The procedure for attempting the separation is, or is extended from, that proposed by Grubbs [4]. Jaech [1,3] has pointed out that when the product variance is large compared to one or more of the method variances, a variance calculated from experimental observations, expected to be sum of the method and product variances, can be smaller than that number which is expected to be only the product variance.

It would be of interest to establish the probability of that event or, in other words, to specify the meaning of "large" as a description of the product variance. That problem as it applies to the use of more than one method has not been solved here, but the solution of a closely related problem is to be reported. If observations are taken on some number of "products" of known values, the obvious procedure for estimating the method variance would be an ordinary least squares analysis. What will be done here, however, is to examine the probability of occurrence of the estimates one would make by subtracting the known product variance from the total variance in the observations.

Some comparisons will be made with what one might expect from the regression analysis. Here, too, it will be seen that there is a not negligible probability that the estimate of the method variance is less than the expected value by more, say, than the expected standard deviation in the estimate of the variance. It is left to the future to examine the usefulness of applying both methods.

## The Probability Density Function

Suppose there are p products and that the ith one, of value $\mu_i$, is measured $n_i$ times. Let the jth one of

* Work performed under the auspices of the U.S. Energy Research and Development Administration and the Nuclear Regulatory Commission.

these observations be $y_{ij}$. The total number of observations will be

$$n = \sum_{i=1}^{p} n_i \ ,$$

the product mean, $\bar{\mu}$, will be

$$\bar{\mu} = (1/n) \sum_{i=1}^{p} n_i \mu_i \ ,$$

the mean of the observations, $\bar{y}$, will be

$$\bar{y} = (1/n) \sum_{i=1}^{p} \sum_{j=1}^{n_i} y_{ij} \ ,$$

the product sum of squared residuals, $q_\mu^2$, will be

$$q_\mu^2 = \sum_{i=1}^{p} n_i \mu_i^2 - n\bar{\mu}^2$$

and the observation sum of squared residuals, $q_y^2$, will be

$$q_y^2 = \sum_{i=1}^{p} \sum_{j=1}^{n_i} y_{ij}^2 - n\bar{y}^2. \quad (1)$$

In this problem, $q_\mu^2$ is a non-random variable and $q_y^2$ is the random variable. It is convenient to define a new non-random variable, $\lambda$, as

$$\lambda = q_\mu^2/(2\sigma^2) \ , \quad (2)$$

where $\sigma^2$ is the true method variance, or the common variance of the populations of differing means from which the observations are drawn, and to define a new random variable, x, as

$$x = q_y^2/\sigma^2 \ . \quad (3)$$

Formally, x is the same as the usual chi-square. Since, however, not every item has the same expected value, x does not have the usual chi-square distribution. Rather, it can be shown to have the non-central chi-square distribution with non-centrality parameter, $\lambda$, and degrees of freedom, f, where

$$f = n - 1.$$

The density function for this distribution is given by Lindgren [5]; it is written here as

$$\phi(x) = (1/2)(x/2)^{(f-2)/2} e^{-\lambda - x/2} \times \sum_{m=0}^{\infty} \frac{(\lambda x/2)^m}{m!\Gamma(m + f/2)} \ . \quad (4)$$

This form is not identical to that given by Lindgren because

$$\Gamma(m + 1/2) = \frac{\sqrt{\pi}(2m)!}{2^{2m}\ m!}$$

has been used and because Lindgren did not calculate an equivalent of the present $\bar{y}$. Thus his density function is for only the first term of equation (1) and his number of degrees of freedom is the total number of observations.

As an aside, equation (4) becomes the density function for the familiar central chi-square distribution if every $\mu_i$ is the same. In that case $\lambda$ becomes zero because $q_\mu^2$ does, and the only contribution from the sum becomes the first term, $1/\Gamma(f/2)$.

## Derived Equations

By the present approach the estimate, $s^2$, of the method variance, $\sigma^2$, is to be made from

$$s^2 = (q_y^2 - q_\mu^2)/f \ .$$

Reference to equations (2) and (3) show that this can be rewritten as

$$s^2 = \sigma^2(x - 2\lambda)/f \quad (5)$$

so that discussion of the distribution of $s^2$ becomes equivalent to discussion of the distribution of x.

From equation (4), the probability that x is less than or equal to some preassigned value, X, is

$$P(x \leq X) = \int_0^X \phi(x)dx \ .$$

A general formal solution for $P(x \leq X)$ could be set down, but an alternate solution which is somewhat simpler, and which is easier to evaluate, can be found if n is odd, or, equivalently, f is even. If

$\ell$ is an integer equal to f/2, this latter solution is

$$P(x \leq X) = 1 - e^{-(\lambda + X/2)} \sum_{m=0}^{\infty} \frac{\lambda^m}{m!} \times \sum_{\nu=0}^{m+\ell-1} \frac{(X/2)^\nu}{\nu!} . \quad (6)$$

By calculating the expected values of x and of $x^2$ from equation (4) the expected values of $s^2$ and its variance can be found to be

$$E(s^2) = \sigma^2 ,$$

$$\sigma^2(s^2) = \sigma^4 (f/2 + 2\lambda)(2/f)^2 . \quad (7)$$

Finally, it is seen from equation (5) that $P(s^2 \leq 0)$ is found by setting $X = 2\lambda$ in equation (6).

## Numerical Results

Values of $P(s^2 \leq 0)$ are shown in Figure 1 for odd numbers of observations from 5 through 15 as functions of $(\sigma_\mu/\sigma)^2$. The latter is

$$(\sigma_\mu/\sigma)^2 = q_\mu^2/(f\sigma^2) = 2\lambda/f;$$

for convenience, $\sigma_\mu^2$ has been defined as though $q_\mu^2$ were a random variable. The general features of the plot are those to be expected; for a given number of observations, $P(s^2 \leq 0)$ increases as the product variance increases and, for a fixed value of $(\sigma_\mu/\sigma)^2$, $P(s^2 \leq 0)$ decreases as the number of observations increases. At $(\sigma_\mu/\sigma)^2$ equal unity, for instance, there is a slightly greater than 10 percent chance of finding $s^2 \leq 0$ at 9 observations and 15 are required before that chance drops below 5 percent.

Figure 1 describes answers to the principal question [6]. One other will be mentioned. This is the probability, to be called $P_{2\sigma}$, that $s^2$ will be in the range $E(s^2)$ plus or minus the square root of the expected variance in $s^2$. That is,

$$P_{2\sigma} = P[\sigma^2 - \sigma(s^2) \leq s^2 \leq \sigma^2 + \sigma(s^2)] ;$$

this has been evaluated for a few cases with the restriction that

$$\sigma^2 - \sigma(s^2) \geq 0 .$$

When the equal sign is used here, it is found that

$$(\sigma_\mu/\sigma)^2 = (f - 2)/4 .$$

With this condition, $P_{2\sigma}$ drops slowly from 0.721 at f = 4 to 0.685 at f = 14.

If f is greater than that least value, it is found, as an example, that $P_{2\sigma}$ is 0.691 at f = 14 and $(\sigma_\mu/\sigma)^2 = 0.5$. The least accepted value for the latter variance ratio is that at f = 4 given above.

## Comparison with Regression Analysis

Had a linear least squares analysis been made and the slope B, whose expected value is unity, been found, the sum of squared residuals, $Q^2$, between the observations and the values calculated from the regression line would be

$$Q^2 = q_y^2 - B^2 q_\mu^2 ,$$

and $Q^2/\sigma^2$ would have the central chi-square distribution with degrees of freedom, n - 2. If, again, $P_{2\sigma}$ is calculated using $\sigma^2(s^2)$ as given by the central chi-square distribution, one would find $P_{2\sigma}$ to be 0.766 for the conditions where it was 0.721 above, and 0.696 where it was 0.685 above. If, for example, $(\sigma_\mu/\sigma)^2$ is 0.5 and there were 5 observations, the noncentral chi-square approach would yield

$$\sigma^2 - \sigma(s^2) = 0 ,$$

$$P(s^2 \leq 0) = 0.130 ,$$

while the regression analysis would yield

$$\sigma^2 - \sigma(s^2) = 0.184\sigma^2 ,$$

$$P(s^2 \leq 0.184\sigma^2) = 0.142 .$$

At $(\sigma_\mu/\sigma)^2 = 3$, n = 15, the above numbers, in the same order, become 0, 0.157, $0.608\sigma^2$, 0.154.

Thus, these comparisons show that the method of estimation discussed in the main body of this paper yields results not greatly unlike those one would get merely by shifting the origin of the central chi-square distribution to $-(q_\mu/\sigma)^2$. This could be viewed as an advantage. From the regression analysis one will always find a positive method variance estimate, and will be tempted to accept it without further examination. The chance, however, that it is smaller than the expected value by an amount at which the warning of a negative estimate would be sounded via the non-central method is about the same as that of getting the warning.

It follows, of course, from such an argument that one should examine the distribution of $(q_y^2 - q_\mu^2)$ for a given value of $Q^2$. From this one could study the usefulness of applying both procedures to the same set of data, but that has not been done as yet.

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[6] In Figure 1, m is used to denote the total number of observations. The text notation got changed during the rewriting which followed helpful suggestions by the reviewers.


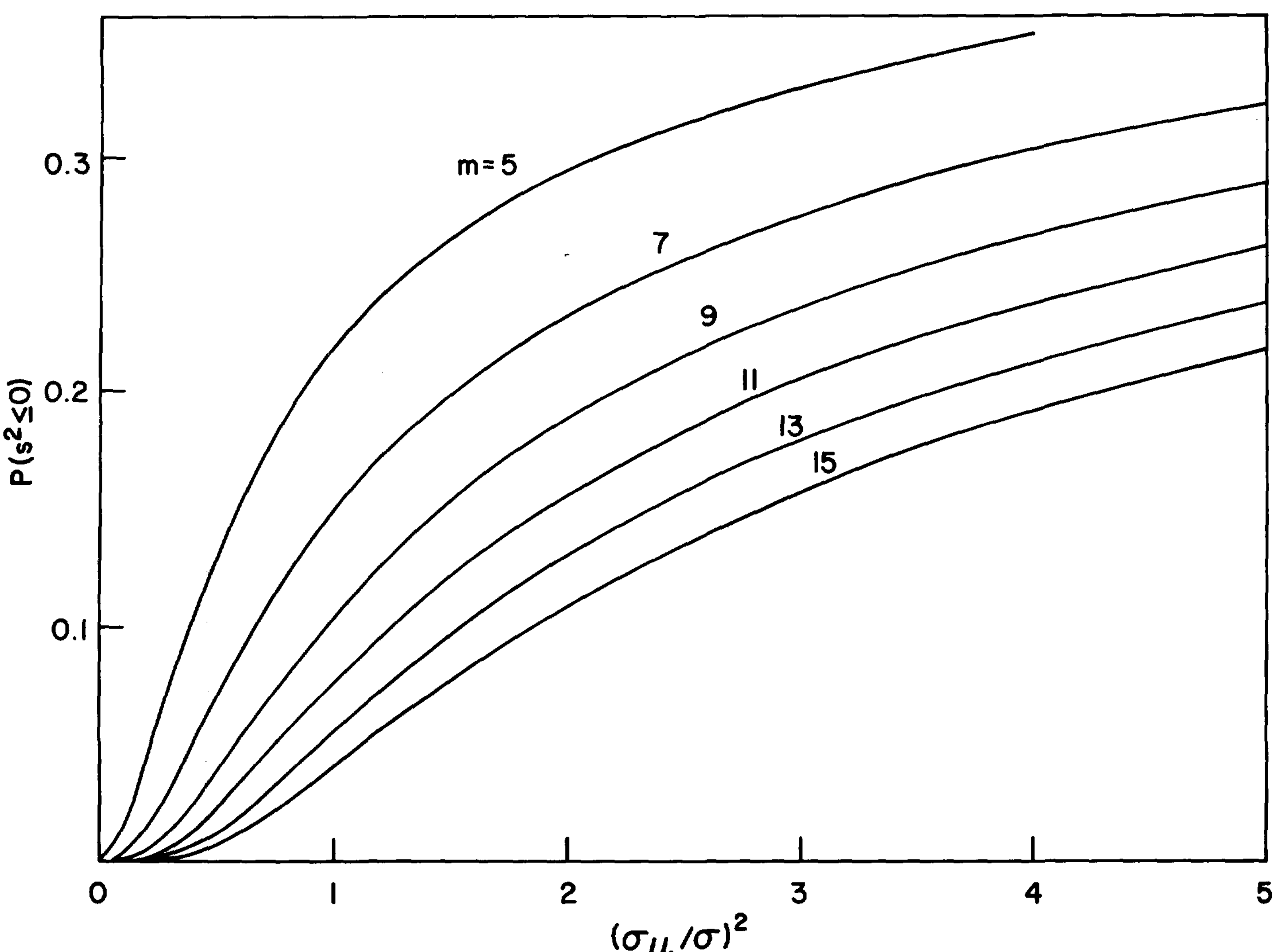


**Fig. 1 The probability of finding the estimates of the method variance to be less than or equal to zero for various values of the number of observations, m, as a function of the ratio of the product variance to the method variance.**

# A GAMMA-RAY PERIMETER ALARM SYSTEM*

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**ABSTRACT**

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

## INTRODUCTION

An increasingly important problem in the nuclear power industry is the protection of nuclear materials. This includes the timely accounting and control of material in process as well as the physical protection of power reactors, waste repositories, and fuel reprocessing and fabrication facilities.

Several perimeter alarm systems have been considered for monitoring the exclusion areas around nuclear facilities. These range from armed guards to more exotic systems such as closed circuit television, infrared monitors, Doppler radar, and electrical fences. Each scheme seems to have its own disadvantages.

A different type of a physical protection system is based on the "electric-eye" principle, where the interruption of a beam of radiation signals the presence of an intruder and activates the alarm. A system based on a light beam is perceivable by the naked eye and could be easily evaded by an intruder. Infrared and ultraviolet radiations are not reliable since these radiations are sensitive to, for example, weather variations, dust, and vegetation. Electronics are associated with both the propagation and the detection of ultraviolet, visible, and infrared radiations.

Another electromagnetic radiation that may be applicable because of its greater penetrability through dense media is gamma rays. The half-thickness for gamma rays in dry air varies from 37 m at 100 keV to 158 m at 3000 keV, a distance that is sufficiently large to warrant further investigation of the gamma-ray beam interrupt system. Elaborate electronic systems are not needed to detect gamma rays, and no electronics need be associated with the source of radiation. Furthermore, gamma rays are not perceivable by the unaided eye. It has been suggested (1), for these reasons, that an alarm system using gamma rays could be a reliable perimeter monitor. Battelle-Columbus Laboratories (2) is involved in a project to assess the particular use of 85Kr ($t_{1/2}$ = 10.8 y) in such an alarm system. They propose to use 125 Ci of Kr, two detectors displaced horizontally, and a source-detector distance of 11 m.

We report here on a model for such an alarm system. Monte Carlo gamma-ray transport calculations covering a wide range of conditions and gamma-ray energies were used to study the feasibility of such a scheme. To support the calculations, experiments with a beam of $^{137}$Cs gamma rays were conducted.

## MONTE CARLO CALCULATIONS

Initially, Monte Carlo gamma-ray transport calculations (3) were performed on a realistic model. A top view of the calculational geometry is shown in Fig. 1. A single source and a single detector were each assumed to be 1 m above the ground. The source was considered to be between a concrete wall (simulating the building to be protected) and a "fence" (simulating an excluded area) 2 m from the wall. Count rates were calculated for a detector placed 93 m from the source. The calculations were performed for dry and wet soil, for dry and wet air, and with and without the concrete wall present. These different conditions were studied as a function of the gamma-ray energy, and only photopeak events were considered.

A possible limiting condition for this system is the attenuation of gamma rays by moisture in the air. Three different models were considered for determining the density of moisture in the air, p. The simplest one used the density of the moisture content of saturated air, which, for an air temperature of 30°C, is 3.4 × 10-2 kg/m3.

The second model assumed 25.4 mm of rain uniformly distributed at some time throughout a distance of 305 m between the ground and a rain cloud. This results in a density of water in the air of 8.3 × 10 -2 kg/m3.

Finally, 25.4 mm of rain was assumed to fall in 1 h. This model is based on calculating the flux of rain

*Work performed under the auspices of the U.S. Energy Research and Development Administration.

passing through a cross-sectional area A for a time t(=1h). The mass of water in the air is ρvAt, where v is the terminal velocity of a rain drop. For a 2-mm-diameter rain drop, v is 6.5 m/s (4). The mass of water on the ground is 25.4 × $10^{-3}$ A$\rho_{H_2O}$. This model predicts the density of water in the air to be 1.1 × $10^{-3}$ kg/$m^3$. For the calculations reported below, a value of 5.0 × $10^{-2}$ kg/$m^3$ for the density of water in the air was assumed. As will be pointed out later, this is not a critical number.

The results of the Monte Carlo calculations showed that both the concrete wall and the moisture content of the soil had a negligible effect on the predicted count rate. Further calculations thus assumed the wall to be present and the soil to be dry.

The human body was approximated by a water-filled cylinder 152-mm in diameter and 1220-mm tall. The detector was taken to be a 127- by 127-mm NaI with an idealized efficiency of 100% for each gamma-ray energy. A 1-Ci source, 93 m from the detector, was also assumed throughout.

The expected count rates as a function of the gamma-ray energy, for dry and wet air, with and without a body in the beam, are shown in Fig. 2. The graph spans the energy range of the common radioactive sources applicable to such a system, from the 60 keV gamma ray of $^{214}$Am to the 2614 keV gamma ray of the $^{232}$Th decay chain.

There is about a 10% difference between the count rates for dry and wet air at 60 keV and a 2% difference at 3000 keV. This change is small, however, compared to the effect of a body. For 60 keV gamma rays, the count rate for the unbroken beam is 9 times that for the broken beam. For 3000 keV gamma rays, this factor is 2. In order for wet air to produce a suppression of the count rate comparable to what the body produces, the density of water in the air would have to be approximately 2 kg/$m^3$, two orders of magnitude larger than the value used. Moist air can thus be eliminated as a possible hindrance to the operation of such a system.

Figure 2 can also be adequately described by considering the absorption of gamma rays by the air and the body and by considering the effect of solid angle. At a distance R (cm) from a point source of strength S (photon/s), the number N (photons/s/cm2) is

$$N = \frac{S \exp(-\mu x)}{4\pi R^2} , \qquad (1)$$

where u is the total linear attenuation coefficient, and x is the thickness of the attenuating medium. To calculate the expected count rate, Eq. (1) must be multiplied by the cross-sectional area and the efficiency of the detector. The good agreement between this simple model and the Monte Carlo calculations indicates that multiple scattering of photons by the air, soil, and concrete wall is not important when only photopeak events are considered.

This method may be used to determine the number of false alarms expected in a given period of time for this proposed gamma-ray alarm system as a function of the gamma-ray energy. These false alarm calculations are summarized in Table I and are based on the assumption that the intruder will break the beam in 0.05 s. Column 2 lists the count rates for the unbroken beam, and column 3 lists the count rates for the beam broken by a body. The standard deviations of the count rates are taken to be the square root of the count rates. The number of standard deviations the broken beam count rate differs from the unbroken beam count rate is shown in column 4. Column 5 shows the probability that this deviation could occur at random in a 0.05-s time interval. The number of false alarms expected per year, shown in column 6, is calculated by multiplying the probability of a single event happening in a 0.05-s time interval by the number of 0.05-s time intervals in one year. The expected false alarm rate shows a significant minimum for gamma rays having an energy in the range 500-1000 keV. (It is interesting to note that the $^{85}$Kr source (Eγ = 514 keV) proposed by Battelle-Columbus Laboratories (2) is an ideal energy source for minimizing the false alarm rate.) For lower energy gamma rays, there is significant attenuation of the gamma rays by the air, and for higher energy gamma rays, there is not much attenuation of the gamma rays by the body.

Expected dose rates at 304.8 mm from a source of radiation can be calculated from

$$D = 6\,C\,E, \qquad (2)$$

where D is the dose rate (R/h) for a source having a gamma-ray energy E (MeV) and a strength C (Ci). Doses for other distances may be calculated assuming an inverse square dependence. For a 1-Ci 500-keV gamma-ray source, the following dose rates are expected:

3 R/h at 304.8 mm
30 mR/h at 3048 mm
0.3 mR/h at 30.48 m
30 uR/h at 91.44 m.

A properly designed collimator for this system inside an exclusion area could be used to direct the well defined gamma-ray beam parallel to the perimeter fence being guarded, thus effecting adequate biological shielding for the point of closest approach to the source without compromising the alarm function. This system would present a negligible health hazard to people.

## EXPERIMENTAL RESULTS

These calculations indicate that a gamma-ray perimeter alarm system should be extremely reliable, so a series of experiments were performed using a 1-Ci $^{137}$Cs source. Cesium-137 was chosen because it emits a 662 keV gamma ray, which is in the energy region producing the minimum number of false alarms as predicted in Table I. Furthermore, since $^{137}$Cs produces only a single gamma ray, any interference from competing gamma rays is minimized. The half life of $^{137}$Cs is 30 y, which is advantageous for actual application. From the calculations presented in Table I, 1 Ci ought to be sufficient to protect an interval of about 100 m.

The experiment was conducted in a long, narrow high-bay of a building that provided a source-detector distance of 21 m under cover. A roll-up door at one end of the building allowed extending this distance to 46 m. The width of the high-bay is comparable to the distance between a fence and a nuclear facility.

A single 127- by 127-mm NaI detector situated 1.2 m off the floor and mounted in a 57.2-mm-thick lead shield was used to detect the gamma rays. The single $^{137}$Cs

TABLE I

Results of Monte Carlo calculations for a 1-Ci source and a 127 - by 127-mm NaI detector 93 m from the source. Listed are gamma-ray energies, unbroken beam count rates, broken beam count rates when a body is assumed in the beam, and the number of standard deviations the broken beam count rates are from the unbroken beam count rates. The probability is the chance that this deviation could occur at random in a 0.05-s interval. The false alarm rate is the probability multiplied by the number of 0.05-s intervals in one year.

| $E_\gamma$ (keV) | Unbroken Beam Counts/ 0.05 s | Broken Beam Counts/ 0.05 s | Number of Standard Deviations | Probability | Number of False Alarms/y |
|---|---|---|---|---|---|
| 60 | 31 | 3 | 5.0 | $4.9 \times 10^{-7}$ | 309 |
| 200 | 55 | 10 | 6.1 | $1.3 \times 10^{-9}$ | 1 |
| 500 | 81 | 22 | 6.6 | $5.0 \times 10^{-11}$ | < 1 |
| 1000 | 106 | 40 | 6.4 | $1.5 \times 10^{-10}$ | < 1 |
| 1500 | 121 | 54 | 6.1 | $1.1 \times 10^{-9}$ | 1 |
| 2000 | 131 | 65 | 5.8 | $7.9 \times 10^{-9}$ | 5 |
| 2500 | 139 | 75 | 5.4 | $5.6 \times 10^{-8}$ | 35 |
| 3000 | 143 | 81 | 5.2 | $2.2 \times 10^{-7}$ | 139 |

TABLE II

Experimental count rates for various modes of breaking the beam when the source-detector distance was 20.9 m. The column headings have the same meaning as in Table I. The arms (walk) row is the result for the arm movement associated with a walk through the beam. Similarly, the arms (jump) row is the result for the arm movement associated with a jump through the beam.

| Mode of Breaking Beam | Unbroken Beam Counts/ 0.05 s | Broken Beam Counts/ 0.05 s | Number of Standard Deviations | Probability | Number of False Alarms/y |
|---|---|---|---|---|---|
| walk | 1093 | 263 | 25.2 | $<10^{-11}$ | <1 |
| jump | 1093 | 380 | 21.6 | $<10^{-11}$ | <1 |
| run | 1093 | 295 | 24.2 | $<10^{-11}$ | <1 |
| hand movement | 1034 | 854 | 5.6 | $2.1 \times 10^{-8}$ | 13 |
| arms (walk) | 1093 | 793 | 9.1 | $<10^{-11}$ | <1 |
| arms (jump) | 1093 | 660 | 13.1 | $<10^{-11}$ | <1 |

TABLE III

Experimental count rates for various modes of breaking the beam when the source-detector distance was 46.2 m. The column headings have the same meaning as in Table I.

| Mode of Breaking Beam | Unbroken Beam Counts/ 0.05 s | Broken Beam Counts/ 0.05 s | Number of Standard Deviations | Probability | Number of False Alarms/y |
|---|---|---|---|---|---|
| walk | 216 | 43 | 11.5 | $<10^{-11}$ | <1 |
| run | 216 | 17 | 13.3 | $<10^{-11}$ | <1 |
| walk behind 1.6 mm iron door | 203 | 37 | 11.9 | $<10^{-11}$ | <1 |

Figure 1

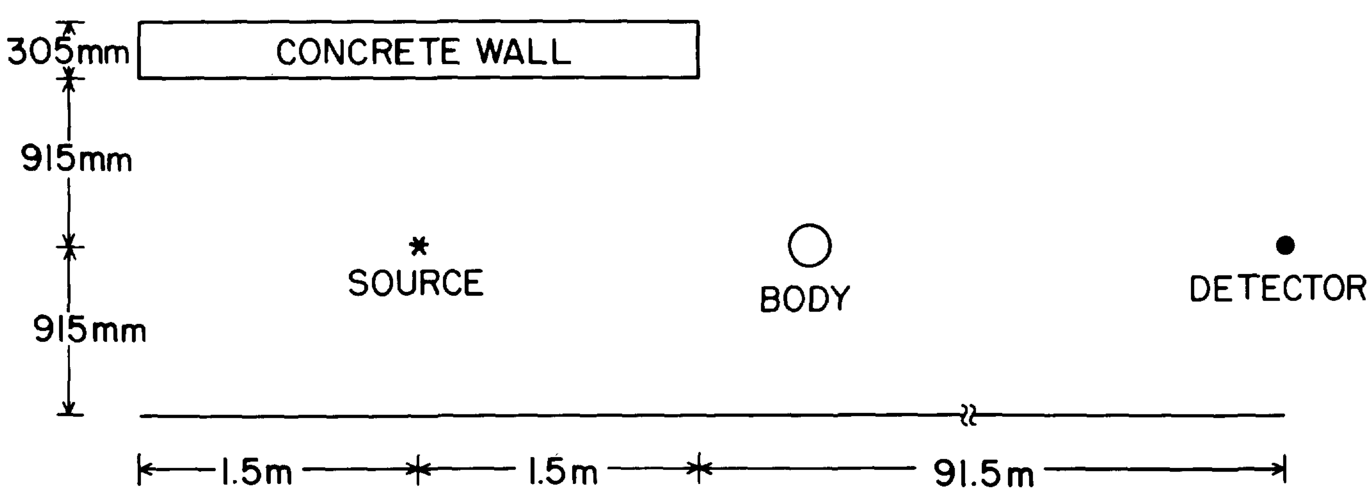


**Figure 1. Top view of the model used in the Monte Carlo gamma-ray transport calculations.**

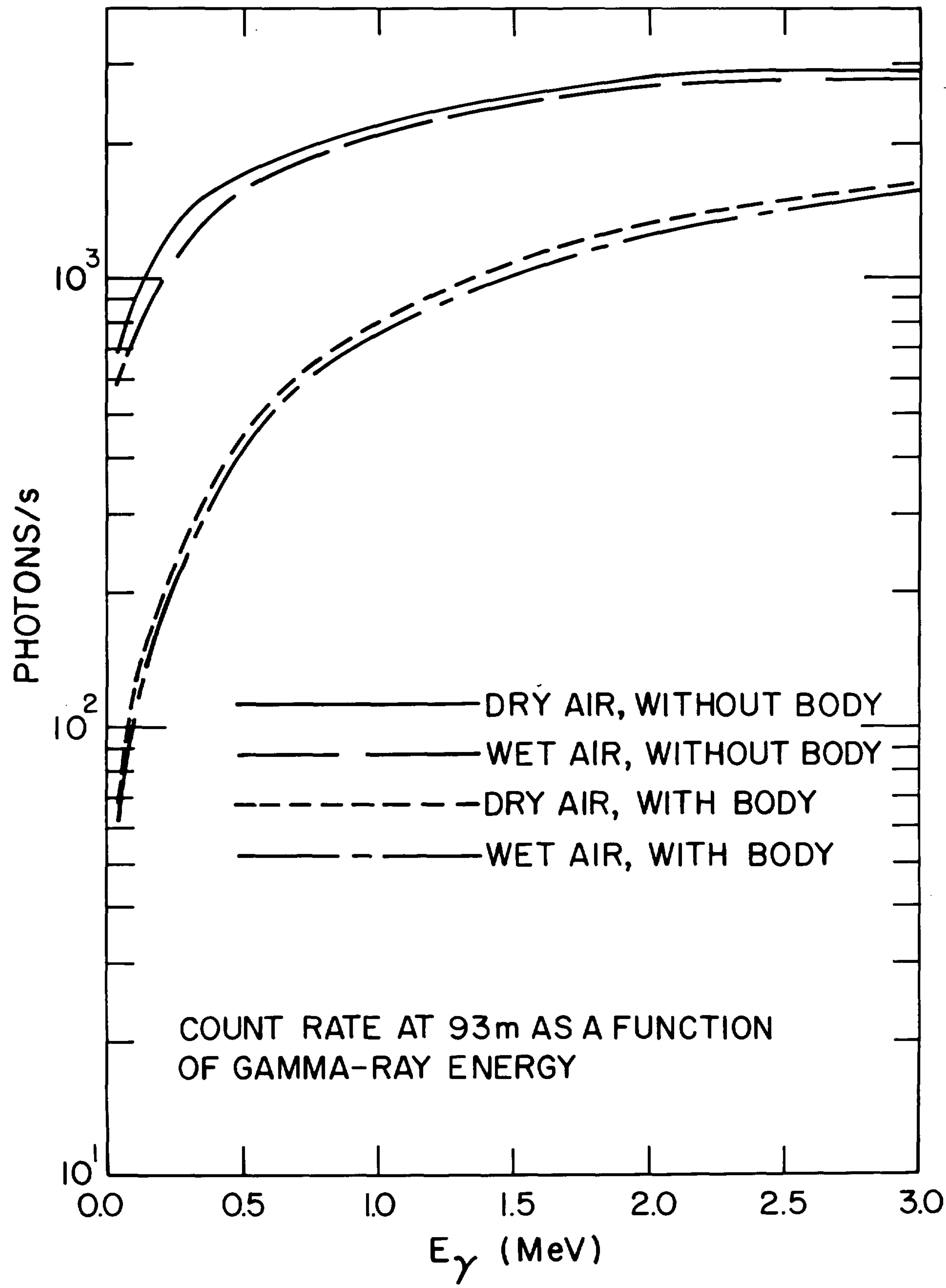


**Figure 2. Expected count rates for a source-detector distance of 93 m as a function of the gamma-ray energy, for dry and wet air, and with and without a body in the beam. These curves assume a 1-Ci source and a 100% efficient 127- by 127-mm NaI detector.**

source was placed in a cylindrical lead collimator that was 508 mm in length and 101.6 mm in diameter having a 7.14-mm-diameter hole along its axis. The signal from the amplifier was fed into a single channel analyzer (SCA) adjusted to detect only the 662 keV gamma rays. The output signal from the SCA was, in turn, sent to a multichannel analyzer operated in the multiscaler mode with a dwell time of 0.01 s per channel. At all times, the electronics were inside the building.

Two source-detector distances, 21 m and 46 m, were used. Even for the shorter distance, the radiation level at the detector was less than 0.5 mR/h, presenting a negligible health hazard to personnel conducting the experiment. The count rates for various methods of interrupting the beam for the 21-m distance are shown in Fig. 3. Figure 4 shows similar results for the 46-m distance.

When a person walks through the beam swinging his arms, the count rate is depressed as shown in Fig. 3a, where the effect of the leading arm, the body, and the trailing arm are all clearly seen. Figure 3b shows the situation when a person jumps through the beam. Here, the leading arms are seen to break the beam first, then the body breaks the beam. For a run through the beam from a standing start, the results are shown in Fig. 3c. The effect of moving a hand through the beam three times is clearly seen in Fig. 3d.

The results for the 46-m source-detector distance, shown in Fig. 4, also indicate that an intruder is easily detectable. A walk through the beam is shown in Fig. 4a. The run through the beam, Fig. 4b, took less time than for the 21-m source-detector distance because, with the source outside the building, it was possible to get a running start. Even with this short transit time, the passing of the person is still very obvious. Finally, the 1.6-mm-thick iron roll-up door was lowered, and a person walked through the beam. This situation is presented in Fig. 4c. Again, the interruption of the beam is obvious.

These count rates are summarized in Tables II and III, for the 21-m source-detector distance and the 46-m source-detector distance, respectively. The standard deviations associated with the count rates are taken to be the square root of the count rates. If a person were to try to pass through a beam of radiation, he would do it as quickly as possible. Since to run through the beam took about 0.05 s, this time interval was used for the calculations. The tables give the number of false alarms expected in one year. Except for the hand movement, less than one false alarm per year is calculated with this gamma-ray alarm system.

As is evidenced by the hand movements through the beam (Fig. 3d), this proposed gamma-ray perimeter alarm system is extremely sensitive. Using the data presented in Table II for the 20.9 m source-detector distance, an estimate can be made of the ability for this system to distinguish between birds (simulated by the hand movements) and people. Assume an average unbroken beam count rate and an associated standard deviation that includes the count rate for the hand movements. Then the count rate when the beam is broken by a body walking through it is 7.6 standard deviations from the unbroken beam count rate. The probability that this large a deviation could occur at random in a 0.05-s interval is less than $10^{-11}$. For the stated assumptions, this gives less than one false alarm per year. Even though this gamma-ray perimeter alarm system is very sensitive, it provides good discrimination between birds and people.

Even though the high-bay did not have any temperature control and no attempt was made to stabilize the electronics, count rates varied by less than 6% during a 24-h period.

## CONCLUSIONS

The proposed gamma-ray perimeter alarm has been shown to be extremely reliable for detecting intruders. Our results indicate that a much longer source-detector distance can be monitored by a much weaker source than envisioned by Battelle-Columbus Laboratories (2). It is an easy task to devise a simple electronic system that will trigger an alarm whenever the count rate varies more than a pre-determined amount from the unbroken beam count rate. One would want to be sure the electronics will also trigger an alarm whenever the instantaneous count rate **exceeds** the average count rate lest a person try to foil the system by using an additional gamma-ray source.

The next obvious step in developing this concept is to place an actual system in a natural environment to determine the optimum number of sources and the optimum arrangement of detectors.

## ACKNOWLEDGMENTS

The author wishes to thank C. Sonnier of Sandia Laboratories in Albuquerque, New Mexico, for suggesting this idea and to acknowledge R.B. Walton for his helpful technical discussions. The assistance of L.G. Speir and C.O. Shonrock in installing the $^{137}Cs$ source in the lead shield is gratefully appreciated.

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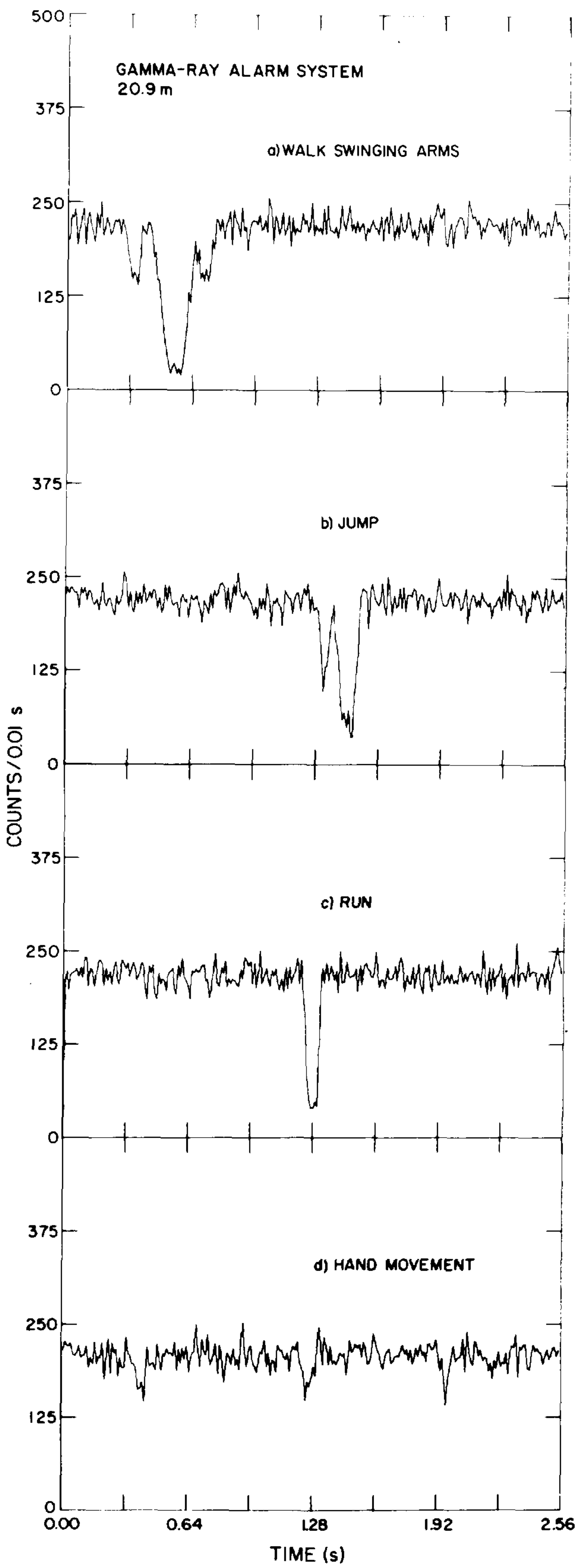


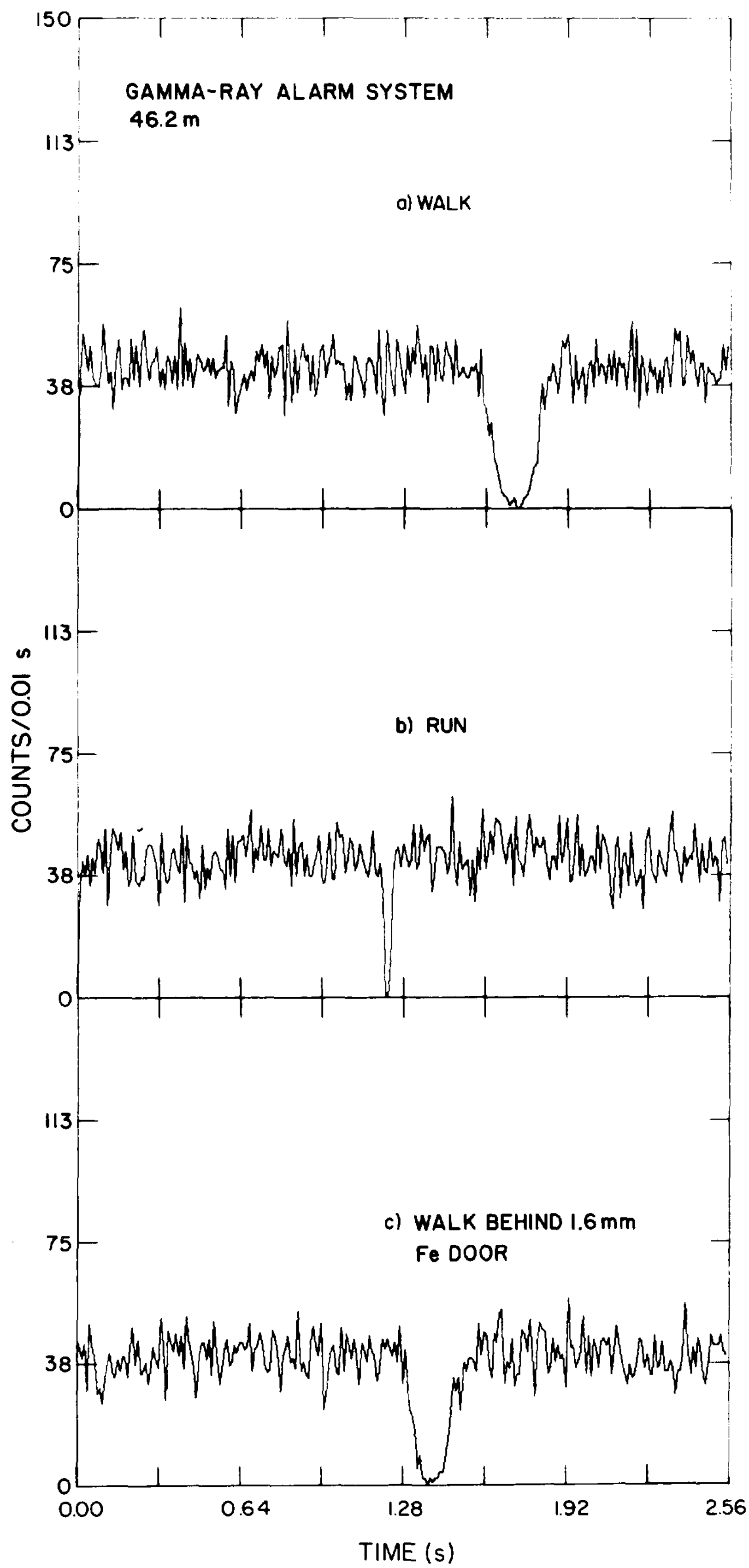


**Figure 3.** Count rates for various ways of breaking the beam for a source-detector distance of 20.9 m: a) walking; b) jumping; c) running; and d) moving hand.

**Figure 4.** Count rates for various ways of breaking the beam for a source-detector distance of 46.2 m: a) walking; b) running; and c) walking when there is a 1.6-mm iron door between source and detector.

# A CONTROLLABLE UNIT CONCEPT AS APPLIED TO A HYPOTHETICAL TRITIUM PROCESS

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## ABSTRACT

A methodology (controllable unit accountability) is described that identifies controlling errors for corrective action, locates areas and time frames of suspected diversions, defines time and sensitivity limits of diversion flags, defines the time frame in which pass-through quantities of accountable material and by inference SNM remain controllable and provides a basis for identification of incremental cost associated with purely safeguards considerations. The concept provides a rationale from which measurement variability and specific safeguard criteria can be converted into a numerical value that represents the degree of control or improvement attainable with a specific measurement system or combination of systems.

Currently the methodology is being applied to a high-throughput, mixed-oxide fuel fabrication process. The process described herein is merely used to illustrate a procedure that can be applied to other more pertinent processes.

## INTRODUCTION

Recent dislocations in traditional energy sources have placed greater emphasis on alternative sources. The nuclear option with an implied widespread national and international economy has generated demands for improved safeguard measures (1-4) to protect against, deter, and detect diversion of special nuclear material (SNM).

Undoubtedly, a comprehensive safeguards program will include some mix of physical and measurement controls since, even in a case of almost total physical control, measurements (2) still will be necessary to ascertain what is being physically secured.

Traditionally, material-unaccounted-for (MUF) and the evolved associated limit of error (LEMUF) have prevailed in nuclear material control programs. At present, however, the sensitivity or adequacy of material balance accounting is, in particular, being questioned for high-throughput plants (5). This, in turn, has refocused attention upon types and availability of measurement systems and upon practical improvement in these systems. Particularly, it has been recognized that process—as well as accountability measurements—may contain diversion information.

This paper describes an integrated system approach to meet basic safeguards material control requirements which include timely detection of diversion, as well as verification, of SNM process plant inventory. In this description, "control" is to be understood in terms of measurement control. The concept provides a rationale from which measurement variability and specific safeguard criteria can be converted into a numerical value that represents the degree of control attainable with a specific measurement system or combination of systems. Through this mechanism, a rational basis for selection of viable options to meet safeguards criteria is provided.

Currently, this methodology is being applied to a high-throughput, mixed-oxide plant, but in order to clearly present the concept and to reduce mathematical complexity a simple model was chosen. Secondly, experience with similar systems and realism of the analytics were important factors in the selection of this particular hypothetical tritium process. At this time the methodology appears equally applicable to a high-throughput mixed-oxide process.

## PROCESS AND METHOD

Briefly, this analysis considers a batch process to provide a titanium tritide-hydride with a hydrogen/tritium ratio of unity. A schematic of the process is illustrated in Figure 1. Helium enters into the process since it is the decay product of tritium. Nominally, the process produces 200 g batches of product with five days or 120 hr necessary to produce a single batch. For these discussions, the front end of the process is considered to consist of a 100 g container of tritium and the mole equivalent container of hydrogen under secured storage. To close the process the final

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product likewise is considered to be in secured storage. The process considered here and briefly described above is illustrated in Figure 1 which displays the functions and activities commonly associated with many processes. The overall process is separated into stations or activities numbered consecutively from 1 through 14. At the various stations methods of measurements control are indicated as pressure-volume-temperature (PVT), mass spectrometric (MS), calorimetric (CAL), titanium sublimation pump (TSP), and the ionization gauge which measures tritium going to the effluent recovery system (ERS). From the hydrogen and tritium feed containers the material moves to the mixing station where the amount transferred is verified by PVT measurements. The secured inventory of tritium and hydrogen is confirmed by calorimetric and PVT measurements. After mixing, the gas moves to the mix storage station and is held for quality control measurements. A rejected batch is sent to station 7 for storage. Upon release, an acceptable mix moves to the reactor wherein the solid tritide product is formed. Finally, the product is analyzed for acceptance and eventually is passed to secured storage.

A controllable unit is defined as the span of control of a measuring system. In this sense it is that magnitude, consistent with a given measuring system's variability, which satisfies some stated criteria. Most often the magnitude represents a property of the material to be controlled such as mass or some related attribute. Mathematically, it is defined as (% variability) (controllable unit size) = $(\text{constant})_{\text{criteria}}$. The constant can evolve from a set of criteria dictated by safeguards considerations. Figure 2 graphically illustrates this simple relationship that governs measurement systems. With the establishment of the constant from a set of criteria and with selection of the variability from available or proposed systems, the largest magnitude under control in the measurement sense is defined. Then from these considerations a rational mating of measurement variability, both desired and available, and measurement nodes of the process can be made. As indicated by the graph in Figure 2, a measurement capability with a small variability allows control over a large magnitude, and conversely, for the same constant, only a small magnitude can be controlled with measurements that exhibit a large variability. Thus the measurements must be reconciled with the available or proposed measurement nodes in the process.

To facilitate demonstration of the method the major emphasis will be directed toward material balance closures although the method is not restricted to these and others will be utilized. Furthermore, to clarify the meaning of a closure equation in the context of this paper, a simple example and its graphical relationship to the process schematic is considered. In Figure 3, several combinations of process stations are encompassed by an assortment, primarily rectangular, of lines which pictorially represent that part of the process to be controlled. The rectangle that encloses stations 4 and 5 isolates an area where a simple closure applies. The symbols $T_{(3)}$ and $T_{(5)}$ represent the amounts of tritium at these stations and within measurement variability an equality should exist. To keep with tradition, the MUF equation is written as $MUF3 = T_{(5)} - T_{(4)}$ which represents the difference between measurements of tritium at the mix storage station and the mix station. In a like manner, other equations can be formulated for the various overlapped and interconnected controllable units depicted in Figure 3. A list of thirteen equations is given in Table 1. This list is neither exhaustive nor unique, but it does represent a set of usable equations that flow from the characteristics of the process and availability of the sampling nodes. Various optimization schemes might be utilized here to obtain an optimum set of equations, but for these discussions, the potential insight gained from such an exercise is considered to be minimal. Instead, attention is focused on various parallel closures such as those given by equations 1 and 5 since in this process the fate of hydrogen is inextricably linked to that of tritium. Likewise, other constituents provide similar redundancies that can be exploited to separate process variability from measurement variability. Finally, these equations utilize a mix of both process and accountability measurements.

## MODEL ASSUMPTIONS AND ANALYTICS

Assumptions for the various loss streams due to normal process activities are stated in Table 2. Similarly, the assumed analytical variabilities that represent a combination of random and systematic errors are listed in Table 3. These variabilities represent a collection of normally available data that include both process and accountability measurements. With a systems approach this diversity of information can be integrated to provide redundancy that not only will sharpen sensitivity to diversion, but also will improve inventory accountability. Additionally, Table 2 highlights the range of variability exhibited by the different analytical methods and identifies each method and variability with different parts of the process. The variability values range from 0.15% for calorimetry to 30% for the ionization gauge which measures tritium going to the effluent recovery system.

The mass spectroscopy, titanium sublimation pump, and pressure-volume-temperature uncertainties represent those derived from system studies.

Model simulation calculations were made using the analytical variabilities listed in Table 3, the nominal batch quantities for the process, and generated random normal data for representing triplicate experimental measurements. In a similar manner, the simulated diversions were made using new nominal batch quantities differing from the original values by the assumed diversion and a new set of generated random normal data for representing experimental measurements.

For all combinational error computations, the root-mean-square (RMS) error model is utilized.

## RESULTS AND DISCUSSION

For this section, the criteria constant is arbitrarily defined to be 0.25 g of tritium in 120 hr, and to maintain consistence, the computed values for all constituents are expressed in grams of tritium.

In order to extend the usage of the previously selected equations Figure 4 presents these same 13 equations regrouped in terms of principal constituents. With this format, the equations can be associated with both operations (stations or activities) and time. As indicated, the top scale denotes the number identification of the

## TABLE 1

## PROCESS MODEL ASSUMPTIONS

| | |
|---|---|
| Transfer Loss in Manifold | 1 vol % |
| MS-TSP Sample Loss | 100 ml |
| Hydrogen Isotopic Loss in Reactor Overgas | 0.1 vol % |
| Analytical Product Sample | 10 g |
| Product Waste in Reactor | 0.1 wt % |

## TABLE 2

## ASSUMED ANALYTICAL VARIABILITIES
(2σ CONFIDENCE LEVEL)

| | |
|---|---|
| **Calorimetry of Tritium in** | |
| Tritium Feed | ±0.15% |
| Analytical Product Sample | ±0.15% |
| Product | ±0.15% |
| Product Waste | ±0.50% |
| **MS-TSP-PVT of Gas Constituents** | |
| Hydrogen Feed | ±0.60% |
| Helium in Tritium Feed | ±0.90% |
| HT Mixture (Each Constituent) | ±1.5% |
| Helium in Reactor Overgas | ±1.5% |
| **Thermal Decomposition Analysis of Hydride** | |
| Analytical Product Sample - Gases | ±1.8% |
| - Solids | ±0.30% |
| **Titanium Mass** | |
| Titanium Feed (Including Assay) | ±0.15% |
| Product Waste | ±3.0% |
| **Ionization Probe of Tritium Losses** | |
| MS-TSP Sample | ±30% |
| Helium Overgas | ±30% |
| **Manifold Volumetric Transfer Loss** | ±15% |

## TABLE 4

## DETECTION AND TIME LIMITS AT VARIOUS DIVERSION POINTS

| Diversion at Step No. | Closure Equations Which Apply | Lowest Detection Tritium (g) | Time of Detection (hr) | Equation Used |
|---|---|---|---|---|
| 1 | 2,4,10,12 | 0.21 | 120 | 2 |
| | | 0.23 | 24 | 4 |
| 3 | 2,4,10,12 | 0.21 | 110 | 2 |
| | | 0.23 | 14 | 4 |
| 4 | 2,3,6,7,10,11 | 0.13 | 4 | 3,7 |
| 5 | 1,2,5,6,9,10 | 0.094 | 92 | 1 |
| | | 0.15 | 54 | 9 |
| 6 | 1,2,5,6,9,10 | 0.094 | 80 | 1 |
| | | 0.15 | 32 | 9 |
| 7 | 1,2,5,6,9,10 | 0.094 | 72 | 1 |
| | | 0.15 | 24 | 9 |
| 8 | 1,2,5,6,9,10 | 0.094 | 65 | 1 |
| | | 0.15 | 17 | 9 |
| 10 | 1,2,5,6,9,10 | 0.094 | 48 | 13 |
| | | 0.15 | 1 | 9 |
| 11,12, or 13 | 1,2,5,6,13 | 0.019 | 35 | 13 |

## TABLE 3

## CONTROLLABLE UNIT CLOSURE EQUATIONS

1. $MUF_1=T_{(14)}-T_{(5)}+T_{(12)}+[T_{(7)F}-T_{(7)I}]+T_{(6)}+T_{(10)}+T_{(13)}$
2. $MUF_2=T_{(14)}-[T_{(1)I}-T_{(1)F}]+T_{(12)}+T_{(13)}+T_{(10)}+T_{(6)}+[T_{(7)F}-T_{(7)I}]+T_{(3)}$
3. $MUF_3=T_{(5)}-T_{(4)}$
4. $MUF_4=T_{(4)}-[T_{(1)I}-T_{(1)F}]+T_{(3)}$
5. $MUF_5=H_{(14)}-H_{(5)}+H_{(12)}+[H_{(7)F}-H_{(7)I}]+H_{(6)}+H_{(10)}+H_{(13)}$
6. $MUF_6=H_{(14)}-[H_{(2)I}-H_{(2)F}]+H_{(12)}+H_{(13)}+H_{(10)}+H_{(6)}+[H_{(7)F}-H_{(7)I}]+H_{(3)}$
7. $MUF_7=H_{(5)}-H_{(4)}$
8. $MUF_8=H_{(4)}-[H_{(2)I}-H_{(2)F}]+H_{(3)}$
9. $MUF_9=HE_{(10)}-HE_{(5)}+[HE_{(7)F}-HE_{(7)I}]+HE_{(6)}$
10. $MUF_{10}=HE_{(10)}-[HE_{(1)I}-HE_{(1)F}]+HE_{(3)}+[HE_{(7)F}-HE_{(7)I}]+HE_{(6)}$
11. $MUF_{11}=HE_{(5)}-HE_{(4)}$
12. $MUF_{12}=HE_{(4)}-[HE_{(1)I}-HE_{(1)F}]+HE_{(3)}$
13. $MUF_{13}=TI_{(14)}-TI_{(9)}+TI_{(12)}+TI_{(13)}$

Figure 1

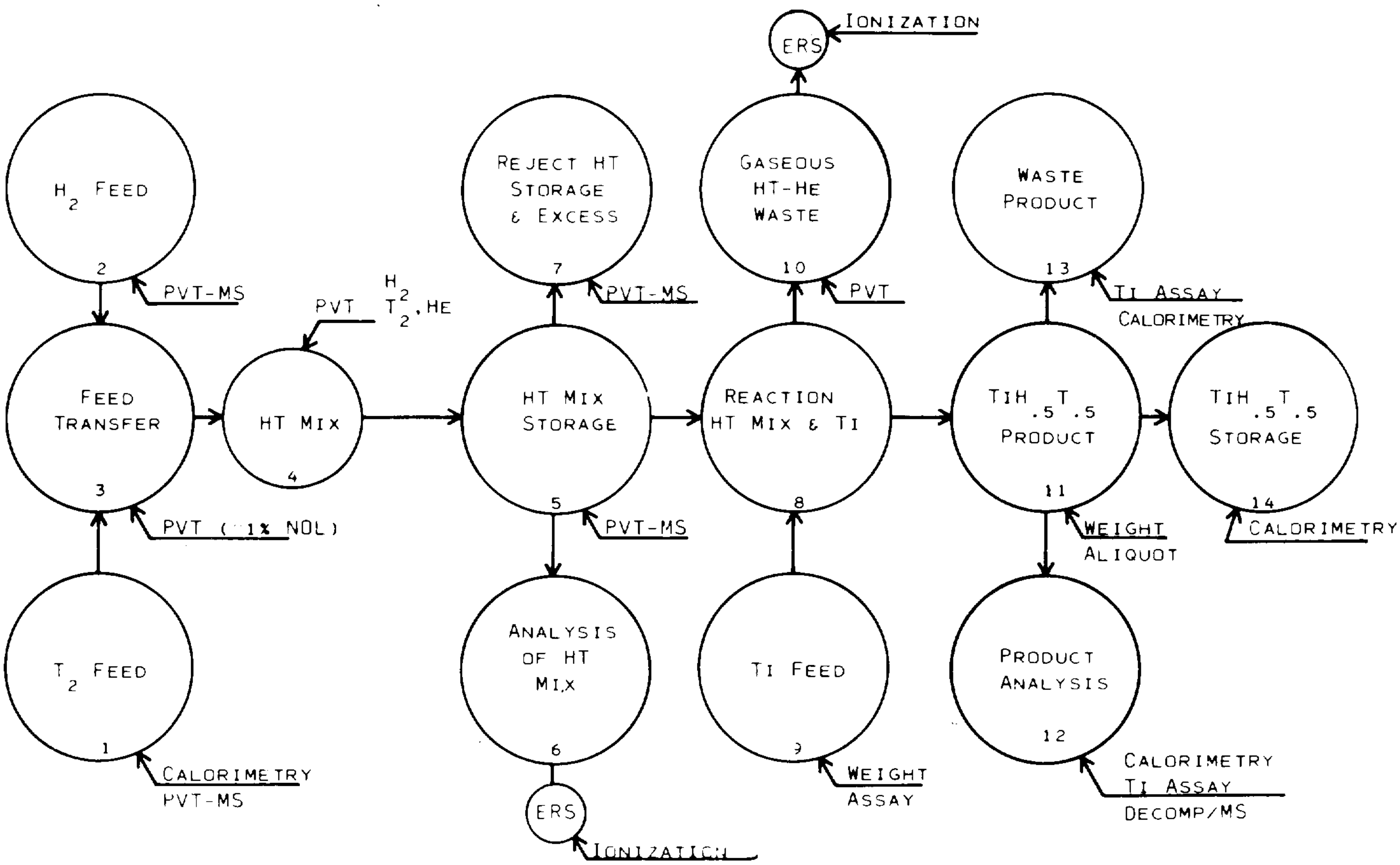



Figure 2

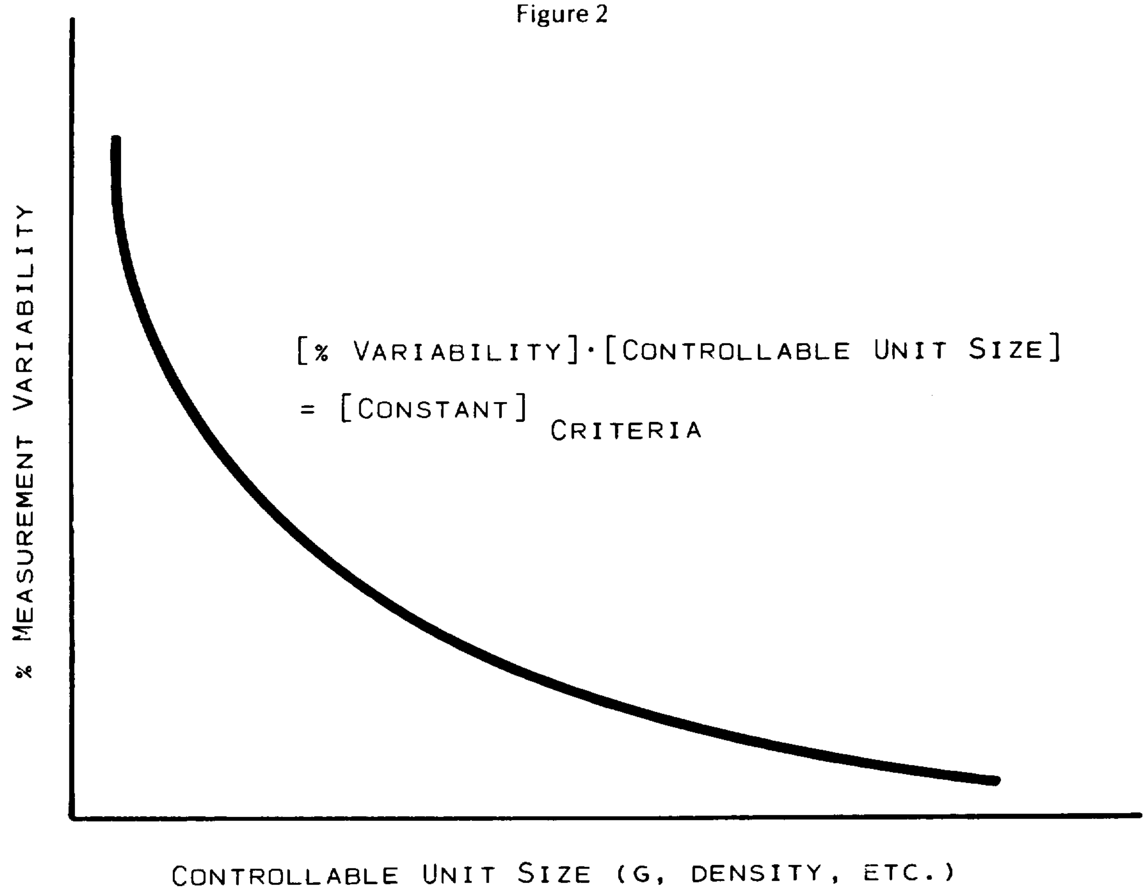


Figure 3

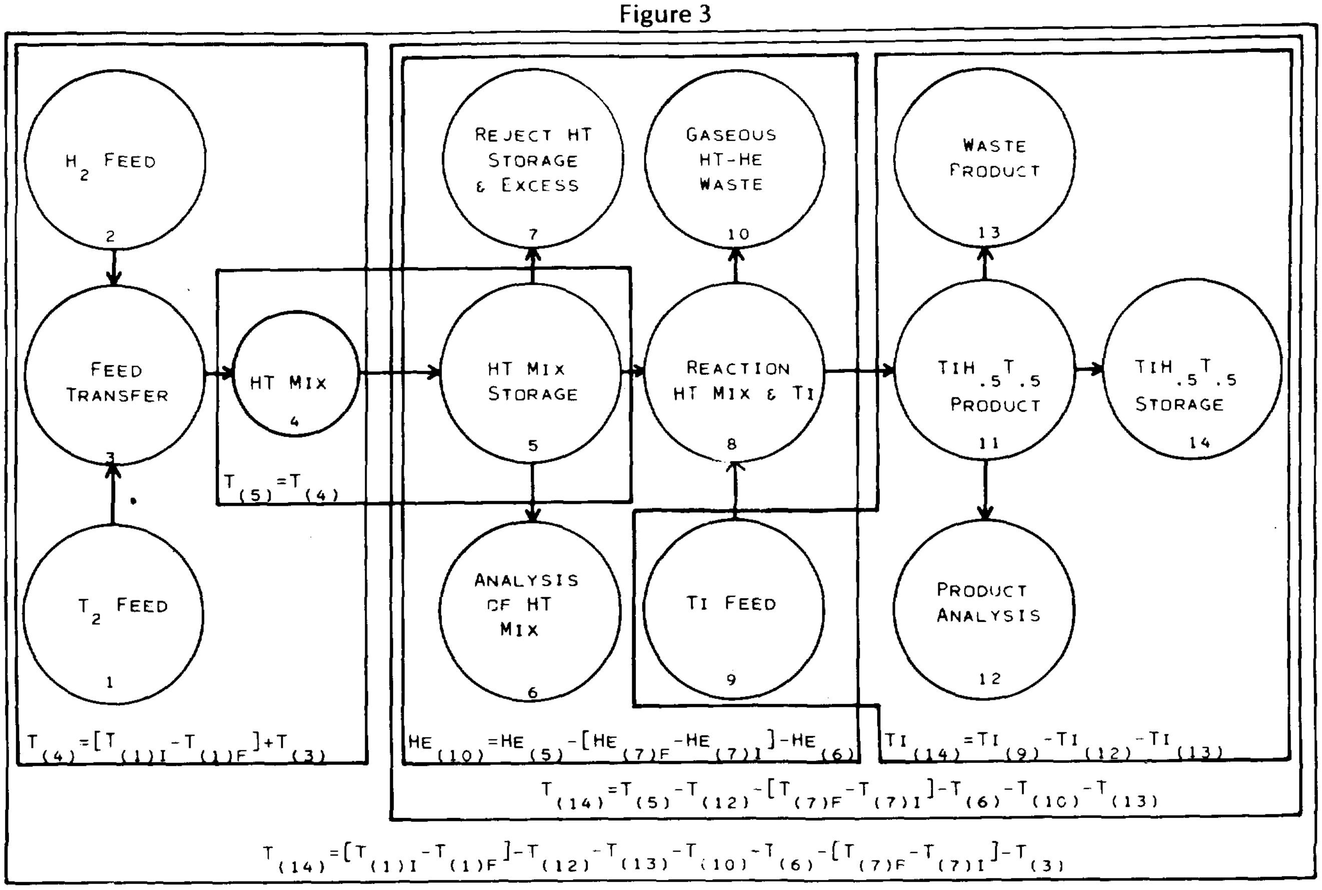
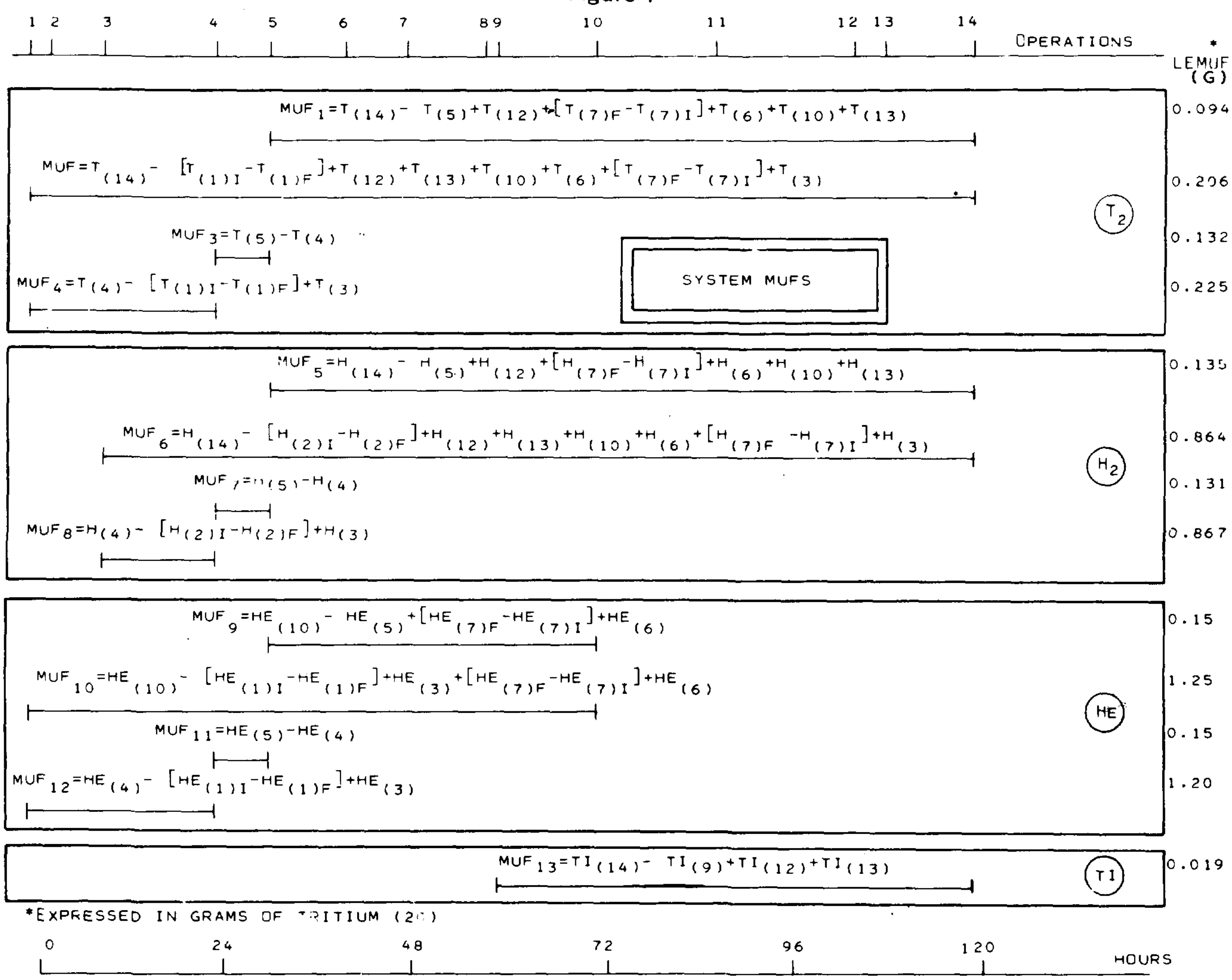



Figure 4



various operations and the bottom scale denotes the time frame in which a particular equation(s) is operative, as shown by the time bars drawn under the equation(s).

The values at the right are the LEMUF values in grams of tritium.

To illustrate the utility of Figure 4, it is postulated that a divertor takes tritium just after Operation 3. By using a straight edge oriented perpendicularly to the operations scale it can be seen that equations 2, 4, 6, 8, 10, and 12 potentially can be used to detect this diversion. Numerically, however, only equations 2 and 4 meet the stated criteria. Equation 2, which would be closely associated with the normal accountability MUF is the most sensitive at 0.206 g, but requires 120 hr to confirm the diversion. Conversely, equation 4 with only a small decrease in sensitivity picks up the diversion in 24 hr. The ultimate usefulness of any given equation depends on the particular emphasis desired but in this instance, equation 4 provides more timely and more localized information. Each system will have its own peculiarity in this regard.

With respect to other constituents, Figure 4 via the LEMUF for equation 10 indicates the inadequacy of helium data for tritium diversion or accountability. Nevertheless, useful information can be inferred. Primarily this large LEMUF reflects the magnification effect of the conversion fact that results from the low percentage of helium in the mix. However, the intimate association of the helium with tritium and hydrogen can be used advantageously since the helium runs as a parallel constituent and since the measurement sensitivity with respect to small changes in helium is high. When used in conjunction with other constituents, ratios such as HE/T at operations 1, 5, and 7 provide a formalism to separate process variability from measurement variability and thereby potentially minimize false alarms, an important practicality.

Another regrouping of the information is illustrated in Table 4. Various operations, applicable closure equations, associative LEMUF values and elapsed times are listed. For instance, the detection and time limits afforded by equation 2 for operation 1 are 0.21 g of tritium and 120 hr respectively. If the emphasis is switched from sensitivity to time, the affected operations and/or equations are easily ascertained through this listing. But perhaps the most important information reflected by Table 4 is the large improvement in diversion sensitivity that is attained when a non-accountable material, titanium, is controlled. That information is quantized through equation 13.

Following the previous general discussions of the concept of controllable units and the attendent closure equations, more specific examples of this will be described. Because of the great reduction in volume, the tritide product is a highly attractive form of tritium to obtain. With this observation it is postulated that one-half of the analytical samples or 5 g from operation 11 have been diverted from each batch. This represents 0.15, 0.05, and 4.80 g of tritium, hydrogen and titanium respectively. For tritium, the simulated results for six batches are illustrated in Figure 5 and the equivalent results for titanium are illustrated in Figure 6. As expected for that amount of material, the measurement graph responding to the diversion faithfully indicates the diversion. The degree of sensitivity for the different constituents to the diversion is represented by the separation between the diversion and no diversion graphs. Although not shown, the average hydrogen sensitivity is approximately one-third of that for tritium and much less than that for titanium; and although the hydrogen sensitivity is not high it is, nevertheless, indicative of diversion. It also suggests the possibility of using hydrogen analysis as a surrogate for tritium if the preferred tritium measurement system should fail. Conceivably, the process or plant might still operate while the system was under repair. These graphs demonstrate the potential utilization of parallel constituents with unequal diversion sensitivity in reducing false alarms since it is highly unlikely that all three constituents would indicate the same directional trend simultaneously. They also imply protection against falsification of data, particularly if each constituent is under different control. The jagged tracks reflect the random measurement variability imposed on the 0.15 g tritium diversion.

In previous graphs the diversion was postulated to occur at a level above the detection limit of the measurement system. So, in order to apply the method to subtle trends, it is now postulated that the diversion occurs at a level within the variability of a single measurement. That is, the diversion takes place entirely below the 2-sigma or any other selected uncertainty level.

Figure 7 illustrates the graph that represents the diversion of 0.04 g of tritium. Perhaps the graph is indicative of a trend, but the data are within the error limits. Similar trends could be attributed to other incipient perturbations or to degraded processes. The search for such trends can be sharpened by a moving average or some other filtered plot of the data. For these data a six batch average* is selected. Figure 8 illustrates the reduced scatter in the averaged results as the moving averages at the last point attain the value for a full six point average. Thereafter the next leading point would be incorporated and the trailing point would be dropped from the average. As also indicated in Figure 8, the graph trends outside the error limit by the sixth batch. If similar graphs are utilized for other constituents and closure equations, then the probability of separating low level diversion activity from other incipient perturbations or small persistent anomalies is greatly enhanced. In particular, if the moving average of the $T_{cal}/T_{ms}$ ratios at operation 12 drifts beyond the error limit, it would be indicative that a measurement system and not the process was degrading or experiencing some small persistent anomaly.

All techniques employed to improve the signal-to-noise ratio provide this improvement at a cost. Here the cost penalty for the gain in sensitivity is the extended time required to reach a conclusion. Nevertheless, this represents a reasonable balance since the additional exposure required to acquire a significant amount of material enhances the risk of detection. Finally, Figure 9 collectively illustrates the relative sensitivities of various constituents and closure equations for differing levels of diversion.

*The number of data used in a moving average involves several trade-offs. Specifically, a sparse data average will effect only a minor reduction in the scatter whereas an excessive data average will render the average insensitive to short-term changes.

Figure 5

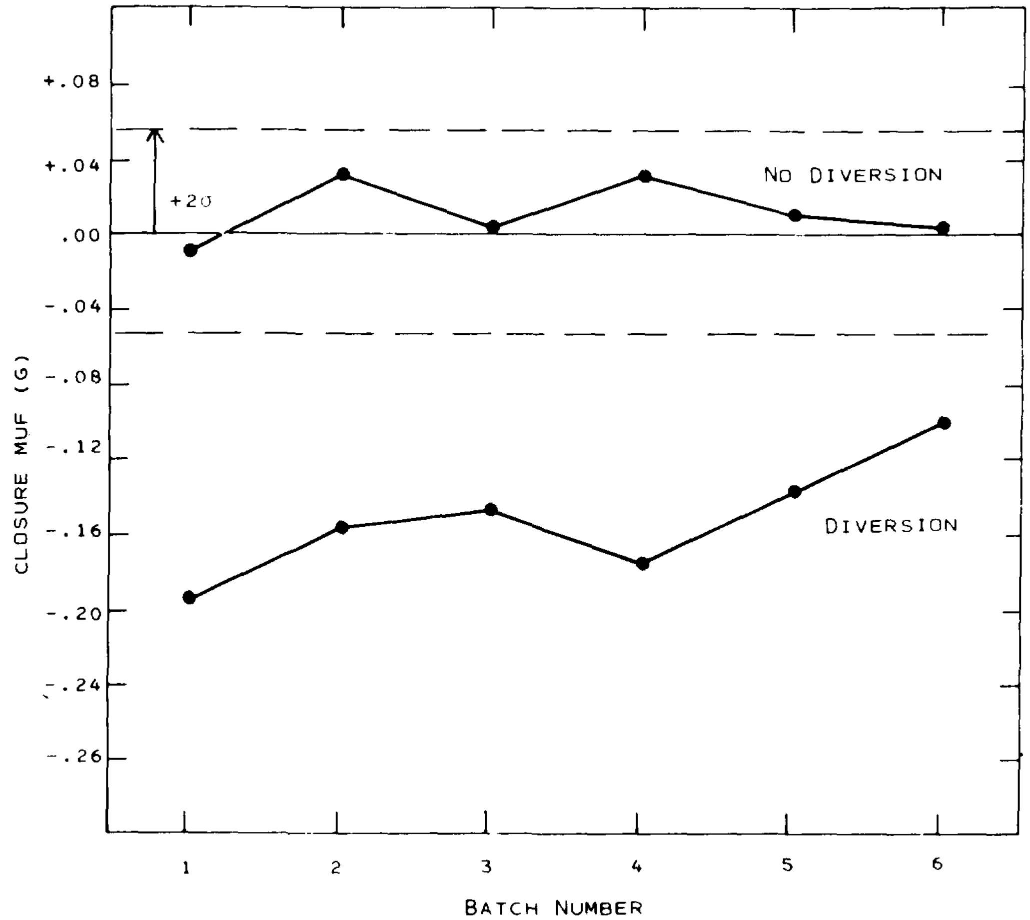
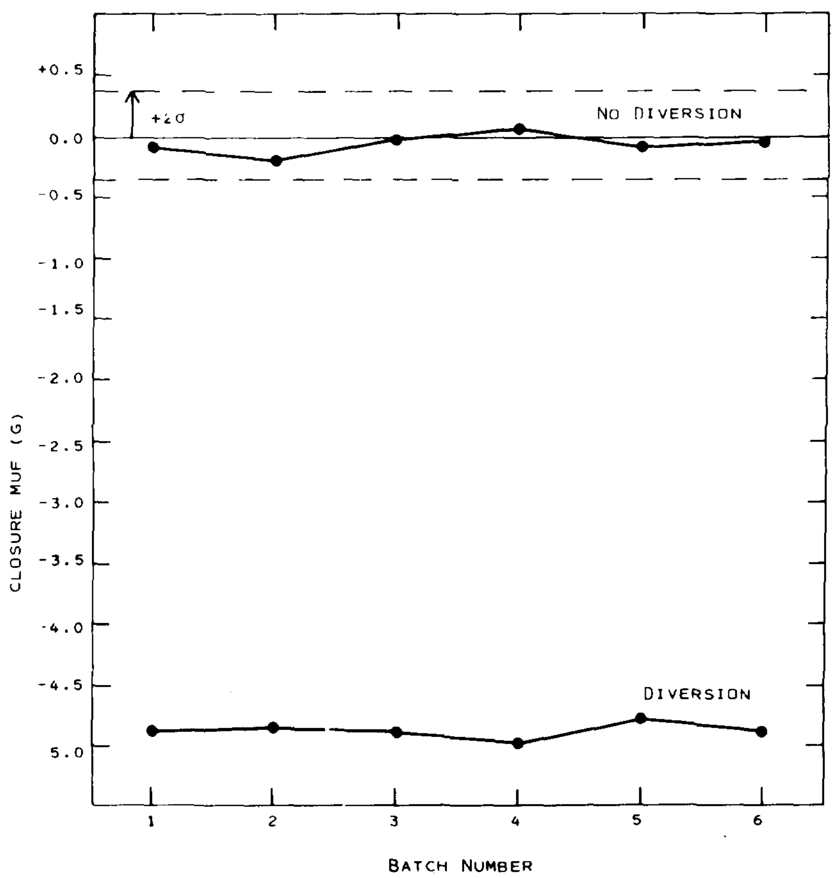



Figure 6



## PROCESS AND OPERATING CONSIDERATIONS

During the design stage for a process, opportunities for a choice among several equally attractive alternatives may arise. In lieu of any other criteria, familiarity may dictate the particular choice. The methodology described herein can provide guidance in a choice if such alternatives exist. With this integrated approach design parameters, process operations, measurement systems, inventory levels, and waste accumulation are areas where productive improvements for control of accountable materials might be realized with minimal incremental cost. For example, if there is a holdup in operation 4 (the mixer) equation 3 becomes

$$MUF_3 = T_{(5)} - T_{(4)} \pm \Delta T_{Holdup}$$

Now if it is assumed that the criteria constant is 0.14 g then the change in $T_{Holdup}$, by the RMS model, cannot be greater than 0.047 g. Consequently, if the holdup change is less than 0.047 g, it is not significant. However, if the change is greater than 0.047 g then it must be measured or be known to at least 0.047 g in order to maintain the criteria constant at 0.14 g.

Table 4 indicates that equation 1, which spans operation 7, provides the smallest LEMUF at 0.094 g. In that calculation it was assumed that the amount of tritium in storage at station 7 was zero. If it is again assumed that the criteria constant is 0.14 g and that the process otherwise is operated ideally, then to maintain the constant the measurement error of the accumulated waste at station 7 cannot exceed 0.104 g. For an analytical variability of 1.5% (Table 2) this translates to 6.93 g of tritium. Consequently, to ensure that the LEMUF does not exceed 0.14 g, tritium must be transferred after accumulation of 6.93 g.

Finally, if the measurement uncertainty of the 100 g container should dominate the LEMUF such that specified criteria cannot be met, then physical security, more accurate assay of tritium at that operation and containment of the tritium in two 50 g containers are tenable options.

## SUMMARY

An integrated systems approach which uses a controllable unit concept has been described. A controllable unit is defined as the span of control of a measurement system. In this sense, it is that magnitude, consistent with a given measurement system's variability, which satisfies some stated criteria. Most often, the magnitude represents a property of the material to be controlled such as mass, density or some other related attribute. Mathematically, it is defined as (% variability) (controllable unit size) = $(\text{constant})_{\text{criteria}}$. The constant can evolve from a set of criteria dictated by safeguards considerations.

For a specified criteria constant and magnitude, the minimum acceptable level of measurement precision that can be tolerated can be inferred. Conversely, if a given process has a measurement mix or a proposed mix, then specific numerical criteria for control of accountable material can be developed. To improve sensitivity to diversion and accountability, the method emphasizes process and accountability measurements and the control of non-accountable materials.

## ACKNOWLEDGEMENT

The authors acknowledge the instructive discussions with Dr. W.W. Strohm. A special acknowledgement is given to the reviewer who offered several alternative wordings that improved the clarity of this paper.

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4. "Statistical Methods in Nuclear Material Control," TID-26298, J.L. Jaech, USAEC Technical Information Center, 1974.

5. Sheldon Kops and Sylvester Suda, "MUF, BPID and Evolution," paper given at the Seventeenth Annual Meeting of the Institute of Nuclear Materials Management, June 22-24, 1976 (Seattle).

## LIST OF FIGURES

Figure 7

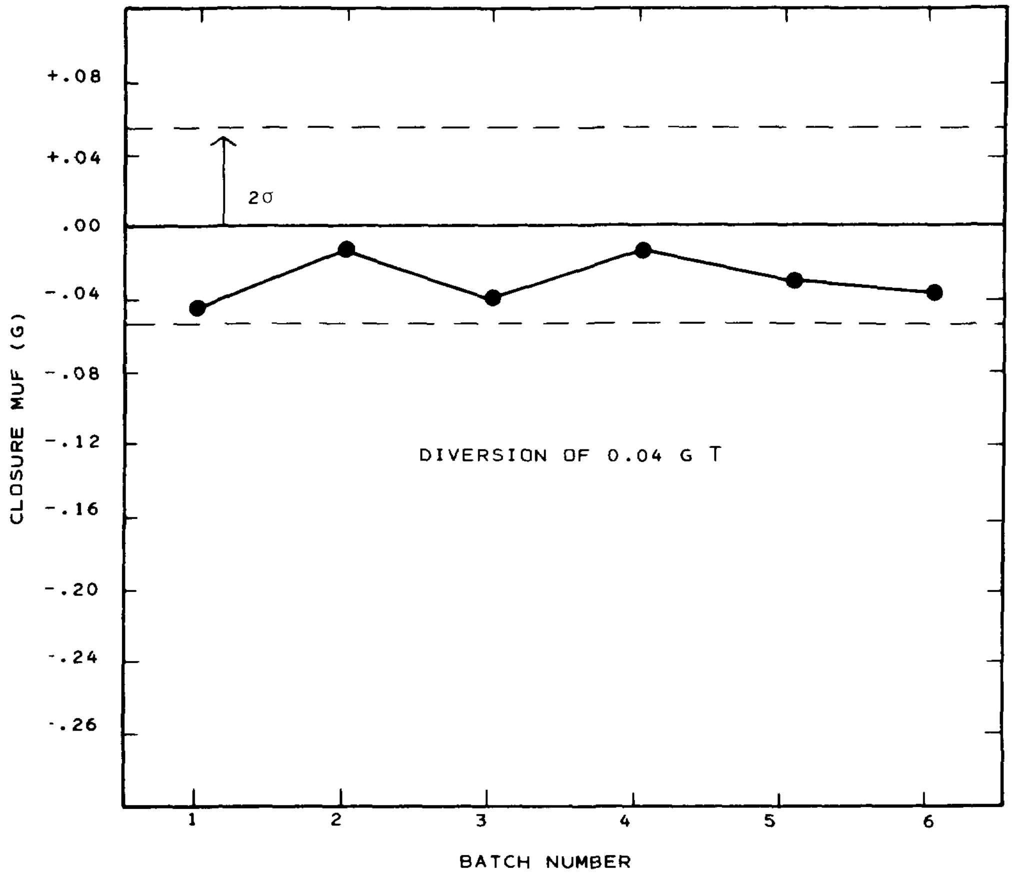



Figure 8

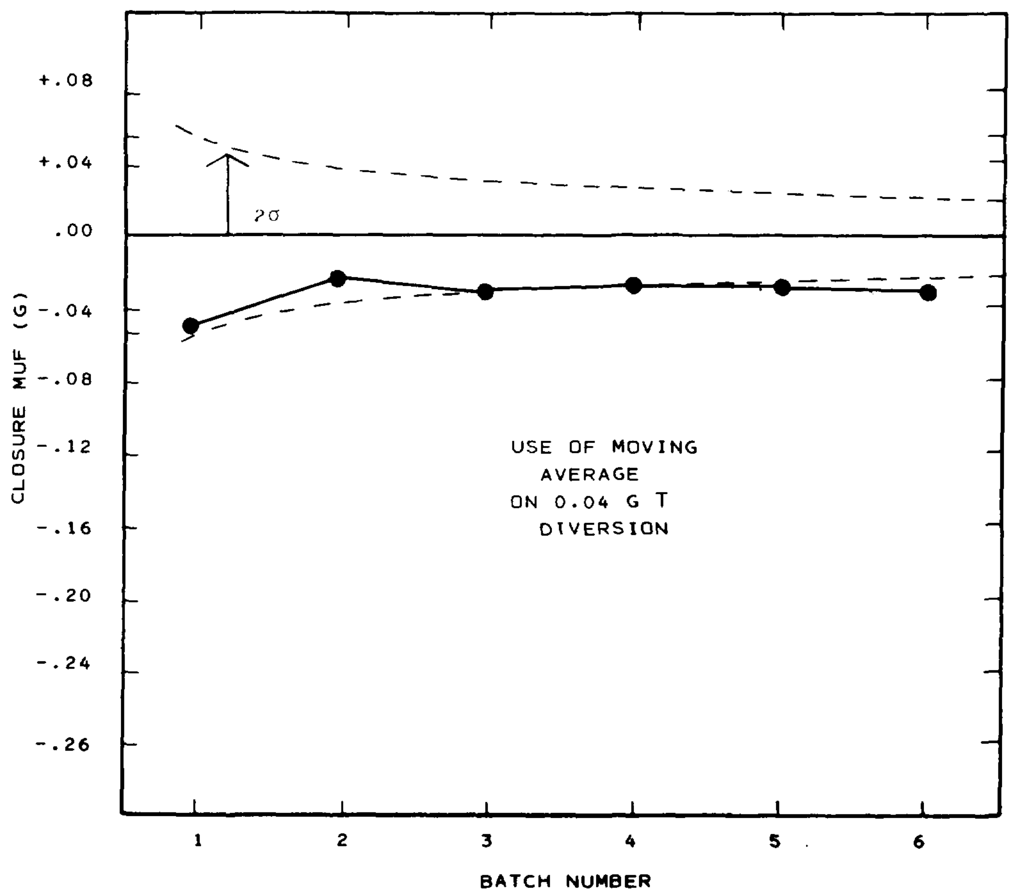
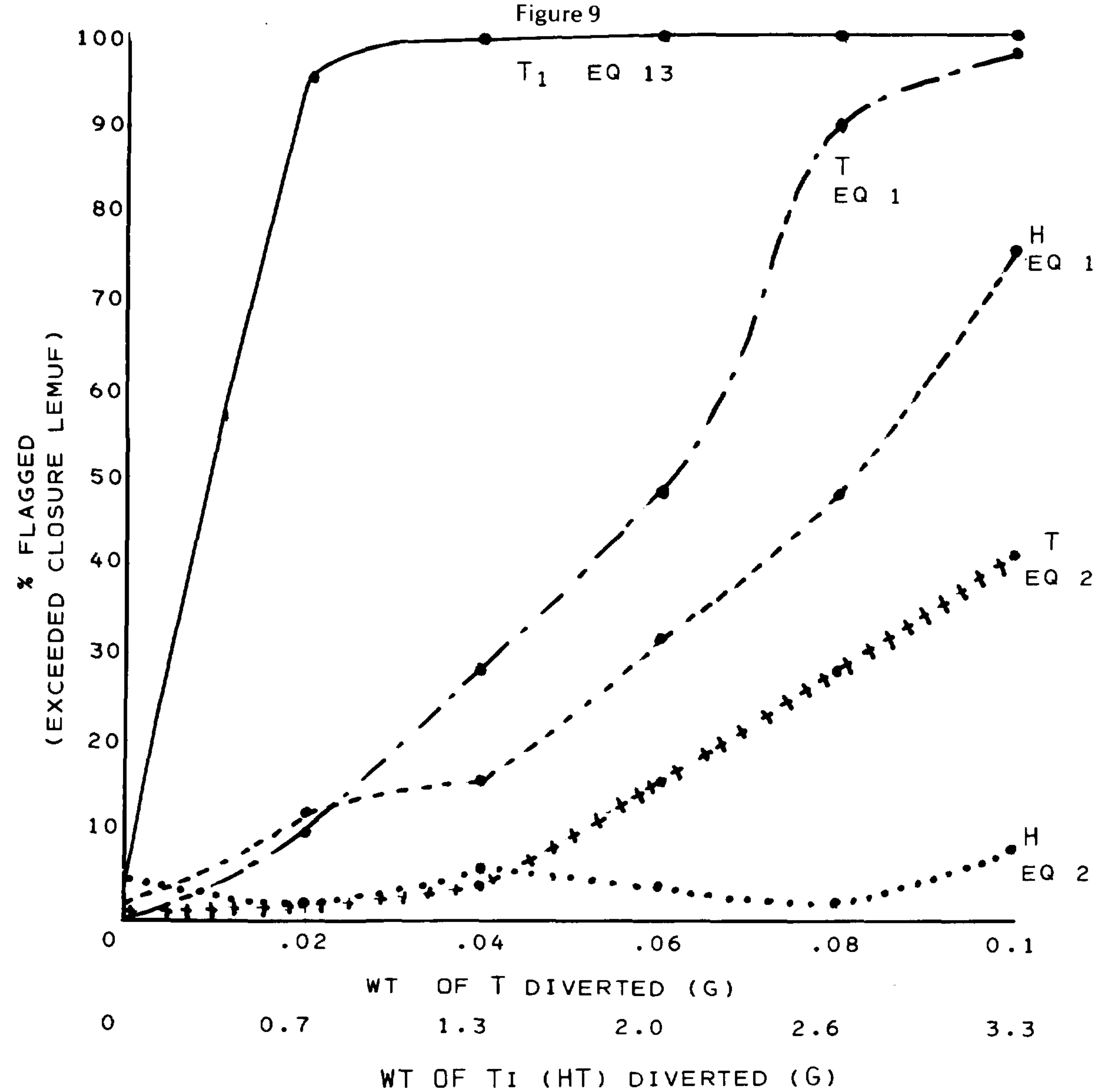


Figure 9




# International vs. Domestic Safeguards

(Continued from page 1)

some inter-agency debate on the latter. (U.S.G.A.O., Room 4522, 441 G. St., N.W., D.C. 20548).

4. Hearings before the Committee on Government Operations, U.S. Senate on S.1439 (Export Reorganization Act of 1976). The testimony covers a wide range of viewpoints. What makes this document of more than passing interest is that 800 of the 2,000 pages have reprints of relevant documents. It's a one volume library, but awkward to handle. (U.S.G.P.O. $17.00).

5. The following useful reference works were produced by The Congressional Research Service of the Library of Congress:

"Facts on Nuclear Proliferation," (63-441), Dec. 1975, U.S.G.P.O., $2.60.

"United States Agreements for Cooperation in Atomic Energy" (64-626 O), Jan. 1976, U.S.G.P.O., $2.50.

"Nuclear Weapons Proliferation and the International Atomic Energy Agency," (67-350 O), Mar. 1976. U.S.G.P.O., $3.40.

1977 will be an interesting year!

# INDEX OF ARTICLES (1972-1976)

**Editor's Note:** Vol, 1, No. 3, Vol. II, No. 3, Vol. III, No. 3, Vol. IV, No. 3, and Vol. V, No. 3 are proceedings of annual meetings of INMM. Copies of the tables of contents for those proceedings are available on written requrest to the editors.

## High Sensitivity Oxygen Measuring System

ORBISPHERE LABORATORIES, Division of ORBISPHERE CORPORATION of Geneva, Switzerland, and York, Maine 03909, announces the Model 2711 High Sensitivity Oxygen Measuring System designed for very low level Oxygen measurement in boiler feed and cooling waters.

The instrument represents a breakthrough because it can measure very low level concentrations with high precision and stability. The instrument has the extended ranges:0-10, 0-30, 0-100, 0-300, 0-1000, 0-3000, 0-10000 and 0-30000 parts per billion (ppb) or micro-grams per litre, and an accuracy of ±1% or 0.5 ppb, whichever is greater.

The system responds to Oxygen concentration changes very rapidly. For example, if the sensor is changed from an air calibration (21% Oxygen) to a zero $O_2$ calibration in sodium sulphite, the time required to indicate a concentration of 10 ppb is less than 5 minutes.

The popular Orbisphere "Quick-change" sensor permits very easy maintenance and rapid change of the sensor in the event of damage. A flow chamber is provided which is designed to by-pass boiler feed and cooling waters for measurement within the 0-50°C temperature range. The sensor and the by-pass flow chamber can be located remotely from the Oxygen indicating instrument (up to 500 meters).

The instrument provides a setting means for both high and low limits and gives an output signal for each. An alarm circuit is optionally available, which continuously compares the oxygen signal with preset "high" and "low" reference limits, and operates a relay if the signal descends below the low limit or rises above the high limit.

The instrument is designed to be portable with battery power or rack mounted with a line supply of 110V60Hz or 220V50Hz. The indicator package is completely sealed and allows no penetration of water.

## Nuclear Reactors Built

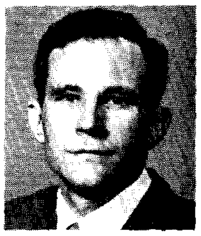
**Nuclear Reactors Built, Being Built, or Planned in the United States as of June 30, 1976 . . .**

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

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

The publication (44 pages, 8 x 10½, paperback) is available as TID-8200-R34 for $4.00 from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.


Bohl


Close


Seabaugh


Sellers


Stewart


Winslow


Woltermann

# ABOUT THE AUTHORS

**Donald R. Bohl** (M.S., Chemistry, Ohio University, 1966) presently is Group Leader of the Instrumental Group in the Analytical Section of the Nuclear Operations Department. He has integrated analytical chemistry and applied statistics for support of energy, environmental and quality control programs. He has published papers in these areas.

**D.A. Close,** Ph.D., Physics, The University of Kansas, 1972 is a member of the Nuclear Safeguards Research and Development Group at the Los Alamos Scientific Laboratory; involved in radiation transport calculations and neutron and gamma-ray measurements for the development of nondestructive assay instruments for fissionable materials.

**Joseph C. Miles** (B.S., Physics, Western Kentucky University, 1965) is a Senior Research Physicist in the Nuclear Operations Department of Monsanto Research Corporation, Mound Laboratory in Miamisburg, Ohio. For the past six years, he has worked in the areas of tritium analysis and handling systems. Recent activities have addressed tritium analytical measurements and their reliability, preparation of tritium-containing mixtures for analytical standards. Prior to this, he worked in mass spectroscopy and radioisotopic heat source programs utilizing 238-PU02.

**Pyrtle W. Seabaugh** (Ph.D., Inorganic Chemistry, Iowa State University, 1961) currently is Project Leader for Controllable Unit Accountability. He is in the Experimental Design Group at Mound Laboratory, Miamisburg, Ohio. He has authored papers in applied statistics, numerical analysis and x-ray diffraction structure analysis. His MBA from the University of Dayton reflects his interest in economics. This interest has led to financial and economic analyses.

**Douglas E. Sellers** (Ph.D., Analytical Chemistry, Kansas State University) is presently manager of Nuclear Operations Analytical Section, Monsanto Research Corporation, Mound Laboratory, Miamisburg, Ohio). Has been Assistant Professor in Analytical Chemistry at Kansas State University and Southern Illinois University and has worked in research and development of analytical measurements and statistics. Presently has over thrity publications in this area. Is currently involved with the management of over 50 people involved with research and development, quality control, quality assurance of analytical techniques used in nuclear weapons, space nuclear, and energy related programs. Currently involved with results associated with several ASTM, ANSI and nuclear safeguards committees, analytical guides, and sample exchange programs.

**John P. Stewart** (M.S., Physics, Portland State University) is the Nuclear Systems Engineer for the Quality Assurance Section of General Electric's Nuclear Fuel Department in Wilmington, North Carolina. In this capacity, he is responsible for all operational Non-Destructive Assay Systems utilized at the Wilmington Fuel Fabrication Facility for Accountability and Quality Assurance Purposes. He is currently serving on two ANSI-INMM standards committees and has presented several papers to both the INMM and the IAEA.

**George H. Winslow** (D.Sc., Carnegie Institute of Technology) has recently transferred to the Quantitative Verification and Safeguards section of the Special Materials Division, from the Chemistry Division, at Argonne National Laboratory. He originally joined the Argonne staff in 1946. He is co-author, with E.M. Pugh, of the college text, **The Analysis of Physical Measurements** (Addison-Wesley, 1966) and is author of the chapter, **Data Evaluation and Analysis,** Techniques of Metals Research, Volume 7, Part 1 (Wiley, 1972, R.F. Bunshah, ed.). Among his publications while in the Chemistry Division were those in the fields of alpha-decay theory, optical pyrometry, optical properties or urania and graphite, vaporization behavior of graphite and potassium, and statistical mechanical modeling of non-stoichiometric crystals, principally reactor fuel materials.

**H. Anthony Woltermann** (Ph.D., Inorganic Chemistry, University of Cincinnati, Cincinnati, Ohio, 1972) presently is Group Leader of the Experimental Design Group at Mound Laboratory, Miamisburg, Ohio. Previously he was a Group Leader and a Senior Analytical chemist in the Analytical Section of Nuclear Operations Department. He has had ten years of experience in the field of plutonium and tritium chemistry. He is the author of several papers in this area and has taught a course on Nuclear Technology at the University of Dayton.

# Constant Monitoring Of Nation's Reactors

LOS ALAMOS, N.M.—Techniques developed at the Los Alamos (N.M.) Scientific Laboratory (LASL) have been adapted to provide a new system LASL scientists believe may provide a simple way of constantly monitoring operation of the nation's nuclear reactors.

Scientists from the neutron measurement group of LASL's Field Testing Division used neutron and gamma-ray radiation emitted by a fuel pin in a test reactor operated by Argonne National Laboratory in Idaho, to photograph directly for the first time, the image of a fuel pin under rapidly changing reactor conditions.

**William H. Roach,** LASL neutron measurement group leader and project manager, said the experiment, called PINEX (for pinhole experiment), used ultrasensitive television cameras to record photographs of the fuel pin under artificially induced stress that brought the pin close to destruction.

Most nuclear reactors operate on fuel contained in slender pins, or rods, assembled in bundles to form a fuel core that is immersed in liquid that transfers the heat of nuclear reactions to produce steam to drive turbines for generation of electricity. The prime goal of both government and industry is to provide foolproof methods of rapidly shutting down a reactor if problems develop in the core.

The LASL experiment may provide an improved means of constantly monitoring operation of a nuclear reactor core, providing immediate information on severe changes that might indicate emergency conditions.

Roach described the LASL experiment as a successful focusing of the flux of neutrons emitted during reactions in plutonium-uranium oxide fuel in a test pin onto a disk that converts radiation signals into light signals. The disk fluoresces in proportion to the number of neutrons striking it. The experiment provided an accurate image of the fuel pin under extreme heat and pressure. This image was then recorded on videotape.

Roach says the next step in the experiment, which is funded in part by the Division of Military Application (DMA) through the LASL weapons diagnostic program and sponsored by the Division of Reactor Development and Demonstration of the Energy Research and Development Administration (ERDA), is to obtain three-dimensional pictures of fuel pins under stress.

Data obtained so far, along with results of three-dimensional studies that may be completed next summer, will prove invaluable, Roach believes, in resolving safety questions relating to operation of nuclear reactors, particularly the liquid metal fast breeder reactor (LMFBR). The fast breeder uses a 25 to 75 per cent ratio of plutonium-uranium fuel and "breeds" more plutonium than it uses.

"The ultimate objective of this series of experiments is to develop instrumentation for constant, direct viewing of the core of a reactor during operation," Roach sums up.

The experiments are a cooperative effort between LASL, which developed and fielded the imaging instrumentation; Argonne National Laboratory, which provided the test reactor facility; and Hanford Engineering and Development Laboratory, which supplied the test fuel pin.

Principal investigators in the LASL program in addition to the project manager are Dr. **George Berzins** and Dr. **Ki Sup Han.**

The Los Alamos Scientific Laboratory is operated by The University of California for the Energy Research and Development Administration.

Smith

## Heads NUSAC Quality Programs

McLean, Va.—Dr. **Ralph F. Lumb,** President of NUSAC, Inc. has announced the appointment of **Wilkins R. Smith** as Manager, Quality Programs Division. Smith's new responsibilities include the management of programs involving quality assurance during the fabrication of nuclear fuel assemblies, confirmation of $UF_6$ procurement, and implementation of nuclear materials control and accounting procedures.

Smith comes to NUSAC from Combustion Engineering, Inc. in Connecticut, where he was in charge of quality assurance engineering for fuel and control element assemblies, components, and material procurement.

NUSAC is an independent consulting firm providing advice and assistance in the areas of nuclear fuel quality assurance and the safeguarding of nuclear materials and facilities, including physical security and material control and accounting.

For further information contact **Robert C. Adkins,** Director of Marketing, (703) 893-6004.

## Automatic Reading System

DataCopy Corporation, Palo Alto, Calif., has developed a system for automatically reading alphanumeric characters which have been stamped or engraved in the metal surfaces of nuclear fuel rods.

The basic component in each system is a proprietary Reading Head which includes an illumination source, optics, a self-scanning photo-diode array, and means for deriving position information of the surface being scanned. Reading Heads are customized to each application so as to accommodate a variety of surface geometries and scanning conditions.

Reading Heads are typically integrated with rod handling equipments such that characters, which are presented circumferentially on rod end plugs, can be automatically positioned for the scanning operation. Speed of rotation is not critical, and characters can be read at any rate between zero and 100 per second. A number of system configurations are available as shown in the enclosed block diagram.

# ASSESSMENT OF DOMESTIC SAFEGUARDS FOR LOW-ENRICHED URANIUM

## SPECIAL INMM REPORT

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# Energy Game Plan Lacks Team

Editor's Note: The following letter-to-the -editor was published in **The Pittsburgh Press** on Sunday, December 26, 1976. The writer is Dr. Frederick Forscher, Chairman of the INMM Certification Committee, who is an Energy Consultant in Pittsburgh, Pa.

Thank you for your plain-speaking editorial, "Oil And Diplomacy," and Tony Auth's excellent cartoon on Dec. 19.

The United States has indeed "lost control of oil prices, and this the future of its economy." Unfortunately, the energy issue has yet to find its constituency so as to have an appropriate political impact.

We hear spokesmen for each of the fuels (oil, gas, coal and nuclear), and a growing voice in favor of renewable fuel sources, primarily solar energy. But energy per se has yet no constituency.

The survival of our society—indeed, of any society—depends on a sufficient supply of energy. Energy considerations must be included in every planning function, be it economic, industrial, regional or national; and by any agency, department, or corporate cost center. Such planning can only succeed with the consent and understanding of the governed.

The public must develop a better awareness and understanding of the energy issues and form a constituency like the environmental movement developed in the '60s. Blaming the Arabs, or the oil companies, or Congress, or environmentalists for our failures will not do.

This blaming-game is divisive and counterproductive.

What we need is a new methodology, a new frame of reference, within which all informed and concerned parties can attempt to resolve the energy issues. This is not a call for a mythical "energy policy," but merely for a framework within which such policies can be intelligently developed and applied.

**FREDERICK FORSCHER**
**Squirrel Hill**

# INMM

# STATISTICS COURSE

# MARCH 28 - APRIL 1

# RICHLAND, WASHINGTON

The INMM in cooperation with the Joint Center for Graduate Study at Richland, Washington, is planning to present the course, "Selected Topics in Statistical Methods for SNM Control," March 28-April 1, 1977, Monday through Friday. The course will be instructed by **John L. Jaech** of Exxon Nuclear Co. This is the course that was last given at the Argonne Center for Educational Affairs in September, 1976. For further information, contact: **Bob Sorenson** at Battelle Northwest at FTS 441-7511 and then ask for 946-2372; or AC 509 946-2372. Tentative fee: $350.

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