SAFEGUARDS
INMM
RELIABILITY ASSURANCE

CONTENTS

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EDITORIAL

Dr. Higinbotham

What Really Counts!

By W.A. Higinbotham

The annual meeting, in Seattle, was outstanding in every way, as others will explain on neighboring pages. The INMM meeting has become **THE meeting** for formal and informal exchange of information on safeguards for professionals in the USA and, to some extent, for international exchanges.

There has been some improvement in the Journal, too, though not to the extent that it could and should have been improved. The Journal should be **THE Journal** for safeguards papers and the standard library reference source on the technical aspects. Although it probably will not become the principal source for articles on the philosophy and politics of domestic and international safeguards, it could be one such source, if the membership so desires.

Shortly after I became technical editor, I requested **Jim Lovett,** in Vienna, and **Norm Beyer** at Argonne, to be assistant editors. They have been very conscientious in reviewing and stimulating papers. At the INMM Executive Committee, it was agreed that the editorial review committee should be considerably expanded. This should improve the quality of the Journal in several ways. It will provide authoritative review of papers submitted in the many different fields which comprise our subject. It will distribute the labor so that no individual will find himself overburdened and help to avoid delays. It should also give the scientists and engineers at the represented institutions a feeling of participation, an opportunity to advise on editorial policy and technical content. Hopefully, the reviewers and their colleagues will feel responsible for soliciting papers which should be published here.

Tom Gerdis and I are in the process of writing to members active in various fields of safeguards, requesting nominations for technical reviewers. We would also welcome volunteers or suggestions from Journal readers. Obviously, reviewers should be competent in one or several fields and willing to comment within a week or two on drafts submitted for comments. Considering all of the activity that is going on in safeguards, it should be possible to fill at least six issues a year with high quality articles.

The INMM safeguards committee, after a prodigious amount of work, has produced a detailed analysis of the considerations which should apply to the safeguarding of low enriched uranium. The committee's paper will soon be published by the INMM as a special report. Although the committee went out of its way to circulate drafts and to solicit comments, several members of INMM, who felt that they disagreed with the conclusions, have expressed concern about the fact that the published report mat be interpreted to represent the considered conclusion of all members of The Institute.

The best thing about our outfit is that everyone in the business can belong to it. Most of them do belong and also participate in the Institute's activities. On every safeguards policy issue there are bound to be differences of opinion. That is a proper state of affairs. Such differences of opinion must not prevent the Institute from forming study groups and issuing papers which discuss basic safeguards matters. It

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THE INMM CHAIRMAN SPEAKS

Mr. Cardwell

CITES KEEPIN'S 'OSCAR' PERFORMANCES

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

This eve of our nation's 200th birthday seems a fitting time to write my first communication to the membership. It is indeed a time to reflect . . . a time to consider the past and to look to the future.

In the few years since its inception, our society has sprung from a small fledgling group (albeit a hyperactive group) of individuals to an organization approaching 500. Last month, we set another record with an Annual Meeting attendance of 348 in Seattle. No single individual can take credit for this. It was a team effort, and many of the original group are still playing key positions on the team.

To retiring Chairman **Armand Soucy,** I convey the sincere thanks of INMM for a job well done and look forward to his counsel on our Executive Committee. To **Bob Curl,** our new Treasurer, and **Gary Molen** and **John Ladesich,** I bid welcome and look forward to my association with them this year.

And finally to **Bob Keepin,** our new Vice-Chairman who has furnished us with two "Oscar" performances as Program Chairman, I bid welcome to the "Con on the flying bridge" where he will set the course and guide us through our next Annual Meeting.

Chairman Soucy mentioned on several occasions that he found himself at the helm during a crucial time for the nuclear profession. I find myself no less in such a period and with our organization that is still the only forum devoted exclusively to safeguards and nuclear materials management.

I am, however, optimistic enough to believe there are now rays of light emitting from the end of the tunnel. Regardless of how many ways it is analyzed and explained, the 2 to 1 putdown of the California moratorium yielded the nuclear industry a definite psychological advantage in future conflicts. I believe we learned a great deal about dealing with the public, and I believe we are learning a great deal about dealing with the press. And, we do have one significant advantage. Nobody wants the lights to go out.

In that vein, I hope to see a "real-time" public information program activated this year. Strong interest has been indicated by a large number of members in a speaker's bureau; and these names have already been organized on a computer mailing list to aid in intercommunication. A video-tape library of safeguards films has been started. Hopefully, we will soon have a PI Chairman.

A vote of thanks goes to **Manny Kanter** who has both chaired our Education Committee and acted as Dean of some very successful schools at ANL for the past 4 years. I believe that this is an area in which INMM can make a significant contribution, and planning is going forward toward an expansion of this education program.

I also believe it is now time for us to seriously consider a Fellows program for the Institute. We have grown and progressed to our present status because some individual members have given time and talent generously and unselfishly. It is time that they are recognized as well as others who shall do so in the future.

Finally, I sincerely appreciate your confidence in electing me your chairman. Over the past few years I have developed a strong attachment to the Institute and have a sincere desire to see it continue to grow and prosper. I shall try hard to merit that confidence.

Dr. Keepin

THE SEATTLE MEETING AND THE CHALLENGE AHEAD . . .

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

The Seventeenth Annual Meeting of the Institute set a new record for attendance of 348, and judging from the response of attendees at Seattle as well as subsequent reactions and correspondence received since the meeting, there seems to be a clear consensus that our 1976 Annual Meeting in Seattle ranks among the best in the Institute's history. This was achieved through the hard work and excellent cooperation of everyone on the 1976 Annual Meeting Committee, headed by its General Chairman, **Roy Cardwell.**

By the time our June meeting in Seattle rolled around, public interest in nuclear issues had risen to unprecedented levels, due in large part to the highly controversial Nuclear Initiative campaign in California which attracted nationwide attention. As several speakers at Seattle pointed out, the 2:1 vote of confidence for nuclear power in California on June 8 was an important victory, but it represents only the first in a series of tough nuclear contests arising in 32 other states, either through initiative action or in state legislatures. Indeed in 11 states, double-barreled action is planned for limiting or stopping nuclear power through both initiative petitions **and** state legislative actions. The prospect of new legislation restricting nuclear power in various states (such as the three new laws restricting nuclear power in California) is seen by some as a bellwether, indicating that the long-standing nuclear regulatory monopoly at the federal level is on the wane. Others see concerns about nuclear issues coalescing into popular crusades in several states. It is particularly noteworthy for us in INMM that the two technical issues of greatest concern to California voters were those bearing on the handling and storing of high-level nuclear wastes and upon the issue of adequate nuclear safeguards.

The critics' attempts—and, so far, failures—at thwarting or stopping nuclear power by the initiative process have had the effect of forcing thoughtful voters in California—and many other states as well—to seek factual information and to become somewhat more sophisticated about nuclear power and related fuel cycle operations. In general this trend toward increased awareness and understanding must be hailed as a step in the right direction, but at the same time it underscores more strongly than ever our responsibility in INMM for public education and honest presentation of the facts about nuclear reactors and the nuclear materials that fuel them. As many of you will recall, **Dean Worthington** handed us quite a challenge in his paper, "Nuclear Safeguards and Nuclear Shutdowns," when he concluded with, "You (in the INMM) are a key group, guardians of the nuclear option in many respects, responsible for safeguards, materials management and safety, and you are going to have to shoulder much of the technical and political defense of nuclear power against a determined group who for many reasons would take the nuclear option away."

There are many excellent opportunities for INMM members to participate directly in the vital task of public education on nuclear power at the local, state and national levels; notable in this connection is the Institute's recently organized Speaker's Bureau to which many of you have responded postively and enthusiastically.

As was very candidly brought out again at Seattle, there is the whole range of complex problems facing the nuclear industry, from supply and enrichment right on through to reprocessing and waste management at the "back end" of the fuel cycle. But equally important is the fact that none of these problems are insurmountable and that practical solutions can be, and are being, worked out and implemented in various types of facilities throughout the fuel cycle. To get this message across to concerned Americans, and to successfully make the case for clean, safe—and safeguarded—nuclear power will require the dedicated efforts of essentially all of us in the INMM and throughout the nuclear community. Toward this important goal, we hope the proceedings of the 1976 Seattle meeting (to be mailed in September) will provide both timely and useful source material.

Mr. DeVito

ORNL's Roy Cardwell New INMM Chairman

By V.J. DeVito
Secretary of INMM

According to Article III, Section 6, of the INMM Bylaws, "The Secretary shall notify each member in good standing of the results of the election by November 15 of each year." For the record, this notice in the Journal shall be construed as having fulfilled that obligation.

In accordance with Article III, Section 4, of the Bylaws, the Nominating Committee selected the following candidates for each office and position:

Chairman .... **Roy Cardwell**
Vice Chairman .... **Robert Keepin**
Secretary .... **Vincent DeVito**
Treasurer .... **Robert Curl**

Executive Committee:
Jimmy Gilbreath
Robert Kramer
John Ladesich
Gary Molen

There were no petitions for candidates to be added to the ballot. However, there were several write-ins.

In accordance with Article III, Section 5, a ballot was mailed to each of the Institute's 490 members, of which 259 returned valid ballots.

As a result of the balloting, the officers and members of the Executive Committee for fiscal year 1977 will be as follows:

Chairman .... **Roy Cardwell**
Vice Chairman .... **Robert Keepin**
Secretary .... **Vincent DeVito**
Treasurer .... **Robert Curl**

Executive Committee:
Member of be appointed to June 30, 1977 (Ralph J. Jones)
John Jaech to June 30, 1977
John Ladesich to June 30, 1978
Gary Molen to June 30, 1978
Armand Soucy— Immediate Past Chairman

The proposed amendment to the Bylaws—Article V—Meetings—dealing with the quorum percentage was passed—the vote for the amendment 209, against the amendment 33.

Advertising Index

Foreign Policy Statement—Forscher

Editor's Note: Statement by Dr. Frederick Forscher to the PITTSBURGH FORUM ON FOREIGN POLICY, *organized* by the World Affairs Council of Pittsburgh, Pa., and the U.S. Department of State, at the William Penn Hotel, Pittsburgh, Pa., on Wednesday, February 18, 1976.

To the Editor:

My name is Frederick Forscher. I am a Consulting Engineer, specializing in energy management, a new profession involving the joint application of economics, engineering and environmental sciences. I am testifying today as a member of the public and in my capacity as a member of the American Jewish Committee, as a member of Americans for Energy Independence, and as chairman of the energy committee of the local environmental group GASP (Group Against Smog and Pollution).

I want to address myself to the subject of Energy and its importance to the survival of our society—in fact, of any society, and any living organism. What I am proposing is not so much a criticism of our foreign policy values, but a new reference point, a new common denominator for policy decisions: namely energy. This country must become self-sufficient in energy as soon as possible, and at the same time must recognize the interdependence among the many regions of the world. The challenge is to reconcile energy independence with worldwide interdependence, conservation with productivity, and cooperation with competition.

It is well to point out, right at the outset, that Western Pennsylvania occupies a very special position in the ongoing search for an equitable solution to our energy dilemma. Of the four basic fuel resources, this region gave birth to three of them: coal, oil and nuclear. In addition, this region has led the nation in urban pollution control through the pioneering efforts of the Pittsburgh Renaissance.

My profession, engineering, and technology have often been criticized as the cause of many of our ills. It has rightly been said that technology is too important to our society, and to any society, to leave it to technologists alone. Of course, the same argument can be made about economics, history and war, education, and nearly every other field of knowledge.

There is a need for a new common denominator, a new social focus that applies equally to economics, technology, environmental and military matters. This new common denominator is energy. I mean the physical and measurable concept of energy, and not fuel. Because it is energy, not fuel, that is a necessary component of **all** fields of knowledge: natural sciences, life sciences, and social sciences. We must begin to distinguish between fuels and energy, as we have learned to distinguish between food and calories.

The basic problem facing our society today, is the problem of survival. For the individual survival means food and calories; for society survival means raw materials and energy. All political/economic issues, such as taxes, unemployment, foreign aid, and defense spending, are rooted in the imperatives of food for the people, and energy for society.

The issue of energy is very complex and all pervasive. Hence, it is not surprising that the public is confused and the media are not very enlightening. Why are we so confused about energy? The answer is that the concept of energy, as a central theme of the social sciences, is as much resisted today as Copernicus' claim that the sun is the center of the solar system, was resisted during the 16th and 17th centuries. The same reasons for resistance apply then and now: 1. A new concept disturbs the dominant system of values. (Incidentally, Copernicus' new idea of revolution about the sun, gave rise to the social meaning of the word revolution.); 2. The basics of the concept of energy (thermodynamics, social metabolism, net energy, etc.) are not clearly understood, and not taught in schools. The distinction between food and calories is a puzzle to most people; and 3. Conclusions drawn from the new concept do not "solve" the timely problems that have been the focal points of political actions. Yet, it can be shown easily that the new concept assists in decision making by introducing the badly needed consistency between short range and long range, domestic and foreign objectives, and between micro and macro economics.

Hence, I urge the Department of State to include energy as a central and fundamental foreign policy value. Is it also a moral value? Certainly, the use of energy has moral overtones. For example, pleasure driving (that is the aimless exercise of your right to get into your automobile and drive to wherever you feel like driving) is an immoral act. It pollutes the air, it depletes essential resources, it endangers people on the highways, and it clogs the arteries of transportation. Yet, today, most Americans don't see it that way. The public still believes that the need for energy conservation is—at best—a temporary fad, and—at worst—a puton by the bureaucrats and the big oil companies. We, as a nation, are years removed from the realization that energy conservation must be practiced like a religion.

History has shown that the Copernican idea of the solar system had many repercussions in unrelated fields. Similarly, we must be aware that the concept of energy as a central value of our foreign policy decision has major implications in many other fields. Clearly, in today's worldwide struggle for natural resources, living space, food and water, we cannot afford to disregard the central function of energy.

If democratic societies have anything in common, it is their belief in participatory government. The idea of "participatory government" includes the whole gamut of institutional arrangements, from free enterprise to a centrally planned economy. Our constitution does not favor one form of economic system over another. It provides a dynamic framework within which all citizens can improve their life, liberty, and pursuit of happiness in a participatory manner. With all its shortcomings, this form of government is still the best (i.e. most productive and creative) the world has yet seen. This workshop is a step

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Dr. Forscher

CERTIFICATION REPORT

PROGRAM STALLED

By Dr. Frederick Forscher, Chairman
INMM Certification Committee

I have bad news for the membership of this organization. **The certification program is stalled;** it is not derailed, but definitely stalled. The proposed standard N15.28, defining the professional requirements for certification as NMM has been voted down by a consensus ballot of N15 and will be withdrawn from ANSI consideration.

While there is a broad consensus that NMM's ought to be considered as professionals, there is no consensus on what constitutes the "profession" and what constitutes the professional content of an NMM. Yet, an accreditable certification is essential for reasons of public credibility and safeguards system's quality alone.

It is perfectly clear that "certification" of NMM's without agreement as to what this profession stands for, is an empty gesture, an ego-trip if you will, for people who like to see a fancy certificate on their office wall. However, to your certification committee "certification" means recognition of professionalism and as such needs definition and content.

I am convinced that the institution of safeguards is too important to the public, to Congress, to other national institutions and to the world community at large, to be left to the whims of special interests, such as business, labor, the military, or even regulators. I believe deeply, that the staffing of whatever safeguards system is finally agreed upon, domestically or worldwide, must strongly lean on professional NMM's with a general knowledge and understanding of material control, measurement and accounting, as well as of material and plant protection.

So far, we have failed in our effort to define, in necessary detail, this knowledge and understanding that constitutes the bases for professionalism. Representatives of the ANS, EEI, and AIF (that means the representatves from the overwhelming majority of the nuclear community) voted NO on the proposed standard. As Westinghouse put it succinctly: "There is not a current need for this standard, nor for the certification of those people engaged in the control of nuclear materials."

This position on the part of the nuclear industry forecloses further committee action toward improvement of the N15.28 standard, and even refuses to recognize the need for a professional certification program. This position of the industry reminds me of the position of the anti-nuclear factions that call for a moratorium on nuclear power. **We have now a defacto moratorium on safeguards;** viz.: the CEQ stopped the GESMO, the courts stopped interim licensing, Congress stopped foreign sales, and now the industry itself stopped professional certification of NMM's.

On June 21, I reported this status to the INMM Executive Committee and proposed that N15.28 be withdrawn from ANSI consideration at the present time. I further proposed that, in the near future, the Certification Committee rewrite the N15.28 document, and issue it as an INMM report to the membership after approval by the Executive Committee.

The modification we have in mind are aimed at clarity and better definition of the substantive content of the profession. The document should clearly state what constitutes the lowest common denominator of professional knowledge and understanding. Added to this common denominator, the document would describe additional requirements for "demonstrated knowledge and understanding" that would qualify a candidate for certification as a nuclear material specialist in three or four areas as practiced by our profession.

Forscher's Foreign Policy Statement

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in the right direction, giving the people a chance to tell it like it is, and our policy administrators a chance to hear it.

The issue of energy has divided the world in haves and have-nots. But the issue of energy can also unify differing factions. Last December, I was fortunate to be allowed to lead a citizen's delegation, consisting of representatives of labor, industry, environmentalists, and professionals (engineers), to Washington to present our regional views on energy to the Congressional Delegation from Pennsylvania. It is noteworthy that the issue of energy, and its significance for this region, created an atmosphere in which normally adversary groups found a common denominator. It is the same common denominator, mentioned above, that is so badly needed in foreign policy values.

Isn't it about time that the State Department treat energy as the central value that it is, rather than a derivative of the economic, monetary, developmental or military issues?

CHARTER MEMBER WRITES ABOUT EARLY DAYS

Editor's Note: Since receiving the following letter from Mr. Youngs, the INMM Executive Committee has voted to waive his dues for the coming year.

To the Editor:

As your records will show I am a Charter Member of INMM. I started Nuclear Materials Management with the Corps of Engineers—Manhattan District in 1946—took the **First** inventory of the Corps' "source and fissionable material" and then in 1947 organized the Source and Fissionable Materials Accountability Branch of the Division of Production, USAEC, Washington, D.C. and headed this branch for five years. (This branch and three others later became Divisions—mine was renamed Nuclear Material Management Division—but I withdrew to become chief of operations at Portsmouth Ohio Gaseous Diffusion Plant, Portsmouth Area office.)

I was very fortunate to be given a free hand to pick the best qualified group of individuals (for the INMM branch) in Systems Accounting (Ed Hall now with Price-Waterhouse), Chemical Analysis and Measurements (C.D.W. Thronton still with ERDA, I believe), Statistical Analysis (Dr. Horace W. (Tod) Norton, now with University of Illinois), Accounting, Douglas E. George, a past Director of NMM Division—now in the business for himself along with Ralph Lumb, Dr. Ralph Lumb who I hired when Dr. Norton left for University of Ill., William (Bill) Ginkel (last I heard, Manager of Operations at Idaho Falls Operations) to run the Engineering-Records—Reports, TS Pipeline Report to the Commission (Degrees in Chemical Engr. and Accounting) and several clerical workers. I failed to mention Donald F. Musser (an understudy of C.D.W. Thornton at Y-12 Electro-Magnet Plant)—a very good chemist without any **college** education but well educated by home study. He was the **first** Director of NMM Div. USAEC when I went to Portsmouth, Ohio. Doug George succeeded Don Musser who joined the Disarmament Group. From what I have been able to learn, the **basic** system which our group developed in the 1947-1952 period was sound and essentially the measurement, analysis, transfer, MUF, transfer, statistical still in use, with improvements and refinements each year. I look on this 5-year period as the most challenging and rewarding of my 31 years of Government service.

I retired February 2, 1973 as Area Manager Pinellas (Fla.) Area office. My energies now are primarily with the Military Order of the World Wars—trying to make sure we have a good national defense, develop nuclear electric generating plants, patriotic education in public middle schools, do not give away the Panama Canal, etc.

So, I have decided to give up membership in INMM and am returning my 1975-76 membership card. I wish all of you continued success in all of your endeavors.

Sincerely,
Walter C. Youngs, Jr.

Member Recommends Award

Patterson

To the Editor:

As a means to get further recognition and public exposure to the INMM as the competent, professional organization, we, as members, acknowledge continually (to each other) that it is, I would like to propose a public relations type of activity which could be an annual affair. This would be an award in the form of a plaque or some other suitable commendation to the "Man (or woman) of the Year in the Nuclear Industry." This or a similar designation could be made.

A committee could be established to select candidates worthy of such an award. The annual recipient could be a nuclear fuels manufacturing executive, a nuclear scientist, a public utility executive whose company includes nuclear power as part of its energy sources, or any other outstanding contributor to the nuclear industry. The requiring qualifications should be of a high level and those selected should be leaders or at least major motivators of nuclear progress.

This award, in whatever form is finally agreed upon by Awards Committee or the Public Relations Committee, would be given advance plus current publicity by as many communications media as are available. The peers approach for the presentation surely would add to the prestige of the occasion and the authenticity as well.

This annual occasion, coinciding with our national meeting, would add a positive breath of life to the much aligned nuclear industry. This may not be an original suggestion, I'm sure, but I would like the suggestion to be seriously considered by the officers and committee chairmen of the Institute.

Yours for a bigger, wiser and more recognized INMM,
James P. Patterson, Elmhurst, Illinois.

Mr. Parks

GOOD COVERAGE OF SEATTLE MEETING

By Richard E. Parks, Chairman
INMM Public Information Committee

"Experts committed to solving the safeguards problems associated with nuclear materials will gather for the 17th Annual Meeting of the Institute of Nuclear Materials Management at the Washington Plaza Hotel, Seattle, Washington on June 22-24 . . ."

This sentence headed the press release which was sent to the media ten days prior to the meeting. Fifty-two releases were distributed. The packages included abstracts of the plenary speakers remarks and an invitation to the public to attend the series of films on nuclear energy to be featured in the mini-theaters.

An announcement of the meeting appeared in the Seattle papers, the Times and P-I on Sunday, 20 June 1976. The opening day session was covered by local television crews from all three networks—CBS, NBC, and ABC, several other local independent radio stations and the Seattle Times and P-I.

The ensuing broadcasts and articles were within reason, although it appeared that the mundane task of solving the nuclear safeguards problems does not have the flair of that of incidents which would be detrimental to the future of nuclear energy.

Response to the mini-theaters was not what one would consider overwhelming. Outside of the INMM members, wives and families, attendance by the general public was somewhere between 5 and 10! We still believe that the idea is worth pursuing, as public education and understanding is essential to the acceptance of nuclear energy. The videotapes are available on loan to the INMM membership and include the following topics: 1. Atoms on the Move, Atomic Power Today; 2. The Day Tomorrow Began; Atoms in the Market Place; Safety Second to None; and 3. Safeguards—The Press and the Public (1975 Meeting at New Orleans).

Roy Cardwell has indicated that he would like to expand the library during the forthcoming year. Suggestions from the membership will be most welcome.

In summary, the press was good to us in Seattle. The INMM has an established credibility, but it needs to be further exploited to the public. Mr. Worthington proposed the challenge in his remarks about the opposition. It is incumbent upon all of us to do what we can towards better understanding of nuclear energy.

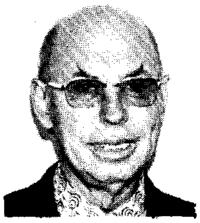
PARKS HEADS INMM INFORMATION

Richard E. (Dick) Parks has been appointed Chairman of Public Information for INMM. He is Manager of the Safeguards and Assurance Analysis Division of Olympic Engineering Corporation in Seattle.

Public Information has been separated from the Safeguards Committee to operate as a separate function. Duties of the Chairman will be to coordinate all activities of the new INMM Speaker's Bureau and to organize and promote other public information activities of the society.

In making the appointment, INMM Chairman **Roy Cardwell** said, "I believe that the enthusiastic response to a speaker's bureau proposal is very indicative of the feeling of the membership toward an active role by INMM in getting a more accurate nuclear message out to the general public. Dick Parks is a most capable individual to manage such a program and I am very pleased that he has agreed to accept the responsibility."

Dick and his wife **Mari Ella** were two of our local hosts at the recent Annual Meeting in Seattle.



Mr. Lee

Membership Report

By James W. Lee, Chairman
INMM Membership Committee

This very short column by the Membership Committee chairman is a direct result of the long and circuitious route he traveled to reach this years annual meeting in Seattle.

As a result, I regret that I cannot keep my promise to list the names of those INMM members submitting the names of INMM prospective members in this issue of the Journal. Appropriate recognition will be published in the next edition of the Journal.

The excellent response to our plea for names, plus the active assistance of many members and officers throughout the just-ended fiscal year was effective, for it produced a grand total of 76 new members this year—more than ever before.

This fine result is a tribute to the interest-provoking programs and activities of the Institute. With the continued cooperation and help of our members, we are counting on the Institute establishing an even greater total of new members during the current fiscal year.

Help your organization by sending the name of a membership prospect today to Membership Chairman, INMM, P.O. Box 14336, North Palm Beach, FL 33408.

New Members

The following 39 individuals have been accepted for INMM membership as of July 14, 1976. To each, the INMM Executive Committee extends its congratulations.

New members not mentioned in this issue will be listed in the Winter 1977 (Volume V, No. 4) issue to be sent out next January.

Glenn L. Booman, Allied Chemical Corporation, OPP-637, 550 Second Street, Idaho Falls, Idaho 83401.

Stephen B. Brumbach, Assistant Scientist, Argonne National Laboratory, Special Materials, Building 16, 9700 South Cass Avenue, Argonne, Illinois 60439.

Pierre Busquet, 75 Rue Dutot, Paris, France F75015.

Alberto Cocchi, ENSL, Via G.B. Martini 3, 00198 Rome, Italy.

John C. Darrin, Hittman Nuclear & Development Corporation, 9190 Red Branch Road, Columbia, Maryland 21045.

R.J. Dietz, 1261 Second Street, Los Alamos, New Mexico 87544.

Frank A. Dougherty, EDS Nuclear, Inc., 220 Montgomery Street, San Francisco, California 94104.

Dean W. Engel, 2126 Cascade, Richland, Washington 99352.

H. Peter Filss, Kernforschungsanlange Zurich, D 512 Zurich, Postfach.

Frank W. Graham, 465 Bedford Road, Chappaqua, New York 10514.

Richard A. Hamilton, 1909 Peach Tree Lane, Richland, Washington 99352.

Clarence F. Hanley, Boeing Engineering and Construction Company, M/S 8K-39, P.O. Box 3707, Seattle, Washington 98124.

Reinsuke Hara, Daini Seikosha Company, Ltd., 31-1 6-Chome, Kameido Koto-Ku, Tokyo, Japan.

Lawrence Harris Jr., Science Applications, Inc., P. O. Box 2351, La Jolla, California 92038.

David E. Hause, Manager, Marketing, United Nuclear Corporation, Fuel Recovery Operation, Wood River Junction, Rhode Island 02894.

Harmon Willard Hubbard, R & D Associates, 4640 Admiraty Way, Marina Del Ray, California 90291.

Clyde P. Jupiter, Office of Nuclear Regulatory Research, Technical Assistant to the Director, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Cecil Kindle, 1117 Marshall Avenue, Richland, Washington 99352.

Hiroyoshi Kurihara, Head, Safeguards Office, Nuclear Safety Bureau, Science & Technology Agency, 2-2-1, Kasumigaseki, Chiyoda, Tokyo, Japan.

Delores McCarthy, 93 Sunny Waters, Old Canterbury Turnpike, Norwich, Connecticut 06360.

Martin Messinger, 10903 Hunt Club Road, Reston, Virginia 22090.

Charles E. Moeller, 2660 Burr Ridge Court No. 112, Woodridge, Illinois 60515.

Richard A. Moschner, Manager of Safeguards, General Electric Company, P. O. Drawer B, Pleasanton, California 94566.

James A. Prell, U.S. Nuclear Regulatory Commission, Nicholson Lane Building, Washington, D.C. 20555.

Nicholas J. Roberts, 556 Humboldt Way, Livermore, California 94550.

Peter Randolph, 1526 Kearney Street, Idaho Falls, Idaho 83401.

Charles Brian Rokes, Nuclear Engineer, Gibbs & Hill, Inc., 219 East 81st Street, Apartment 5H, New York, New York 10028.

David Rudolph, 1131 University Boulevard West, Silver Springs, Maryland 20902.

Edward P. Schelonka, Staff Member, Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87545.

Tom A. Sellers, 2519 Elfego Road, N.W., Albuquerque, New Mexico 87017.

Francis Smith, 9013 Franklin Road, Pasco, Washington 99301.

G. Dan Smith, Material Control Analyst, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Herbert E. Smith, Atlantic Richfield Hanford Company, 234-5 Building, 200-W Area, Richland, Washington 99352.

Woodford F. Spencer, 154 Cumberland View Drive, Oak Ridge, Tennessee 37830.

Shugo Suenaga, Nippon Electronics Company, 26 Shiba Nishikubo No. 5, Tokyo, Japan.

James W. Tape, Los Alamos Scientific Laboratory, Group R-1, MS 540, Los Alamos, New Mexico 87545.

Arthur Waligura, 11-13 Kaernterring, Vienna, Austria

George H. Winslow, Associate Scientist, Argonne National Laboratory, SPM-QVS, Building 16, 9700 South Cass Avenue, Argonne, Illinois 60439.

Howard T. Yolken, National Bureau of Standards, Department of Commerce, Building 222, Room B311, Washington, D.C. 20234.

ADDRESS CHANGES

The following 11 changes of address have been received as of July 14, 1976 by the INMM Publications Office at Kansas State University, Manhattan.

David W. Christopher, Partner, Price Waterhouse & Co., Suite 4500, 600 Grant Street, Pittsburgh, Pennsylvania 15219.

Charles R. Condon, 3421-40th Avenue West, Seattle, Washington 98199.

Daniel Heagerty, President, Power Services, Inc., Northgate Office Building, 5861 Rivers Avenue, North Charleston, South Carolina 29405.

R.C. Janka, Kerr-McGee Technical Center, P.O. Box 25861, Oklahoma City, Oklahoma 73125.

Willis T. King Jr., Johnson & Higgins of California, 4201 Wilshire Boulevard, Los Angeles, California 90010.

Paul N. McCreery, NL Industries, Inc., P. O. Box 928, Barnwell, South Carolina 29812.

Gavin R. Mallett III, 418 Windemere Road, Wilmington, North Carolina 28401.

Ken Sanders, P. O. Box 645, Vienna, Austria.

Dean D. Scott, 1887 Alder Avenue, Richland, Washington 99352.

D.B. Sinden, P.E., 4 Warden Avenue, Orleans, Ontario, Canada K1E 1T4.

H. V. Werner, P. O. Box 645, Vienna, Austria.

REVISED A.N.S. PUBLICATION

HINSDALE, Ill.—A completely revised version of the most widely distributed publication ever printed by the American Nuclear Society—"Nuclear Power and the Environment: Questions and Answers"—was published in April.

Since its first publication in 1973, the original version has had six printings. Scores of organizations have used more than 300,000 copies of the first Q&A book in seeking better public understanding of nuclear power.

Revision of the first edition was prompted by the drastic change in the overall energy outlook in the United States—caused by the Arab oil embargo, subsequent oil price increases, the natural gas shortage, and controversy over coal strip mining and nuclear power growth. A complete revision of the book presents these events and their impact as of late 1975 to early 1976.

Responding to the changed energy/environment outlook, the expanded Q&A book adds to the original 16 sections these new or broadened sections: The Energy Perspective and Nuclear Power, Economics and Reliability, Energy Independence and Conservation, Public Risk from Nuclear Power, Benefit and Risk Perspective, Fuel Reprocessing and Nuclear Waste Disposal, Plutonium Toxicity, Diversion of Nuclear Fuel, Nuclear Plant Security, and Alternative Technologies.

The current edition of this ANS publication provides answers to 317 questions in 22 subject areas. Doubled in size, the book now has 132 pages.

Distribution of the Q&A book is primarily through bulk order purchases from ANS by utilities, manufacturers and allied organizations in the nuclear field. However, single copies are available from ANS headquarters (244 E. Ogden Avenue, Hinsdale, Illinois 60521) for $4.00 a copy, prepaid.

Along with several INMM members, Bill DeMerschmann of Westinghouse HEDL took in the Atomic Industrial Forum's Conference on Nuclear Safeguards April 11-14 at the Orlando (Fla.) Hyatt House. Bill served as local arrangements chairman of the 1976 INMM annual meeting this past June in Seattle.

Among participants in the AIF safeguards conference last April was Harley L. Toy (center) of Battelle Memorial Institute, Columbus, Ohio. Mr. Toy completed two years on the INMM Executive Committee this past June 30 as immediate past chairman (1972-1974).

AIF MEETING . . .

RENTED A CAR, TOOK IN ORLANDO

By William A. Higinbotham
Brookhaven National Laboratory

AIF meetings are an experience. The subject is topical and the list of speakers impressive. They sock you $250 for the privilege of attending and put you in a plush motel in the middle of nowhere.

This one was at the Orlando Hyatt House, which one might expect to be in or near Orlando. It isn't. It's a couple of miles from Disneyland but 15 to 25 miles from any other place to eat or to have a sociable drink on a per diem.

There was a good turnout, 200 to 300 top level government and industrial managers and a few peons. Much of what was said, INMM members have heard before. However, the emphasis keeps changing and there were new ways of looking at various issues.

In a few words, it is not possible to summarize the meeting as a whole. So, I will mention the theme of some of the papers that caught our interest. Commissioner **Victor Gilinsky** felt that the IAEA accountability system is not yet good enough and urged restraint on foreign sales until the system is improved. He also urged consideration of multinational reprocessing and storage facilities. The paper by **R.L. Dickeman** is reprinted in this issue. **Carl Builder** (NRC) presented a very thoughtful paper on the problem of threat definition which I hope will be reprinted somewhere. **Si Smiley** reported on the NRC nuclear energy center study. The conclusion is that colocation has no great impact on safeguards or anything else. The report is in the NRC public document room. **Russ Wischow** summarized the study that E.R. Johnson Associates did for A.I.F. Get it from A.I.F. **R.G. Page** spoke on the current status of licensing, which probably will have changed again by the time that this gets published. He was followed by **Gary Molen** of AGNS who described some of the problems involved in complying with license requirements. That could have changed too. **Warren Donnelly** of the Library of Congress explained that the Congress is especially worried about the subject of proliferation and presented a summary of Congressional activities in our field which would be of interest to have on file. General **Edward B. Giller** (ERDA) described some of the current safeguards R & D projects, presented a table of terrorist activities which may have some significance for nuclear safeguards and said that thought is being given to establishing international communications procedures for non-military nuclear emergencies. Inspector General **Rometsch** of the IAEA described how the IAEA plans to inspect U.S. facilities under the President's offer and covered several other topics. Very interesting. **Herb Kouts** talked about the NRC safeguards R & D program, **Jack Edlow** on the advantages of private transportation, **Bernard Cohen** on toxicity of plutonium, etc. I do not mean to slight anyone, but am running out of ink. If the A.I.F. would publish proceedings, I would be spared this chore and you would have the opportunity to make your own review.

This meeting came just after a joint NRC-ERDA team had visited a number of licensees and asked them to propose how to deal with performance criteria regarding certain postulated threats. Since the A.I.F. had arranged for no escape except to Disneyworld, half the audience took Disney and the other half discussed how to reasonably respond to NRC-ERDA. We rented a car and took-in Orlando.

Mr. Jaech

N15 REPORT

TOTAL REACHES TWENTY

By John L. Jaech, Chairman

"The total number of INMM sponsored ANSI standards now stands at 20. Considering our size, this represents an accomplishment that is a credit to our Institute."

"This total represents many hours of dedicated involvement on the part of a large percentage of our total membership. To each of you who has contributed to this work over the years, be assured that the INMM Executive Committee, speaking for the total membership, is fully appreciative of your efforts. Standards-writing is regarded as one of the most important activities of our society."

"This fact was once again brought to my attention during the June meetings in Seattle. Some nine writing groups were in sessions in Seattle, which speaks to the importance of this activity. Impressive as this is, even more impressive is the news about those writing groups that met far into the evening on Sunday before the convention, that met on Thursday night after the convention, and that stayed over on Friday for still more meetings. This is the kind of dedication and hard work needed to produce standards. Progress is agonizingly slow at times, but with so many dedicated people in our organization, we cannot help but continue to move forward and add to our excellent track record."

"There are setbacks and disappointments. Many drafts must be prepared and reviewed before balloting. Negative ballots, after such dedicated effort, are always a disappointment. Elsewhere in this issue you will read of the withdrawal of the Certification Standard because of negative ballots. Yet, we must admit that the end product of our endeavors is without exception much improved because of the many reviews required before a standard is created."

"I am personally disappointed that the Executive Committee has thus far failed to develop an awards program to recognize the contributions of those individuals responsible for the creation of standards. This problem is still being addressed, and hopefully some day, more tangible recognition can be given. In the meantime, I was gratified that **Lou Doher,** Chairman of INMM-8 was honored in Seattle for his contributions to standards development. Lou is certainly a deserving recipient of this honor. He is the first to state, however, that no chairman can accomplish anything without willing workers. The award, directed at Lou, is intended to convey the gratitude of the INMM membership to all those who gave so freely of their time and brain cells to produce the four INMM-8 standards published during 1975."

"In looking ahead, we cannot afford to rest on our laurels. While glowing with past triumphs, we must also burn with the desire to accomplish even more in the coming year. Your continued help is needed; it is appreciated!"

Aerial Survey for Mound Laboratory

MIAMISBURG, OHIO—A small green and white Hughes helicopter will fly at low levels over Mound Laboratory from July 7 through July 13. The Hughes H-500, flying 100 to 200 feet above the ground, is part of an environmental program conducted by the U.S. Energy Research and Development Administration. Mound Laboratory is operated under contract for that Federal agency by Monsanto Research Corporation.

The aircraft will map the terrestrial radiation profile of the areas on and surrounding the Laboratory, covering 3.75 square miles. The survey is part of a routine nationwide program to document the radiation environment and is conducted for ERDA by EG & G of Las Vegas, Nevada.

A similar survey of Mound was conducted in April, 1968, using a fixed wing aircraft. The entire fly-over will be coordinated through the Cincinnati Regional Federal Aviation Administration office to permit low level flying. The flights will be made during daylight hours and as weather conditions permit.

John R. McClain (seated, left), newly appointed Vice President of Monsanto Research Corporation and Director, Mound Laboratory with members of the Mound Laboratory Nuclear Materials Management group. (Seated L-R are John R. McClain and Daniel D. DeBord. Standing L-R are Donald R. Fidler, Mose Baston, Jr., and Everett A. DeVer, SS Representative).

One of the behind-the-scenes individuals in the INMM publications operation is James W. (Bill) Woolsey (left), an accounting major at Kansas State University, Manhattan. Woolsey, a Vietnam veteran and native of Coin, Iowa, is married and his wife Linda is expecting their first child. Woolsey has been handling business and circulation functions in the INMM Publications Office assisting Tom Gerdis (right), editor of the Journal.

More Highly Regarded . . .

By Tom Gerdis, Editor
Nuclear Materials Management
Journal of INMM

I have really enjoyed my association with the INMM over the past four and one-half years. It all began one weekday noon hour during the summer of 1971 when Dr. **Curt Chezem,** met me on the street on my way over to Ahearn Fieldhouse at Kansas State University where it is my custom to jog two miles a day. Curt indicated to me then that "an organization he was associated with" was interested in beginning a journal. I was serving then in my present position—publicity man for the engineering college at K-State*. If my memory is correct at the time I was a little fuzzy as to what he was asking for. What I remember is that we agreed in that brief conversation that I should put together a short proposal which he would review and we would send in to the INMM executive committee to review at its regular fall meeting.

The proposal called for a $200/month salary for me. We would try to publish three regular issues of an INMM journal and the proceedings of the next annual meeting held in Boston (May 31-June 2, 1972). I started work "on a moonlight basis" on the journal about mid-November and Curt and I were able to persuade **Roy Cardwell** of ORNL (who became INMM chairman on July 1, 1976) to develop two technical articles. Roy wrote one article on accounting of nuclear materials and persuaded two ORNL colleagues to write another. We had hoped to print the first issue of the Journal in January of 1972. However, it turned out we were not able to get the first issue out in April, all 12 pages of it, prior to the annual meeting in Boston where **Jim Lovett** (now with I.A.E.A., Vienna, Austria) was chairing his last INMM meeting.

Chezem was kind enough to fly me to Boston from Manhattan (120 miles west of Kansas City) in his beautifully equipped small four-seat plane replete with the latest in avionics that he bought from **Ed King** of King Radio Corporation in Olathe, Kansas. Chezem paid for the trip and the INMM executive committee was kind enough to reimburse me my out-of-pocket expenses for the meeting. This Connecticut Yankee transplanted to Kansas met scores of people in safeguards, a field I knew little about then (The grasp I have of the field has fortunately increased somewhat since that time).

The present 8-3/4 by 11-3/4 format of the journal was quite frankly lifted from "The K-State Engineer," the student engineering magazine at KSU which comes out four times during the school year. Your INMM editor has served as faculty adviser to the publication since 1970. The K-State Printing Service headed by Mr. **George Eaton,** superintendent of the fine publishing facility for many years, agreed to begin printing INMM publications. The design and layout of the Journal has been modified, hopefully improved, several times since 1972. There have been many helpful suggestions from officers, chairmen and other INMM members which have helped improve the publication.

*Since then, I have been given a joint appointment as news editor for the College of Education at KSU in addition to my duties for the engineering college.

The first executive editor of the INMM journal, Nuclear Materials Management, was Dr. Curtis G. Chezem (left), director of nuclear activities at Middle South Services, Inc., New Orleans, La. When the journal was founded (April 1972), Chezem was serving as professor and head of nuclear engineering at Kansas State University, Manhattan. Chezem is shown with James W. Lee, chairman of the INMM Membership Committee from North Palm Beach, Fla., at the 17th annual INMM meeting in Seattle in June.

Last April, the first issue of Volume V of the Journal was printed and mailed with the excellent help of Mr. **Bill Woolsey,** a K-State student who helps with circulation of the Journal and many miscellaneous mailings, etc., which are handled for INMM.

More timely and better prepared articles are starting to appear now that we have added Dr. **W. A. (Willy) Higinbotham** of BNL as Technical and Editorial Editor, two editorial advisors—Mr. Lovett of IAEA and **Norman S. Beyer,** formerly of ANL, now with I.A.E.A. I have become better trained in running the publication purely by the experience of the past four years. Willy is in the process of adding more editorial advisors at this writing.

There are plans to expand the number of issues of the journal in a few years, increase advertising, improve the review process, etc. **I have been told by some that the Journal is regarded more highly in the field of safeguards than it was initially.** Of course, this is encouraging to me, the executive committee, and probably should be to each member of the Institute.

A couple of years have passed since I last prepared an editorial or column for the journal. I hope to start preparing more of this kind of comment and reporting in this publication in the future.

There are several ways that you as an INMM member can boost the quality of this publication:

1) Commenting constructively about all phases of the publication—telling us what you would like to see changed, added, deleted, etc.

2) Having your institutional library order a subscription ($25 a year in U.S. and $35 per year foreign rate).

3) Encouraging potential advertisers to begin advertising in this journal. An ad rate schedule is printed elsewhere in this issue. Perhaps **YOU** are a prospective advertiser for our publications. Call me at 913/532-5837 if you have any questions.

4) Supply us with photos, news articles on promotions, work activities, research programs, honors and awards received by you and other INMM members you would like to have appear in the news section of the Journal.

5) Writing technical articles and notes which might be useful to your colleagues in safeguards and nuclear materials control. Manuscript deadline for the winter issue is October 1.

6) Being creative and devising other ways to make INMM and its publications better.

All for now until the Winter '76 issue which we hope to put in the mail on or about next January 21.

INTERVIEWS WITH SELECTED ATTENDEES AT 1976 ANNUAL MEETING

Compiled by Tom Gerdis, Editor
Nuclear Materials Management
Journal of INMM

Larry V. East represented Canberra Industries, Meriden Conn. He joined the firm after working at LASL. Larry grew up in Wichita, Kan., and studied at Wichita State and Case-Western Reserve universities.

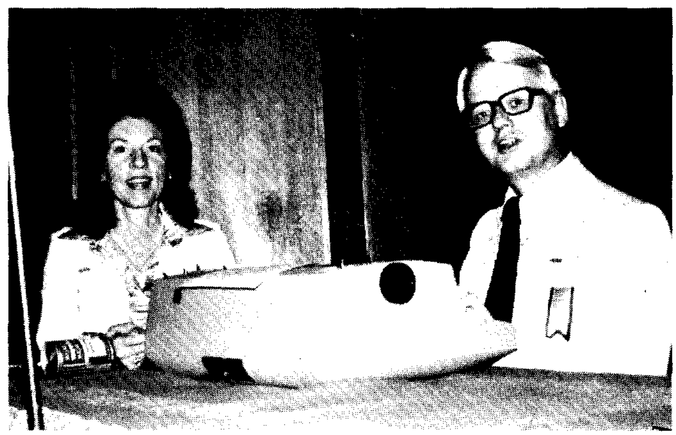
William J. (Bill) Lanouette, staff writer with **The National Observer,** Washington, D.C., came back to the INMM annual meeting for the second straight year. According to **Bob Keepin,** Technical Program Chairman for the Seattle meeting, the two principal reasons Lanouette was invited to participate in the panel again this year were 1) his candor in describing the problems and potentials of safeguarding nuclear materials, and 2) his broad background in covering nuclear affairs. Lanouette attended Fordham University and earned his Ph.D. at London School of Economics.

John F. Lemming joined Mound Laboratory of Monsanto Research Corporation, Miamisburg, Ohio, in October, 1974. He presented a paper at the Seattle meeting on his current work—automated nondestructive assay systems. He earned his Ph.D. at Ohio University, Athens, in nuclear physics.

Francis X. Haas, also with Mound Laboratory, has been there since 1962. Reared in Cincinnati, Haas earned his three degrees at Xavier, St. Louis and Cincinnati universities. His current activity deals with nondestructive measurements of plutonium isotopic ratios. Haas is a Ph.D. nuclear physicist who did his doctoral research at ORNL.

A.J. (Al) Skinner, is chief of safeguards and materials accountability for U.S. ERDA at Savannah River at Aiken, S.C. Al has attended 8 or 10 INMM annual meetings over the years. His principal duties in the broad term at Savannah River—overseeing the materials accountability and safeguards function overall at the Savannah River Plant operated by Du Pont for ERDA. Al grew up in South Georgia and went to school at the University of Georgia, Athens.

Yvonne M. Ferris of Rockwell International at Rocky Flats, Colo., felt that the opening papers at Seattle were among the best first-day papers in recent INMM meeting history. Yvonne is manager of statistics and nuclear materials control at the Rocky Flats. Her section handles statistical functions for the entire plant. In addition, the section supervises SS materials control. "We're also in charge of the new computerized paperless nuclear materials control system which will be implemented there next January," she said.



Yvonne M. Ferris of Rocky Flats was among those interviewed by the INMM publications man, Tom Gerdis of Kansas State University, Manhattan. This visit took place during the 17th annual INMM meeting June 22-24 at the Washington Plaza Hotel in Seattle, Wash.

Cecil H. Kindle is working with Atlantic Richfield Hanford Co., Richland, Wash. He is involved in developing and implementing nondestructive assay techniques for plutonium finishing plant use. He's finishing up the project on plutonium plant holdup. Kindle graduated from Princeton and grew up at Nyack, N.Y. He's been with ARHCO for about three years. He became an INMM member at the 1976 meeting.

R.J. (Dick) Brouns has been an INMM member for more than a year. He is technical leader for nuclear safeguards in the Department of Nuclear Technology at Battelle Northwest. Dick has been with Battelle for nearly 12 years and has been at the Hanford site since 1948. Prior to his employment with Battelle, he was with General Electric. Dick has been in the nuclear business almost 28 years. He gave a paper at New Orleans and another this year at Seattle. His special interests are nuclear material measurements and measurements control. Dick is a native of Minnesota and earned his Ph.D. in analytical chemistry at Iowa State University, Ames.

Robert U. (Bob) Curl of Idaho Falls became the INMM Treasurer in March succeeding **Bill Gallagher** of U.S. ERDA, San Francisco, who resigned in February. Bob was appointed to fill Bill's position by the INMM Executive Committee. Bob was in charge of registration at the annual meeting. He works for Argonne West as manager of their special materials section. Bob has been there since 1968. He attended William Jewell College, Liberty Mo.,

Shirley McCreight (left) of the Seattle Convention and Visitors Bureau helped with registration during the convention. Kitty Curl (right), wife of Robert U. (Bob) Curl, who is our new INMM Treasurer, helped Shirley and Bob with the record registration of 348 at the Seattle meeting. An even larger registration is expected at the 1977 meeting next June 28-30 in the Washington, D.C. area.

and the University of Missouri, Columbia. His wife **Kitty** helped out with registration and the ladies' program at the annual meeting in Seattle.

David E. Hause is the new manager of marketing at United Nuclear Corporation's Fuel Recovery Operation in Wood River Junction southwest of Providence, R.I. Dave succeeds **Bill Gustin** who is now senior planner with UNC's Naval Products Division in Montville, Conn. Dave is an aviation enthusiast who is the corporate pilot, who at one time was pilot for the Governor of Pennsylvania, **Milton Shapp.** He went to school at Union College, Schenectady, N.Y., and later worked with General Electric-MAO in Schenectady, sales manager of Genuine Tool Company in Irwin and plant manager of Penn State Tool & Die at Irwin, Pa., before joining UNC nearly five years ago. Before taking his current marketing job, he was in the Naval Products Division of UNC in Montville. Dave hosted the UNC hospitality suite at the INMM annual meeting.

James W. Lee of North Palm Beach, Fla., is a transportation consultant for Tri-State Motor Transit Co., Joplin, Mo. Jim has been doing an outstanding job of attracting new members to the Institute. He reported to the INMM Executive Committee that we gained 76 new members since last July 1 as compared to 65 new members for the comparable period the previous year. This was due in great part to suggestions given to Jim by many members of the Institute. We responded to 51 inquiries. Jim Lee and **Chuck Mayer** of Tri-State have been active INMM boosters over the years.

Seth G. Nelson of Safety and Supply Co., Seattle, was an exhibitor at the 17th annual meeting. Nelson, who has been with the firm, markets radiation protection apparel and temporary shielding and special enclosures used for maintenance repair work in nuclear facilities. This firm exhibited for the first time at INMM meetings in Seattle. Nelson exhibits at many health physics meetings.

Don Brown and **Ron Tschiegg** of Westinghouse Pittsburgh Nuclear Fuel Division felt the morning plenary sessions at Seattle were somewhat disappointing in that societal problems such as security forces, personnel clearances, use of deadly force and, security classifications, were not more adequately covered and discussed. We are deeply involved with technology, but these abstract features are not nearly so well covered, according to Brown.

Dick Chanda of Rocky Flats (center) chaired the INMM—9.1 standards session on Material Categorization on June 21, the Monday preceding the start of the 1976 annual meeting in Seattle.

David W. Zeff, Lynchburg, Va., who earned his master's degree in industrial administration from Purdue University, is involved in licensing and safeguards at Babcock & Wilcox Commercial nuclear fuel plant in Lynchburg. He is a member of the INMM statistics standards committee and participated in the writing of "Assessment of Domestic Safeguards for Low Enriched Uranium."

Two lovely ladies from the Northwest— Mrs. Dick (Mari Ella) Parks (left) of Seattle and Mrs. Bill (Beverly) DeMerschmann of Richland—were excellent hostesses during the annual meeting in Seattle. Dick Parks is chairman of the INMM Public Information Committee and Bill DeMerschmann was local arrangements chairman for the 1976 meeting.

Henry H. McClanahan, also of Lynchburg, joined the Institute at the Gatlinburg annual meeting in 1971. He is manager of nuclear materials control at Babcock & Wilcox. His areas of oversight include licensing, accountability, nuclear criticality safety, and the licensing end of radiation safety and security and safeguards. One other function is the coordination of the chemical uranium process.

June INMM Annual Meeting Has Record 348 Attendance

Dr. Norman C. Rasmussen, an INMM member who is chairman of the nuclear engineering at MIT, gave the Institute Paper at Seattle: "Probabilistic Risk Analysis— Its Possible Use in Safeguards Problems."

During the annual business meeting at Seattle, Lou Doher (right) of Rockwell International's Rocky Flats Plant in Golden, Colo., was honored for his outstanding standards writing work for INMM. Tom Bowie (center), chairman of the INMM awards committee who completed his term on the INMM Executive Committee this past June 30, presented a recognition plaque to Doher. John L. Jaech (left) of Exxon Nuclear Co., Inc., is chairman of the ANSI-INMM N-15 Standards Committee.

Ray Lang (right) of the U.S. ERDA Chicago Operations Office has been serving the INMM membership the past few years as chairman of the Site Selection Committee. Manny Kanter (left) of Argonne (Ill.) Center for Educational Affairs has been directing INMM educational efforts.

Bill Murphey (left) of the National Bureau of Standards frequently gives contributed papers at the INMM annual meetings. Bob Rinne of Sandia Laboratories, Livermore, Calif., actively participated in the meeting.

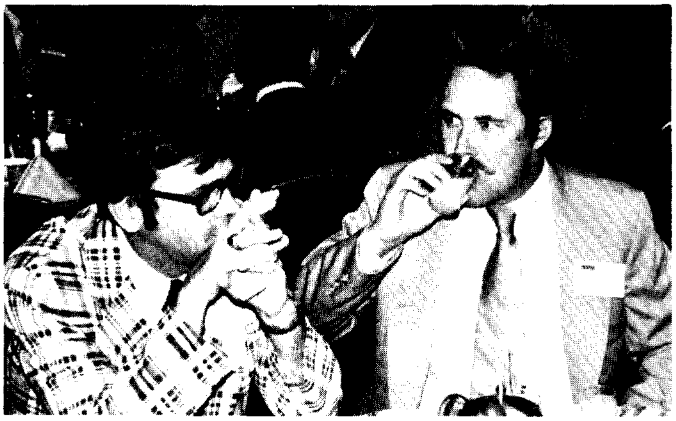
Herman Miller (left), president of National Nuclear Corp., Redwood City, Calif., was chairman of the Exhibits Committee for the Seattle meeting. He was instrumental in securing 10 exhibitors for the meeting. Miller, Steve Shepard (right) and others from NNC gave three papers at Seattle.

Dr. Bob Bearse of the University of Kansas, Lawrence, physics faculty has coordinated the transcriptions of invited papers and panel discussions for the past two annual meetings. Bearse, who has worked summers at LASL, is shown working with a Kelly girl in Seattle. Bob has done an excellent job in assisting Dr. Bob Keepin of LASL.

Al Squires, president of Westinghouse-Hanford, delivered the keynote address—"Nuclear Materials Management: A Government Perspective"—for Hon. Mike McCormack, congressman from Washington.

In apparent happy mood, Roy Cardwell of ORNL was feeling pretty good leaving the podium after his election as chairman of INMM for the coming two years. Cardwell previously served as Technical Program Chairman and Vice Chairman of the Institute.

Harvey Lyon, director of U.S. ERDA's Division of Safeguards and Security, gave an invited paper on "The Role of Material Control and Technology Development in ERDA's Safeguards Program." Photographer Dick Parks caught Lyon in between steps on this shot.



Glenn A. Hammond (left) of U.S. ERDA and a member of the Technical Program Committee for the 1976 meeting visited with Dr. William Lanouette, senior staff writer who gave an invited paper on "Safety in Numbers." Hammond is chief of the systems studies branch of the Division of Nuclear Materials Security.

Professor Ryohei Kiyose of the University of Tokyo nuclear engineering faculty visited with the INMM Executive Committee about plans to initiate an INMM chapter in Japan where there are currently seven members. Jim Lovett, past INMM chairman (1970-1972) now with IAEA, is hopeful of establishing a chapter in Europe.

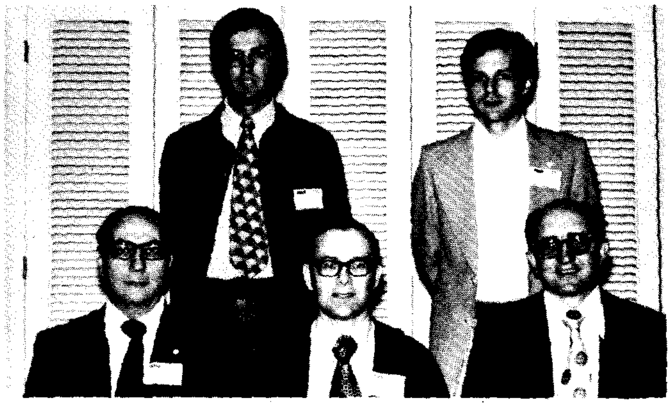
Jimmy David Gilbreath (left) and O.P. Pitts of the Tennessee Valley Authority, Chattanooga, Tenn., during one of the technical sessions . . .

Shelly Kops (left) of the U.S. ERDA Chicago Operations Office has completed his two-year term on the INMM Executive Committee. R.H. James of Aldermaston, U.K., gave a paper on "Hidden Inventory and Safety Considerations." Kops coauthored a paper with Syl Suda (BNL) on "MUF, BPID and Evolution."

Sara Molen (right) joined her husband Gary to hear Bill Lanouette's talk on numbers. Gary, manager of nuclear materials security for Allied-General Nuclear Services, Barnwell, S.C., has been elected to the Executive Committee for the next two years and will serve as Chairman of the Technical Program for the 1977 meeting in Washington, D.C. Molen was on the program committee for the Seattle meeting.

Dr. G. Robert (Bob) Keepin, nuclear safeguards program director at LASL, has masterminded the technical programs for the past two annual meetings: New Orleans in 1975 and Seattle this past June. Keepin was elected vice chairman of INMM at Seattle and will be general chairman of the 1977 and 1978 meetings. His work has done much to increase growth and impact of INMM in the nuclear community.

A.J. Waligura (left) of IAEA visited with Richard J. Schneider of Richland, Wash. Waligura presented a paper on the IAEA program for the non-destructive vertification of safeguarded nuclear material. Schneider collaborated on a paper on the technical objectives of inspection.



The above group chaired by Dennis W. Wilson (seated center) gave a paper on "Assessment of Domestic Safeguards for Low-Enriched Uranium." It was based on a larger report currently in press to be distributed this fall by INMM. Members of the writing committee: (from left) Ron Tschiegg, Westinghouse; Dennis M. Bishop, GE; David W. Zeff, Babcock & Wilcox; and Gary Molen, AGNS. Ralph Lumb was not at the Seattle meeting.

Some 348 registrants plus another 92 wives and other guests enjoyed a superb Indian salmon bake at Kiana Lodge Wednesday evening. In a beautiful Northwest setting, the staff at Kiana Lodge served INMM-ers clam chowder followed by a delicious fresh salmon dinner quickly and efficiently.

The "Goodtime" took registrants and guests at the 1976 annual meeting to the Kiana Lodge in the Garden of the Gods on the beautiful Olympic Peninsula in the heart of the evergreen playground. The Puget Sound "salmon barbecue" was every bit as good as it was advertised.


Mike Raudenbush, INMM Member

STOLLER CORP. SERVES UTILITIES

The S. M. Stoller Corporation, one of the nation's leading nuclear power consulting firms, was formed in 1969 as an out-growth of the proprietary consulting practice of S.M. Stoller Associates started in 1959. The Corporation is now a subsidiary of Arthur D. Little, Incorporated. SMSC has been deeply involved in nuclear power's transition from a developmental technology to a commercial reality. The utility clients it has served collectively represent more than half the nuclear power capacity committed to date in the U.S. The experience of several of its key personnel pre-dates the nuclear power program and goes back to the very beginnings of the national atomic energy effort.

S. M. Stoller Associates, was formed to serve the electric utility industry in the many broad phases of nuclear power programming. It was recognized at that time that the transition to nuclear power by utilities represented not only a step change in technology and an unprecedented rate of engineering innovation, but that with these changes would come new procedures, new methods of contracting for plant and fuel, new financing requirements, and new requirements in plant operations.

Most of the experience at that time had come out of the $12 billion worth of facilities constructed by the U.S. Government. Mr. Stoller, as Vice President of Engineering of Vitro Engineering Company, and his principal associates, had played a major engineering role in the design and construction of a large share of such facilities. It was felt that this practical engineering experience overlaid on a background of scientific competence, would provide the necessary adjunct support for utilities starting in the nuclear power field, and the company was thus formed in 1959 for that basic purpose. SMSC has since expanded its activities to virtually all aspects of nuclear energy.

Specifically, the organizational plan was and still is, to assist utilities, government, industry, and research groups over the entire spectrum of nuclear power involvement, including:

1. General consultation on the technical and economic status of nuclear power to assess developments and trends, and formulate policy in this field.

2. Planning a specific nuclear power project; setting the criteria; evaluating site possibilities; preparation of bid invitations; evaluation of bids; reporting the findings; and assistance during negotiations.

3. Technical assistance during the project; assessment of research and development programs; reactor design review and evaluation; plant design and performance reviews; quality assurance and quality control audits; preparation of hazards reports and license applications; and assistance in plant maintenance and operations.

SMSC has a special relationship with the Empire State Electric Energy Research Company (ESEERCO), an organization formed to plan and administer research development jointly funded by the major electric utilities in New York State. S.M. Stoller has served as the Technical Director in ESEERCO and its predecessor organization ESADA, since its formation in 1960, and SMSC provides technical services in support of ESEERCO's R&D program. This organization has spent over $30 million for R&D and has earned national recognition for pioneer work in the nuclear-electric field.

The bulk of SMSC's work has been devoted to technical, economic, and management studies in the nuclear power field.

Fuel services include:

- Technical evaluation of reactor core designs
- Fuel procurement planning, bid evaluation, and cost estimating (uranium, fabrication, enrichment, reprocessing, safeguards, waste disposal)
- Assistance in fuel contract negotiations
- Studies of Uranium Supply-Demand; Strategy studies involving uranium contracting; capability of various supplies; evaluation of properties and participation programs, etc.
- Fuel management services, including the training of utility personnel, in the use of proprietary SMSC computer codes.
- Fuel Quality Assurance (fuel design reviews and manufacturing quality control audits, etc.)
- Fuel Performance Analysis, Monitoring, Evaluation, Code Development
- Technical Support Services for Fuel Leases

In addition to services provided to individual utility clients, SMSC conducts a continuing program of technical and economic studies of developments affecting the nuclear fuel cycle, supported by annual subscriptions from major utilities. The objective of the program is to help member utilities evaluate technical, economic and industry factors affecting their nuclear fuel cycle planning activities. Building upon their technical activities in the fuel area, SMSC has carried out, on behalf of both industry and government, a variety of assignments having to do with meeting the long-term nuclear fuel needs of the U.S. including the study under EEI auspices, of industry alternatives for meeting enrichment requirements. SMSC had a major role in the 1975 EEI study of the nuclear fuel cycle and has recently performed assessments of the regulatory prognoses and probable costs of waste disposal, safeguards, and reprocessing off-gas controls.

Plant-related activities include:

- Plant procurement planning; specification and management of bid evaluation
- Assistance in plant contract negotiations
- Assistance in selection of plant Architect-Engineer
- Owner's general nuclear consultant for third party plant review
- Plant design reviews from safety, operations and maintenance viewpoint
- Licensing assistances, including providing expert witnesses testimony on a wide range of subjects
- Consultation on special siting problems
- Assistance in the preparation of environmental impact statements and in other phases of plant licensing
- Participation in Utility Safety Review Boards
- Assistance in planning and auditing plant operations and maintenance activities
- Expansion of spent fuel storage capability
- Refueling and cask handling design reviews
- Plant operations and maintenance procedures

On the economic side, SMSC has participated in a number of studies for utility top managements, including evaluation of base-load alternatives for future generation. One such study, done in 1973 for the Board of Directors of Northeast Utilities, was given broad public distribution by that utility. Similar studies completed in 1974 for LILCO and in 1975 for New England Electric have received wide circulation in the press. SMSC has also performed a number of assignments relating to integration of nuclear power plants into utility systems.

Among the Industry and Governmental organizations serviced by SMSC is the Electric Research Institute (EPRI). SMSC is currently participating in a number of EPRI programs relating to the fuel cycle.

An active program of support to the Investment Community involving Annual Nuclear Energy Conferences, reporting on the status of the nuclear industry, investment opportunities, etc. is conducted by SMSC.

In the management area, SMSC work has involved collaboration with ADL on management consulting assignments, including organizational planning and assessment.

Further questions regarding SMSC may be directed to **Mike Raudenbush,** Suite 800, Colorado Building, Boulder, CO 80302. (Phone: 303 449-7220).

Build Addition to NBL Safeguards Laboratory

The U.S. Energy Research and Development Administration (ERDA) has signed a $3.339 million construction contract for an addition to the New Brunswick Laboratory (**Carleton Bingham,** Director) located on the Argonne National Laboratory site near Chicago.

Construction of the new building, designed by architects Metz Train Olson & Youngren, will begin later this month. The contract is with the Northrop Corporation through the George A. Fuller Co. of Chicago. The firm was selected from a number of construction contractors submitting bids on the project.

The new facility will complete the move started in 1973 of ERDA's New Brunswick Laboratory from New Jersey to Argonne.

NBL is the government's principal analytical chemistry laboratory supporting the nuclear materials safeguards program. Work in the new addition involves studies with uranium and other related materials.

The Laboratory also provides analytical services on various nuclear technology materials to private industries, such as ore processors and fuel fabricators, and to other laboratories when services are unavailable elsewhere.

The uranium operation will remain in New Jersey until the spring of 1977, when construction at Argonne should be completed. About 50 employees from the New Jersey laboratory are expected to move to the Illinois site when uranium operations begin at Argonne.

In addition to the uranium laboratory, NBL has a plutonium facility which was moved to Argonne in July of this year.

Dr. Carleton D. Bingham (right), director of the New Brunswick (N.J.) Laboratory, conducted a special NDA workshop on "Traceability of Measurements" June 21, the Monday preceding the start of the 1976 annual meeting. In this issue is an article by Bingham and H. Thomas Yolken and William P. Reed of NBS, "NDA Measurements Can Be Traceable." At left is Dr. Ron Harlan of Rockwell Internal's Rocky Flats (Colo.) Plant. This photo was taken during the NDA workshop.

NBL was created in 1949 to carry on the work started by chemists at the National Bureau of Standards in Washington. The Laboratory supplied the Bureau with the first uranium samples for use as a standard reference. NBL also developed a fast, reliable method of measuring uranium.

In addition to uranium and plutonium studies, the laboratory performs various analyses on thorium, zirconium, magnesium and boron materials.

New UNESCO Catalogs Now Available from Unipub

Two newly issued catalogs of publications reflect the diverse activities of UNESCO (United Nations Educational, Scientific and Cultural Organization), a specialized agency of the United Nations.

The Unesco Press 1976 Publications List, an 80-page catalog, includes all books, periodicals, and audiovisuals in print. Among subjects covered are: education, science teaching, mass communication, earth science, oceanography, social science, art and culture, and library science. An extensive index arranges titles by subject and by series.

Scientific Maps and Atlases Catalog 1976 is of major value to earth and environmental scientists. The illustrated booklet fully describes published and projected geological, tectonic, metamorphic, mineral, climate, oceanographic, and soil maps.

Both catalogs are available free on request from Unipub, the exclusive United States distributor for all UNESCO publications. Write: UNIPUB/Box 443, Murray Hill Station/New York, NY 10016.

Adkins Named To NUSAC Position

Falls Church, Va.—Dr. **Ralph F. Lumb,** President of NUSAC, Inc., has announced the appointment of **Robert C. Adkins** as Director of Marketing. Mr. Adkins will direct the firm's marketing efforts for providing technical services and consultation related to nuclear fuels quality assurance, nuclear materials safeguards, and industrial security services.

NUSAC, Inc. also provides technical representation for nuclear fuels fabricators at USERDA owned fuels enrichment plants.

Mr. Adkins comes to NUSAC, Inc. from the management consulting firm of Adkins and Huminik, Alexandria, Va. where he has headed operations since 1966. Prior to that time he was in charge of marketing of technical services and products for Isotopes, Inc., now Teledyne-Isotopes, in Westwood, N.J.

NTIS Publication On Nuclear Reactors Now Available

In view of the relevancy and timeliness of this material on nuclear reactors, we believe it will be of interest to you.

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

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

The publication (44 pages, 8 x 10 1/2, paperback) is available as TID-8200-R33 for $4.00 from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

VS-230 desk top calculator from Victor Comptometer Corporation makes slide rules, formulas and log, trig and conversion tables obsolete for scientists and engineers. It performs 57 functions. Price is $199.50.

DESKTOP COMPTOMETER

Scientists and engineers can throw out their slide rules, formulas, and log, trig and conversion tables thanks to a new calculator from Victor Comptometer Corporation.

The scientifically-dedicated desktop model VS-230 performs 57 functions. The VS-230 automatically executes sub-problems and storage of intermediate results within two levels of parentheses. Scientific notation, with an eight-digit mantissa and two-digit exponent increases accuracy.

Degree and coordinate conversion, full trigonometric functions with degree/grad/radian format and the ability to raise values of a, e and 10 to an x power are automatic.

The VS-230 also has the standard scientific modes such as Pi, squaring and square root as well as normal arithmetic capabilities. The large display has 10 digits. The price is $199.50: Victor Comptometer Corp., 3900 North Rockwell St., Chicago, IL 60618.

Figure 1. Attendees and instructors at the LASL—U.S. ERDA NDA Training Program course on Gamma-Ray Spectroscopy for Nuclear Material Accountability (from the left): First Row: J. Tape, LASL; N. Ensslin, LASL; S. Sanatani, IAEA; B. Agu, IAEA; A.T. Gody, U.S. NRC; M. Chiles, ORNL; T. Shaub, U.S. NRC; C. Lin, IAEA; E. Clark, ORGDP; C. Smith, U.S. ERDA; R. Martin, LASL. Second Row: N. Roberts, LLL; C. Kindle, ARHCO; A. Janikowski, IAEA; D. Perricos, IAEA; T. Rosescu, IAEA; R. Hoffmann, Babcock & Wilcox; D. Holody, U.S. NRC; S. Carpenter, National Bureau of Standards; T. Crane, LASL. Third Row: J. Parker, LASL; A. Adamson, UK AEA; R. Augustson, LASL; T. Canada, LASL; R. Lux, U.S. ERDA; P. Ting, U.S. NRC; S. Baloga, U.S. ERDA; D. Sherrill, Babcock & Wilcox; J. Griggs, Goodyear Atomic Corp.; T. Metzgar, General Atomic; E. Selleck, U.S. NRC; C. Harvey, Battelle Pacific Northwest Labs.

A Report On The May 1976 LASL NDA Training Course . . .

By T.R. Canada and J.L. Parker
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

The LASL-ERDA Nondestructive Assay Training Program course on Gamma-Ray Spectroscopy for Nuclear Material Accountability was given by the Nuclear Safeguards Research Group, R-1, at Los Alamos, May 17-21, 1976.

The demand for the courses offered in this program continues to be high. In this case, enrollment was originally limited to 20 participants. However, in order to accommodate as many of the 35 applicants as possible, the enrollment was increased to 25. As shown in Fig. 1, the participants represented the full spectrum of the national and international safeguards community. This mix of ERDA, NRC, IAEA, national laboratory, and private industry personnel provided a stimulating environment for both the laboratory exercises and informal technical exhanges.

The course, which has been described in an earlier issue of this journal,[1] stresses the powerful techniques available for the NDA of SNM using high resolution gamma-ray detectors. Nine R-1 staff members, a number of whom are pictured in the accompanying photographs, were involved in various facets of the course, including lectures, demonstrations, and the instruction of small laboratory groups. In the latter case, one instructor assisted each group of four to five attendees.

In the coming year (1976-1977), the program curriculum will be expanded from two to four courses (Fig. 6), each of which will be offered once per year. This winter the courses entitled "Fundamentals of Nondestructive Assay Using Portable Instrumentation" and "In-Plant Nondestructive Assay Instrumentation" will be offered during the weeks of November 1-5 and December 6-10, 1976, respectively. The remaining two are scheduled for the spring of 1977.* This training program has proven, over the last three years, to be an effective method of transferring laboratory-developed NDA technology to the diverse safeguards community; it is believed that this expanded curriculum will help meet the growing needs of this community.

*For further information write to: U.S. ERDA Nondestructive Assay Training Program, Nuclear Safeguards Research Group, R-1, MS 540, Attn: T.R. Canada, Los Alamos Scientific Laboratory, P.O. Box 1663, Los Alamos, NM 87545.

REFERENCES

1. "The LASL-U.S. ERDA Nondestructive Assay Training Program," R.H. Augustson, T.D. Reilly, and T.R. Canada, **Nuclear Materials Management**, Vol. V, No. 1 (Spring 1976).

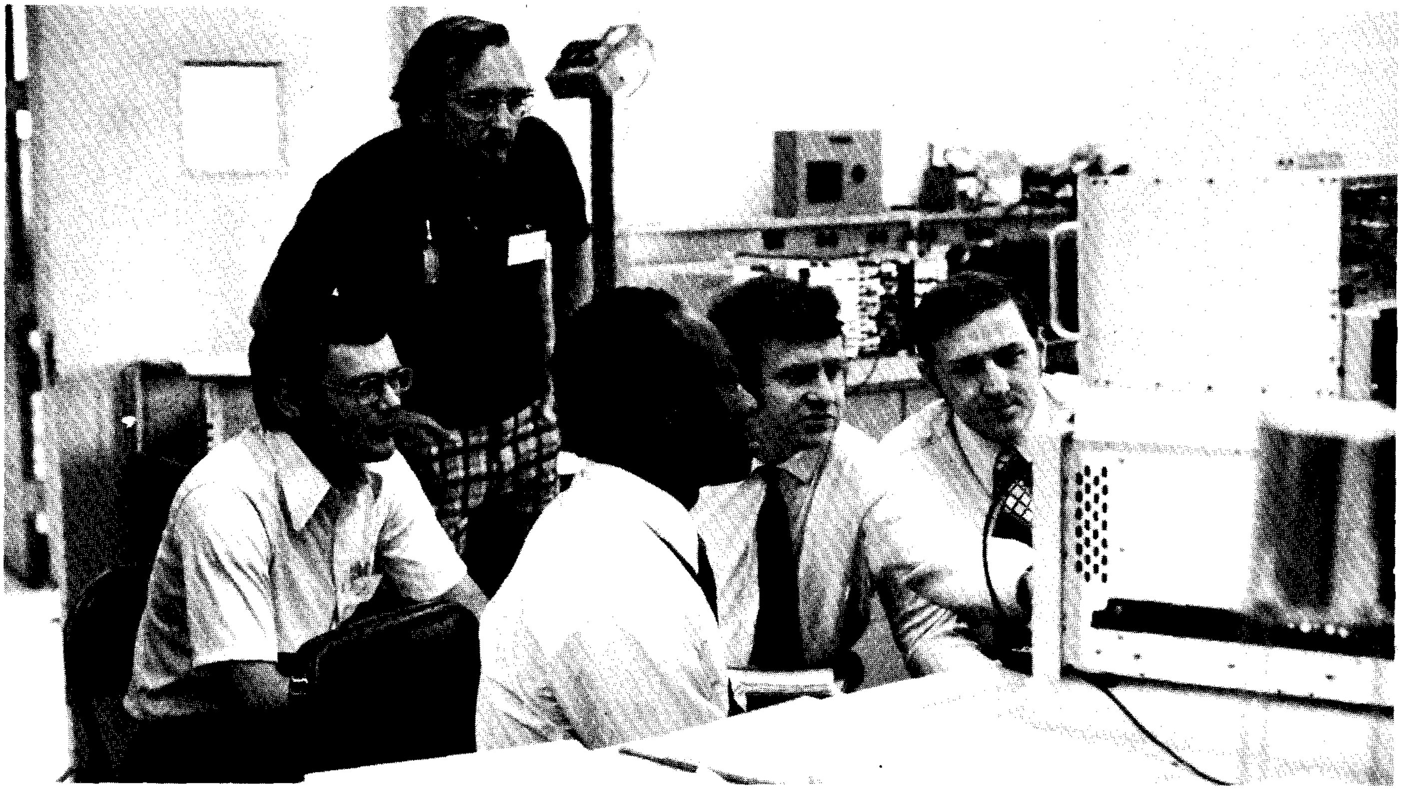


Figure 2. This intrigued group of data collectors includes (from the left): D. Sherrill (Babcock and Wilcox), R. Augustson (LASL instructor), B. Agu (IAEA), A. Adamson (UK AEA), and R. Lux (ERDA).

Figure 3. LASL instructor, Jack Parker, discusses a problem with a group of participants, two of whom, R. Hoffmann (Babcock & Wilcox) and A. Janikowski (IAEA) (facing the camera), appear unconvinced.

Figure 4. The intricacies of a computer base multi-channel analyzer are explained by N. Ensslin, LASL instructor, to a group including (from the left): C. Smith (ERDA), T. Rosescu (IAEA), and J. Griggs (Goodyear Atomic).

Figure 5. D. Perricos (IAEA) poses a problem for LASL instructor, J. Tape. Others in the group (from the left) are: N. Roberts (LLL), C. Harvey (Battelle), and P. Ting (NRC).

Figure 6. The LASL-U.S. ERDA Nondestructive Assay Training Program Curriculum

I. **Fundamentals of Nondestructive Assay Using Portable Instrumentation**
A survey of passive gamma-ray and neutron SNM assay techniques, including detector characteristics and operation procedures. Topics include enrichment measurements, corrections for sample self-attenuation of gamma rays, quantitative plutonium assay, neutron scattering, and the measurement of plutonium metal buttons, mixed-oxide fuel rods, and UF_6 cylinders.

II. **Gamma-Ray Spectroscopy for Nuclear Material Accountability**
A Study of the applications of high resolution gamma-ray spectroscopy to the nondestructive assay of uranium- and plutonium-bearing materials. Topics include: general techniques of high resolution spectroscopy, differential gamma-ray absorption, transmission correction factors, and gamma-ray densitometry. Demonstrations of automated systems are given.

III. **In-Plant Nondestructive Assay Instrumentation**
An in-depth study of the capabilities and limitations in practical plant situations of the neutron well coincidence counter, the random driver, the transmission-corrected segmented gamma-scan system, and a passive gamma-ray solution analysis system. The instruments will be available and hands-on experience will be emphasized, along with a sound understanding of the generic instrument types.

IV. **Integrated Nondestructive Assay Systems—Concepts and Implementation**
An overview of real-time dynamic materials accounting and control concepts and the techniques for their incorporation into practical safeguarded plants. Topics will include methods of defining material balance areas, process line modeling and simulation for the purposes of performance evaluation, possible impacts on process operations and a brief survey of available NDA instrumentation. Examples of the implementation of an integrated safeguards system including computer/information subsystem will be drawn from the DYMAC project.

MORE ANNUAL MEETING PHOTOGRAPHS

Clemens Auerbach (left) and Syl Suda of Brookhaven National Laboratory relaxing in between sessions . . .

John F. Mahy Jr. of the U.S. Department of State Mission to IAEA . . .

The Homer M. Fausts of Battelle Memorial Institute, Columbus, Ohio

Paul DeBievre (left) of EEC, Geel, Belgium with Harvey Lyon, director of the Division of Safeguards and Security, U.S. ERDA . . .

NONDESTRUCTIVE ASSAY MEASUREMENTS CAN BE TRACEABLE

Carleton D. Bingham
U.S. Energy Research and Development Administration
New Brunswick Laboratory

H. Thomas Yolken
William P. Reed
U.S. National Bureau of Standards

ABSTRACT

The use of nondestructive assay (NDA) techniques for the analysis of Special Nuclear Materials is one of the keystones in the development of safeguards technology. Currently this effort to use NDA is being frustrated because of a lack of "demonstratable traceability." Presented here is a discussion of what traceability means and how it can be achieved. Specifically, traceability means far more than having a series of calibration standards for each individual NDA technique. It means defining the limits of uncertainty for both random and systematic error components of a set of measurements (i.e. precision and accuracy). Realizing this, an approach to these evaluations is suggested. In addition, the authors emphasize that the availability of standards is not holding back the use of NDA.

The use of NDA is actually limited by the poor accuracy (possible systematic error) of many methods and the availability of real calibration standards would only tend to accentuate this point.

Finally, the suggestion is made that calibration standards will only be available when the demonstrated need is limited to a finite number of sets.

Introduction

The development and application of nondestructive assay (NDA) to quantitative assays of Special Nuclear Material (SNM) can provide rapid determination of material balances to detect losses or unauthorized removal of SNM. In addition, NDA techniques can provide qualitative and quantitative measurement of material which is not otherwise measurable (at least without great difficulty), such as process and equipment holdup, can assure that the material in a container and its enrichment are as stated without time consuming and hazardous sampling or analysis, and can provide a means of control and measurement when chemical analysis would destroy a valuable finished product.

The potential of nondestructive assay (NDA) as a technique for the measurement of nuclear materials has been recognized for many years.[1] This emerging technology has rapidly progressed from that of making qualitative comparisons toward that of making quantitative measurements. It has been held that if accuracy and precision of NDA could approach that of destructive chemical analysis, then NDA could economically provide more timely data. This potential has been a primary stimulus in NDA developmental and application projects in this country and around the world.[2] However, the required levels of accuracy have not yet been achieved except for isolated cases.

In research directed toward realizing the potential of NDA, active and passive techniques for measuring different categories of material in the fuel cycle have been investigated. Containers constructed of varying materials and exhibiting varying dimensions have been used to hold subgram to kilogram quantities of SNM. Unfortunately, a consistent pattern of observations has emerged from these investigations, viz, for a given NDA measurement method, the response observed for a given container of SNM is strongly dependent upon the other materials in the container and the container-detector system interaction. For simplicity, call the former a **matrix effect** and the latter a **geometry effect.** (A corollary to this pattern also exists, namely, for a given container of SNM, the observed response varies according to the NDA system employed).

In recognition of the limitations of NDA due to the geometry effects, standards writing groups are currently developing standards of SNM container material and container dimensions. In addition, in recognition of the limitations imposed by the matrix effect, investigative teams are seeking to devise correction factors and/or interrogation systems which would render the observations "matrix independent." If successful, these efforts will remove major sources of systematic error. These improvements would allow a finite number of meaningful calibration materials (standards) to be prepared and allow a more valid comparison to be made of laboratory performance. As is frequently the case, however, Mother Nature has not been cooperative and no truly matrix independent technique has yet been discovered.

Nevertheless, stimulated by economic attractiveness, timeliness of results and **precision** of NDA measurements, (i.e., reproducibility), SNM fabricators and processors have begun to use NDA in process control, material accountability and safeguards measurements. These users of NDA have incurred a "burden of proof" as stated in a recent paper by Bishop.[3] Bishop defines the need to achieve measurement traceability as a cardinal prerequisite for the user to satisfy current safeguards measurement control regulations. His paper also discusses deficiencies in current development programs which limit the use of NDA. His underlying theme, however, is the inability of users of NDA to demonstrate traceability to the national measurement system. The purpose of this paper is, first of all, to discuss the implied meaning of "traceability" when used in conjunction with a measurement system and then to suggest the various mechanisms available to achieve this goal.

When most people use the word traceability, it is used in conjunction with a regulatory, contractual or other legal requirement. Although not always the case, the word traceability should mean the demonstration or confirmation of the correctness of the results of a set of measurements within a stated uncertainty relative to a nationally accepted system. An example of this useage is the recent Nuclear Regulatory Commission statement[4]:

> 70.57 (a) (4) "Traceability" means the ability to relate **individual measurement results** to national standards or nationally accepted measurement systems . . . (emphasis added).

Thus even having established the uncertainty relative to an accepted system, there still remains the question of the adequacy of the measurement relative to its intended use. Thus one's measurements could be "traceable" (uncertainty is known) but not traceable "enough" (uncertainty is too large for the purpose).

With the above understanding of the word traceability, it is now appropriate to ask how this "traceability" can be demonstrated for purposes of NDA measurement. There is nothing mysterious about the basic concept of measuring SNM, however difficult it may be in practice. In fact, one should say that the technology for demonstrating traceability does exist (that is, the ability to assess the uncertainty of a specific method). This road to traceability may not be smooth or easily negotiated, but developers of NDA techniques, users, as well as the national standards laboratories, cooperatively have a job to do in traveling this road. On a positive note, cooperation is already taking place through voluntary standardization programs (e.g., ANSI, ASTM, etc.) on container geometry and composition, packaging and sorting methods, categories of materials, etc. However, materials and processes as well as finished products differ within both the public and private sectors. The state of the NDA measurement "art" is such that not all products, scrap, and waste are amenable to any one NDA measurement system. Because of these complexities no single set, nor even a reasonably finite set, of calibration materials (standards) can be conceived as meeting the wide variety of current NDA technology needs. Consequently, the monitoring of a measurement process to establish that it is behaving in a state of statistical control and for determining bounds to the possible offset of the process from the national system become the responsibility of the user.

In NDA measurements the random uncertainty in a given measurement result may be determined by a replicate series of measurements utilizing the same sample and the same measurement system. This determination can, of course, be done quite easily by the user. It should be emphasized that the random error associated with a measurement is the result of the total measurement system being employed by the user. This could include random operator error, geometry effects from repositioning of the sample in the instrument, counting statistics, and variations in sample size and concentration. In addition, different measurement systems utilizing the same measurement principles (e.g., gamma spectrometry) may have differing amounts of random error associated with their measurement results.

The determination of a bound to the systematic error or offset of the measurement process relative to the national system is a much more difficult task than the determination of the random error. The systematic error associated with an NDA measurement result is composed of two major components as discussed by Shea.[5] The two components are errors due to calibration and errors due to variability of matrix, isotopic composition, spacial distribution of SNM, etc., between sample sets. For an excellent example of measurement process control and a good discussion of the philosophy leading to measurement assurance one should read the ANSI standard on mass measurements.[6]

Verification and certification of NDA calibration materials can result in an improved determination of the systematic errors arising from both calibration and sample-to-sample variation. The maximum expected systematic error as a result of sample-to-sample variation could be determined from a "worst case" experiment by the user utilizing his calibration materials along with **his** "worst case" samples. These samples would need to be, in effect, another set of calibration materials that were characterized, independently of the calibration materials used in the experiment.

Unfortunately, the uncertainty due to sample-to-sample variability and the resulting unknown mismatch between calibration materials and unknown samples can be quite large. In fact, for waste and scrap it is usually the largest source of systematic error. It should be emphasized that determining the uncertainty of the measurement results relative to nationally accepted standards will not improve the quality of the measurement results in this case. The "worst case" systematic error will be known but not reduced. This knowledge should be quite useful, however, in pursuing improved methodology. This point is demonstrated by a recently completed interlaboratory evaluation of the measurement of HTGR fuel material.[7] Two laboratories performed NDA measurements on samples containing mixtures of high-purity UO_2 and ThO_2 and on BISO and TRISO fuel particles. In spite of the advantage of having identical sample vials and high purity reagents (UO_2 and ThO_2) from which to prepare calibration standards, NDA measurements on the oxide mixtures exhibited definite and statistically significant biases relative to the prepared and chemically verified values. Statistically significant differences, of the opposite sign, were likewise observed in the comparison of results obtained by NDA and destructive chemical analysis of BISO and TRISO fuel particles. In a precious, related program,[8] the choice of the two materials (glass or polyethylene) available for sample containers was such that either material was incompatible with the measurement system of at least one site participating in the NDA comparison. These are isolated and not universally applicable examples, but they serve to identify the limitations in the **concept** of centrally prepared and supplied standards and also the concept of standards comparison to demonstrate traceability. This is not to say, however, that **some** standards cannot be prepared and distributed and the observed results evaluated. Indeed this may even suggest an approach to standardization and the determination of the uncertainty of measurement.

The U.S. NRC Regulatory Guide 5.53 recognizes and endorses calibration of an NDA system by independent verification of uncertainty as described in ANSI N15.20-1975. ANSI N15.20-1975 defines a calibration standard "as an item physically and chemically similar to the items to be assayed, for which the mass of the nuclide(s) of interest and **all properties to which the measurement technique is sensitive are known**" (emphasis by authors). This same document specifies requirements for fabricating calibration standards and emphasizes that any calibration based upon a given set of calibration standards is valid only for the assay of unknown items having the same properties as those standards. It states "Knowledge of the mass of the nuclide(s) of interest contained in calibration standards is insufficient to ensure meaningful assay of unknown material. The standards must also represent the unknown items in all other properties which can affect the measured response." The user is more likely to know what variables will be introduced by his process, materials, etc. Therefore, the user is in the best position to define the required composition of calibration standards for his system.

Following the recommendations of ANSI N15.20-1975, a prospective user of NDA, knowing his measurements needs relative to his categories of materials, assesses the range of the variables which his measurement system is likely to encounter. He then prepares a set (or sets) of calibration samples by adding materials of known composition to meet his measurement requirements. As indicated in ANSI N15.20-1975, knowledge of the quantity of SNM is, in itself, not enough; the other factors contributing to the response of an instrument system have to be specified. (Up to this point the tasks described by Bishop and those assumed in this paper are in agreement.) The task of synthesizing calibration materials, albeit not simple, can be performed in a manner which is traceable to a national measurement system. The mass and composition of SNM added to a container for the preparation of the calibration materials can be determined with an uncertainty less than 0.1% by destructive chemical and isotopic measurements relative to uranium or plutonium assay and isotopic standards from NBS. Similarly, the mass and composition of the matrix can be traced, though not to the same level of uncertainty. No "cook book" exists for determining the uncertainty of each and every measurement; however, there is long standing practice in scientific research of assessing the uncertainty of one's measurements by comparing them to a "standard." The choice of a detailed procedure for accomplishing this comparison should be the user's, based on his experience and particular application. This is the same direction as taken in the recently completed NRC draft Regulatory Guide for plutonium nitrate calibration materials. The scientist must be capable of defending his choice of measurement method and establishing the uncertainty of his results (whether it be in NDA or classical chemistry). The verification and certification by an outside source, within the constraints of the present state of technology, can only be accomplished, in most cases, by destructive chemical and isotopic analysis. It must be remembered that most passive and active NDA measurements in common use require a knowledge of the isotopic composition of the SNM.

High resolution gamma-ray assay can give the SNM content without prior isotopic knowledge. K- and L-edge gamma-densitometry uniquely give the uranium, thorium and/or plutonium elemental concentration in solutions. A multi-energy interrogation system, such as MECAS, can give the ^{235}U, ^{238}U and total uranium content for pellets, powders, etc.[9] High resolution gamma-ray spectrometry and calorimetry can be used for plutonium assay. One overpowering reason for the omission of independent verification of NDA physical calibration standards is not the lack of measurement technology, but rather costs associated with a destructive verification and certification of the SNM content of calibration standards. Future work in this area should be aimed at identifying a limited number of NDA calibration materials that would find wide-spread use.

The following example illustrates an approach that can and is being used to fabricate or synthesize a series of standards (stacks of pellets, fuel pins, cans of product or input oxide powder, material distributed and diluted in waste drums, etc.). If, within a given set of these standards, it has been demonstrated that similarity of materials has been maintained, the constituents of each set can be repetitively measured by NDA to a high degree of statistical precision. The observed responses can be related to the quantity of material loaded into each standard by the usual least squares approaches. Certain selected items of the set now can be destructively analyzed using weights, volumes, temperatures, and chemical or electrochemical measurements that are based on NBS standards. This is the approach many facilities use today and they accept the cost of destructively analyzing a portion of that which has been created, at no insignificant cost, as part of doing business. Whether the fabrication and analysis of the quantity of material loaded into each standard and the destructive chemical analysis are performed by the user laboratory, a different laboratory in the same company, a commercial testing laboratory or by a government certifying laboratory, the same procedures can be used to determine uncertainty relative to national standards.

The concept of a National Nuclear Materials Measurement Assurance (NNMMA) Program has been proposed by NBS with endorsement by NRC, ERDA and the Atomic Industrial Forum. This program would not only help identify existing gaps in measurement technology which limit the ability to assure the quality of measurements, but would also propose actions to supply the necessary data, calibration materials, statistical sampling plans, and reference methods to fill those gaps. This is an integrated program which will look at all of the measurement requirements in the fuel cycle, (chemical, physical and NDA) and identify a priority of effort based on Safeguards needs.

As most of the audience is aware, the application of NDA for the Safeguards needs of various portions of the fuel cycle is being developed at LASL, LLL and Mound Laboratory under contract to ERDA. Widening the scope of application and reducing the inherent limitations to the application of the NDA system are included among the goals of ERDA's development efforts. The numerous measurement methods and instruments available to a user to measure a quantity of material in a given category reflect attempts by the developers of NDA to overcome the limitations to accuracy imposed by matrix and/or geometry effects. The design/performance criteria for many of these systems have been defined by LASL and instruments are now commercially available based on these criteria.

Efforts at NBL have been involved in applying technology developed elsewhere to a broad spectrum of matrix materials. These efforts using gamma-ray spectrometry for small samples (about 20 g) of widely varying atomic number and density by very carefully controlled geometry have produced measurements which agree to within 1% of values determined by destructive chemical analysis.

In summary, most users of NDA now feel that their needs have not been met and that answers to their problems have not been provided. However some reflection on the existing problems on all sides may lead us to some reasonable conclusions.

The first conclusion to be reached is that in well defined systems where causes of bias can be discovered and eliminated or brought under control, uncertainty of measurement results can be ascertained by preparation of in-house standards using chemical techniques and material references either directly to NBS Standard Reference materials or to NBL certified calibration materials.

The second conclusion is in the area of scrap and waste analysis. In-house standards can also be prepared for scrap and waste which are related to NBS-NBL certified materials. Current results indicate dissatisfaction with this approach because of lack of appropriate matrix, difficulties in fabrication and analysis, and resulting large measurement errors. However we believe that these measurement errors are actually reflections of the inaccuracies or bias of the methodology and that the situation will improve until method development removes or controls current causes of bias. These currently uncontrolled biases must be considered as part of the uncertainty of the measurement process even though the internal consistency of the "data" might be incorrectly viewed as indication that the measurements are far better.

Finally if there was reasonable agreement within the NDA community for a limited set (perhaps a half dozen) of calibration material to be prepared applicable to the most accurate NDA techniques and the most commonly measured materials, the fabrication and evaluation could be accomplished in a reasonable time scale (about 1-2 years). This modest beginning could be an important first step.

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Dale Moul Joins NUSAC, Inc.

Dr. **Ralph F. Lumb,** President of NUSAC, Inc., Falls Church, Virginia, announced today that **Dale A. Moul** has joined the company as a Senior Technical Associate with the Security Programs Division.

Mr. Moul comes to NUSAC from the U.S. Army where he served as Physical Security Officer and Budget Officer for the Office of Provost Marshal, Ft. Meade, Maryland. Mr. Moul holds a B.S. in Police Administration (Magna Cum Laude), Michigan State University.

NUSAC's Security Programs Division provides consulting services to the nuclear power generation industry. Services include all facets of security program development from design through operational stages.

NUSAC also provides consulting services in nuclear fuel quality assurance and accountability, nuclear materials licensing and safeguards, and confirmation of uranium hexafluoride delivered to nuclear fuel fabricators.

ON THE VARIANCE OF A PRODUCT WITH APPLICATION TO URANIUM ESTIMATION*

by

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1. Introduction

Currently there are two methods used for estimating the amount of uranium in a container. One of these methods estimates the amount of uranium directly by certain N.D.A. techniques. The second method is to obtain estimates of both the weight of material in the container and the concentration of uranium in this material. These estimates of weight and concentration are then used to estimate the amount of uranium in the container. Regardless of the method used, uncertainties of estimates of the amount of uranium should be carefully studied.

It is important to carefully examine the statistical properties of estimating the amount of uranium by multiplying the estimates of weight and concentration. We will assume the estimates of weight and concentration are unbiased so that our main interest will be to estimate the variance of the product. The variance of the product is important to determine the accuracy of the estimate of the amount of uranium and could, for example, be used to find LEMUF. The purpose of this paper is to examine the properties of estimates of the variance of the product of two random variables.

The variance of a product has already been examined in this context by Post [2]. We will give a more general consideration of the same problem and give a new comparison of his three estimators. During our study we will add a set of assumptions that are valid for application to nuclear material estimation. These assumptions are very useful for this work.

2. Estimation of the Variance of a Product

Consider $Z=UV$ where U and V are arbitrary independent random variables with finite means and variances. It follows that

$$E(Z) = E(U)E(V) = \mu_U \mu_V \quad (1)$$

and

$$\begin{aligned} Var(Z) &= E^2(U)\ Var(V) + \\ &\quad + E^2(V)\ Var(U) + \\ &\quad + Var(U)\ Var(V) \\ &= \mu_U^2\sigma_V^2 + \mu_V^2\sigma_U^2 + \sigma_U^2\sigma_V^2 \end{aligned} \quad (2)$$

where, in general, μ_W denotes the mean of W and $\sigma_W^2 = Var(W)$ denotes the variance of W. The equation for Var(Z) can be found in [1, p. 180].

In our application $U=\overline{X}$ and $V=\overline{Y}$ where X_i, $1 \le i \le N_1$, estimates the total weight of U_3O_8, Y_j, $1 \le j \le M_1$, estimates the concentration of uranium, and $\overline{X},\overline{Y}$ denote the arithmetic means. Also assume that sample variance estimates s_x^2 of σ_x^2 and s_y^2 of σ_y^2 have been computed from samples of size N_2 and M_2, respectively. Not only do we wish to allow the possibility that $N_2 \neq N_1$ and $M_2 \neq M_1$ but also the possibility that $\overline{X}$, s_x^2, $\overline{Y}$, s_y^2 are all computed from distinct samples. For the present discussion assume only that each X sample is independent of each Y sample. Our interest is in estimating the product $\mu_x\mu_y$. A reasonable estimator of this quantity is $\overline{X}\,\overline{Y}$ since this estimator is unbiased and the variance of the estimator can be seen to approach 0 as N_1 and M_1 become large. For more restrictive assumptions, estimators other than $\overline{X}\,\overline{Y}$ might be preferable. The estimator $\overline{X}\,\overline{Y}$, however, has the desirable properties noted above for the minimal assumptions made here.

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

For $U=\overline{X}$ and $V=\overline{Y}$, (1) and (2) become

$$E(Z) = E(\overline{X})E(\overline{Y}) = \mu_X\mu_Y \qquad (3)$$

and

$$\begin{aligned} Var(Z) &= E(\overline{X})Var(\overline{Y}) + E^2(\overline{Y})Var(\overline{X}) + \\ &+ Var(\overline{X})Var(\overline{Y}) \qquad (4) \\ &= \mu_X^2 \frac{\sigma_Y^2}{M_1} + \mu_Y^2 \frac{\sigma_X^2}{N_1} + \frac{\sigma_X^2\sigma_Y^2}{N_1M_1} \end{aligned}$$

As noted above Var(Z) gives valuable information about our unbiased estimator Z. Unfortunately Var(Z) is a function of μ_x, μ_y, σ_x^2 and σ_y^2, all of which are unknown. Consequently Var(Z) must be estimated. Post [2] considers three estimators of Var(Z); here we consider a model which generalizes Post's estimators. Our model consists of estimators of the form

$$T_\alpha = \overline{X}^2 \frac{s_Y^2}{M_1} + \overline{Y}^2 \frac{s_X^2}{N_1} + \alpha \frac{s_X^2 s_Y^2}{N_1M_1} \qquad (5)$$

where α is any real number.
Post's three estimators correspond to $\alpha=-1,0,1$.

3. Mean Squared Error Comparison of the Estimators

Suppose θ is a parameter to be estimated and $\hat{\theta}$ is an estimator of θ. Then the *mean-squared error* of $\hat{\theta}$ is defined as

$$MSE(\hat{\theta}) = E((\hat{\theta}-\theta)^2).$$

This standard definition [1, p. 291] is used to distinguish between estimators. Of a class of estimators, the one with minimum mean-squared error is said to be *best*. This is a reasonable definition since the best estimator has the smallest average squared distance from θ. Notice that it is not necessary to calculate values of mean-squared error but only to compare the mean-squared error of estimators of interest. We now proceed to examine mean-squared error properties of T_α.

First consider

$$\begin{aligned} E(T_\alpha) &= E\left(\overline{X}^2 \frac{s_Y^2}{M_1}\right) + E\left(\overline{Y}^2 \frac{s_X^2}{N_1}\right) + \\ &+ \alpha E\left(\frac{s_X^2 s_Y^2}{N_1M_1}\right) \\ &= E(\overline{X}^2)E\left(\frac{s_Y^2}{M_1}\right) + \\ &+ E(\overline{Y}^2)E\left(\frac{s_X^2}{N_1}\right) + \\ &+ \alpha E\left(\frac{s_X^2}{N_1}\right) E\left(\frac{s_Y^2}{M_1}\right) \\ &= \left(\frac{\sigma_X^2}{N_1} + \mu_X^2\right)\frac{\sigma_Y^2}{M_1} + \\ &+ \left(\frac{\sigma_Y^2}{M_1} + \mu_Y^2\right)\frac{\sigma_X^2}{N_1} + \\ &+ \alpha \frac{\sigma_X^2\sigma_Y^2}{N_1M_1} \\ &= \mu_X^2 \frac{\sigma_Y^2}{M_1} + \mu_Y^2 \frac{\sigma_X^2}{N_1} + \\ &+ (\alpha+2) \frac{\sigma_X^2\sigma_Y^2}{N_1M_1} \end{aligned} \qquad (6)$$

Comparison of (6) with (4) shows that T_α is unbiased, or $E(T_\alpha)=Var\ Z$, if and only if $\alpha=-1$. It is useful to define the bias of T_α, β_α, by

$$\begin{aligned} \beta_\alpha &= E(T_\alpha) - Var(Z) \\ &= (\alpha+1) \frac{\sigma_X^2\sigma_Y^2}{N_1M_1} \end{aligned}$$

From [1, p. 293] we know

$$MSE\ (T_\alpha) = Var(T_\alpha) + \beta_\alpha^2.$$

Therefore to compute $MSE(T_\alpha)$, we need to find

$$Var(T_\alpha) = E(T_\alpha^2) - (E(T_\alpha))^2 . \qquad (7)$$

From (7) it is clear that our task is to find

$$E(T_\alpha^2) = E\left[\left(\bar{X}^2 \frac{s_Y^2}{M_1} + \bar{Y}^2 \frac{s_X^2}{N_1} + \alpha \frac{s_X^2 s_Y^2}{N_1 M_1}\right)^2\right]$$

$$= E\left(\bar{X}^4 \frac{s_Y^4}{M_1^2} + \bar{Y}^4 \frac{s_X^4}{N_1^2} + \alpha^2 \frac{s_X^4 s_Y^4}{N_1^2 M_1^2} + \right. \quad (8)$$

$$\left. + 2\frac{\bar{X}^2 s_Y^2 \bar{Y}^2 s_X^2}{M_1 N_1} + 2\frac{\alpha\ \bar{X}^2 s_Y^4 s_X^2}{N_1 M_1^2} + 2\frac{\alpha \bar{Y}^2 s_X^4 s_Y^2}{M_1 N_1^2}\right)$$

One difficulty with (8) is those terms, say, where $\bar{X}$ and s_x^2 occur as products. In the nuclear industry the variance of a measuring device is often estimated with a standard and hence the X sample and the s_x^2 sample can be assumed independent. This same assumption will be made for both the X and Y samples for the remainder of this paper. Thus each term of the last expression for $E(T_\alpha^2)$ is a product of computable terms if it is assumed that the fourth moments of each distribution exist. Therefore, in principle at least, the mean-squared error can be calculated.

By use of a program, MACSYMA, available at The Massachusetts Institute of Technology, (8) was expanded and the mean-squared error found. The symbol $\mu_{X:k}$, say, denotes the k[th] central moment of X.

$$\begin{aligned}
MSE(T_\alpha) = {} & (M_1 N_1 (\alpha^2 ((N_2-1)\mu_{X;4} + \\
& + (N_2^2-2N_2+3)\sigma_X^4)((M_2-1)\mu_{Y;4} + (M_2^2-2M_2+3)\sigma_Y^4) \\
& + 2\alpha N_2(N_2-1)\sigma_X^2(N_1\mu_X^2 + \sigma_X^2)((M_2-1)\mu_{Y;4} + \\
& + (M_2^2-2M_2+3)\sigma_Y^4) + 2\alpha M\ (M_2-1)((N_2-1)\mu_{X;4} + \\
& + (N_2^2-2N_2+3)\sigma_X^4)\sigma_Y^2(M_1\mu_Y^2 + \sigma_Y^2) + \\
& + 2M_2(M_2-1)N_2(N_2-1)\sigma_X^2(N_1\mu_X^2 + \sigma_X^2)\sigma_Y^2 \qquad (9) \\
& (M_1\mu_Y^2 + \sigma_Y^2)) + M_1N_2(N_2-1)(\mu_{X;4} + 4N_1\mu_X\mu_{X;3} + \\
& + N_1^3\mu_X^4 + 6N_1^2\sigma_X^2\mu_X^2 + (3N_1-3)\sigma_X^4) \\
& ((M_2-1)\mu_{Y;4} + (M_2^2-2M_2+3)\sigma_Y^4) + \\
& + M_2(M_2-1)N_1((N_2-1)\mu_{X;4} + (N_2^2-2N_2+3)\sigma_X^4) \\
& (\mu_{Y;4} + 4M_1\mu_Y\mu_{Y;3} + M_1^3\mu_Y^4 + 6M_1^2\sigma_Y^2\mu_Y^2 + \\
& + (3M_1-3)\sigma_Y^4))/(M_1^3M_2(M_2-1)N_1^3N_2(N_2-1)) -
\end{aligned}$$

$$- \Big(M_1^2 \sigma_X^4 \mu_Y^4 + 2M_1 N_1 \sigma_X^2 \mu_X^2 \sigma_Y^2 \mu_Y^2 +$$

$$+ 2\alpha M_1 \sigma_X^4 \sigma_Y^2 \mu_Y^2 + 4M_1 \sigma_X^4 \sigma_Y^2 \mu_Y^2 + N_1^2 \mu_X^4 \sigma_Y^4 +$$

$$+ 2\alpha N_1 \sigma_x^2 \mu_x^2 \sigma_y^4 + 4N_1 \sigma_X^2 \mu_X^2 \sigma_Y^4 + \qquad \text{[Eq. (9) cont.]}$$

$$+ \alpha^2 \sigma_X^4 \sigma_Y^4 + 4\alpha \sigma_X^4 \sigma_Y^4 +$$

$$+ 4\sigma_X^4 \sigma_Y^4 \Big) \Big/ N_1^2 M_1^2 + (\alpha+1)^2 \frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} .$$

It is obvious that finding the best mean-squared error directly from (9) is a nontrivial task. Another approach has been taken in which the influence of α can be determined in a less direct fashion.

$$\begin{aligned} MSE(T_\alpha) &= Var(T_\alpha) + \beta_\alpha^2 \\ &= Var(T_\alpha) + (\alpha+1)^2 \frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} . \end{aligned}$$

Let

$$\begin{aligned} T_\alpha &= \frac{\bar{X}^2 s_Y^2}{M_1} + \frac{\bar{Y}^2 s_X^2}{N_1} + \alpha \frac{s_X^2 s_Y^2}{(N_1)(M_1)} \\ &= U + V + \alpha W \end{aligned}$$

so that [1, p.178]

$$\begin{aligned} Var(T_\alpha) &= Var(U) + Var(V) + \alpha^2 Var(W) + \\ &\quad + 2\ Cov(U,V) + 2\alpha Cov(U,W) \\ &\quad + 2\alpha Cov(V,W) . \end{aligned}$$

Therefore

$$\begin{aligned} MSE(T_\alpha) &= (\alpha+1)^2 \frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + \alpha^2\ Var(W) + \\ &\quad + 2\alpha Cov(U,V) + 2\alpha Cov(V,W) \qquad (10) \\ &\quad + Var(U) + VAR(V) + 2\alpha Cov(U,W) \end{aligned}$$

Now consider that part of (10) which depends on α and call this quantity $f(\alpha)$. Clearly $f(\alpha)$ is the sum of terms which will determine the smallest $MSE(T_\alpha)$. We have

$$\begin{aligned} f(\alpha) &= \alpha(\alpha+2) \frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + \alpha^2\ Var(W) + \qquad (11) \\ &\quad + 2\alpha Cov(U,W) + 2\alpha Cov(V,W) . \end{aligned}$$

Now, taking the derivative of f,

$$\begin{aligned} f'(\alpha) &= 2\alpha \left(\frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + Var(W) \right) \\ &\quad + 2 \left(\frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + Cov(U,W) + Cov(V,W) \right) \end{aligned}$$

and also

$$f''(\alpha) = 2 \left(\frac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + Var\ W \right) > 0$$

This shows that

$$\alpha_o = - \frac{\dfrac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + Cov(U,W) + Cov(V,W)}{\dfrac{\sigma_X^4 \sigma_Y^4}{N_1^2 M_1^2} + Var(W)} \qquad (12)$$

is the best α. That is, for all α,

$$MSE(T_{\alpha_o}) \le MSE(T_\alpha) \quad . \qquad (13)$$

Of course (13) does not solve the problem of which α to use in practice since α_o depends on all the unknown parameters. We can, however, perform a comparison of Post's estimators: $\alpha=-1,0,1$. Since $\alpha_o<0$ and $MSE(T_\alpha)$ behaves like a quadratic in α, we have

$$MSE(T_o)<MSE(T_1)$$

and

$$MSE(T_{-1})<MSE(T_1).$$

It remains only to compare T_o and t_{-1}. Now $f(0)=0$, $f(2\alpha_o)=0$, and $f(\alpha_o)<0$. Therefore

$$MSE(T_{-1})\le MSE(T_o)$$

if and only if

$$2\alpha_o\le -1$$

or

$$0 \le \frac{\sigma_X^4\sigma_Y^4}{N_1^2M_1^2} + 2\ Cov(U,W) + 2\ Cov(V,W) - Var(W) \quad . \qquad (14)$$

We remark here that if A,B,C,D,E,F are independent random variables, then

$$Cov(AB,BC) = \sigma_B^2\mu_A\mu_C$$

and

$$Var(EF) = \sigma_E^2\sigma_F^2 + \mu_E^2\sigma_F^2 + \mu_F^2\sigma_E^2 \quad .$$

Using these relations and the definitions of U, V, and W we have

$$Cov(U,W) = \frac{Var(S_Y^2)}{M_1^2}\ \frac{\sigma_X^2}{N_1}\left(\mu_X^2 + \frac{\sigma_X^2}{N_1}\right) ,$$

$$Cov(V,W) = \frac{Var(S_X^2)}{N_1^2}\ \frac{\sigma_Y^2}{M_1}\left(\mu_Y^2 + \frac{\sigma_Y^2}{M_1}\right) ,$$

and

$$Var(W) = (N_1M_1)^{-2}\left[Var(S_Y^2)Var(S_X^2) + \sigma_X^4\ Var(S_Y^2) + \sigma_Y^4\ Var(S_X^2)\right]$$

Substituting these values, (14) becomes

$$0 \le (N_1M_1)^{-2}\left[\sigma_X^4Var(S_Y^2) + \sigma_Y^4Var(S_X^2) + 2N_1\ \sigma_X^2\mu_X^2Var(S_Y^2) + \sigma_X^4\sigma_Y^4 + 2M_1\sigma_Y^2\mu_Y^2Var(S_X^2) - Var(S_X^2)Var(S_Y^2)\right] \quad . \qquad (15)$$

Now (15) cannot be shown to hold in general but it holds for either N_2 or M_2 sufficiently large. Recall that N_2 and M_2 are the sample sizes to determine the sampling variances and are therefore usually rather large. Therefore we conclude that $\alpha=-1$ should be the preferred value among $\alpha=-1,0,1$ unless other information is present. We would never recommend $\alpha=+1$.

We add one more argument in favor of $\alpha=-1$. The value $\alpha=0$ was obtained by a Taylor series approximation and T_o is biased. Recall that T_{-1} is unbiased. Under the assumption of normality (which has not been made until this point), the Lehmann-Scheffé theorem [1, p. 326] states that T_{-1} is the uniform minimum variance unbiased estimator for Var(Z).

4. Application

Assume that we have L containers of U_3O_8 and we wish to estimate the total amount of uranium in the L containers. For the i^{th} container, let

$$X_{i1}, X_{i2}, \ldots, X_{in_i} \qquad (16)$$

be the estimates of weight of the i^{th} container and

$$Y_{i1}, Y_{i2}, \ldots, Y_{im_i} \qquad (17)$$

be the estimates of concentration of uranium in the i^{th} container. Clearly $1\le n_i$ and $1\le m_i$. Let

$$X_i = \frac{1}{n_i}\sum_{j=1}^{n_i} X_{ij}$$

and

$$\bar{Y}_i = \frac{1}{m_i} \sum_{j=1}^{m_i} Y_{ij} \quad .$$

Our estimate Z of the total amount of uranium is

$$Z = \bar{X}_1\bar{Y}_1 + \bar{X}_2\bar{Y}_2 + \ldots + \bar{X}_L\bar{Y}_L \quad . \qquad (18)$$

We assume all estimates are independent so that

$$E(Z) = \sum_{i=1}^{L} E(\bar{X}_i\bar{Y}_i) = \sum_{i=1}^{L} \mu_{X_i}\mu_{Y_i} \qquad (19)$$

and

$$Var(Z) = \sum_{i=1}^{L} Var(\bar{X}_i\bar{Y}_i) \quad . \qquad (20)$$

The problem clearly reduces to L problems, each of which has been considered above.

To relate these results to Post we mentioned that his Case 2 is the situation $n_i = m_i = 1$ for $1 \leq i \leq L$ and that his Case 3 is the situation $L=1$, $m_1=1$, and $n_1=K$.

Acknowledgement

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Safeguards Perspectives An Expression Of Industry's Responsibilities And Views

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Editor's Note: The following paper was recommended to the editors by John Jaech, a member of the INMM Executive Committee and Chairman of the ANSI-INMM N-15 Standards Committee. The article by Mr. Dickeman is printed with permission of the Atomic Industrial Forum, Inc., and was presented at the April Safeguards Conference of AIF in Orlando, Florida.

INTRODUCTION AND BACKGROUND

The subject of safeguards, and in particular plutonium safeguards, is a widely discussed issue in today's nuclear deliberations. In fact, it is said that plutonium safeguards may be the most important remaining issue related to licensing the nuclear fuel cycle and could take as long as other prior nuclear regulatory issues to resolve. The importance of plutonium safeguards lies not only in the context of closing the back end of the light water reactor fuel cycle today, but extremely important, long-range considerations in extending the utilization of uranium through the breeder reactor are also at stake. Apart from the near and long term aspects mentioned above, there is emerging a concern of threat deterrence which is being examined by segments of our government, the public, and as well by the fuel cycle industry.

How did we get to the situation we are faced with today? The AEC's plutonium Utilization Program which ran from 1956 to 1972 and the EEI and SEFOR programs were judged at the time to be responsive to solving the technical problems involved with the utilization of plutonium in light water reactors. Mixed-oxide fuel irradiations have behaved within predictive bounds in several reactors such as Dresden 1, Big Rock Point and San Onofre. Important reactor safety indices were not significantly affected by mixed-oxide cores; in fact, the situation was improved in more instances than not. Plutonium has been handled in fuel fabrication plants without incident. Plutonium fueling was viewed as being different in degree but not different in kind. Now, what was considered only a few years ago as a technical extension of current light water reactor fuel technology and readily manageable on an incremental approach is no longer accepted in this light. Plutonium recycle is now viewed as presenting considerations differing in **kind** as well as in **degree** from those related to safety and safeguards in the uranium fuel cycle.

The common error, if one was made, was the failure to recognize that the established ways may not be acceptable in the future when plutonium becomes a major item of commerce. The delay now resulting from the careful and thorough deliberation which GESMO must follow is in part our failure to predict the future, and, expensive as it is to adjust now, the cost to adjust later may be much greater as the level of economic and commercial commitments increase. Widespread plutonium utilization will materialize when 1) it is needed in the national interest, and 2) when it can be shown to meet the public acceptance criteria with the necessary degree of assurance.

We presuppose that plutonium utilization is warranted in the commercial nuclear fuel cycle. I do not intend to debate here the economic and resource conservation incentives. However, I remind you that Exxon Nuclear has recently submitted an application to construct a nuclear fuel reprocessing plant at Oak Ridge, Tennessee. We would not be taking this step if we did not feel that fuel reprocessing and re-use of plutonium and uranium values in spent fuel were less than fully justified.

In preparation for testimony on GESMO, we have made cost/benefit studies taking into account recent information on fuel cycle costs and nuclear projections. These studies show economic incentives for recycle. If plutonium and uranium are not recycled in mixed oxide fuels, the result will be an increase of approximately 20 percent in the amount of uranium and separative work required to satisfy the same fraction of the nation's need for electricity. There will be a shift in the component costs of the nuclear fuel cycle in the absence of recycle whose net effect will be to increase the cost of electricity by about one-half mill per kilowatt-hour.

There will undoubtedly be some real cost increases for enriched uranium due to the higher level of investments required as the demands are increased to compensate for the absence of recycle which could easily increase the future price of uranium and enrichment by at least

10 percent. Their effect would be to increase the cost of electricity by another 0.4 mill. Thus, the overall difference in the fuel cycle cost due to recycle of uranium and plutonium is at least a half mill/kwh and may be as high as one mill/kwh. This implies a savings to the nation's economy by the year 2000 due to recycle, if ERDA's Forecast C (moderate growth) eventuates, of at least 25 billion dollars and possibly as much as 50 billion dollars. Even under the low ERDA D Forecast, the savings are between 20 and 40 billion dollars. The effects of continued inflation are likely to cause these numbers to nearly triple by the end of the century to a range of 60 to 130 billion dollars of added cost to the nation's electrical consumers if plutonium and uranium are not recycled.

My remarks will be confined to the utilization of plutonium in the commercial sector, although I recognize that safeguards considerations are also very real and of major importance in the ERDA programs involving plutonium and highly enriched uranium.

Following the issuance of GESMO in 1974 and the division of the AEC into NRC and ERDA in 1975, there have been a large number of studies by both industry (AIF, INMM, etc) and government on the safeguards aspects of the overall cost/benefit of plutonium recycle. My position is consistent with many of the suggestions already furnished by the industry papers and NRC studies. However, I differ in some respects; in those cases, the views expressed here today are the views of my company.

It may appear that in some cases I appear critical of the industry's record and the government's approach to the regulation of safeguards. I do this in a constructive manner, because I think we, as a responsible industry, can do better than we have in the past, and likewise the NRC can do better than its predecessor, the AEC. This should not be viewed as admittance of irresponsibility on either industry's or government's part because up until now the safeguards risk, as far as the commercial plutonium sector is concerned, has been manageable and the steps taken to date have and continue to be fully adequate when viewed in terms of the very small amounts of plutonium involved in the commercial plutonium sector. In fact, there is essentially no "commercial" plutonium in existence today except that under reactor irradiation, in spent fuel pools, or lock in company vaults.

The regulatory process must be allowed to examine alternatives as new technologies, such as plutonium recycle or the fast breeder, emerge and better ways of accomplishing results in the public interest are developed. This is an iterative and continuing process which must go on. Care must be exercised to assure that the public forum permitted by our regulatory decision-making process is used in a constructive manner and in such a way as to efficiently determine the underlying facts and reach decisions without emotion and misinformation.

INDUSTRY'S RESPONSIBILITIES

The nuclear industry is responsible for providing electrical energy to society. Energy production must be accomplished with prudent management of finite resources and concern for and protection of the health and safety of employees and the public. The industry must operate within the standards and regulations of the government regulatory agencies. The industry must have credibility and an understanding of public needs and concerns.

Beyond these well-understood responsibilities, there are additional ones which are specific to safeguards. I wish to expand on these.

1. Custodial Responsibility

Industry has the custodial responsibility for the control and protection of strategic special nuclear material (SSNM). Its protective measures must be sufficient to: 1) preclude unauthorized access to plutonium or highly enriched uranium; 2) detect attempts at theft, diversion or sabotage; 3) enable the mobilization of assistance if needed; and 4) delay such attempts until legally authorized response forces can effectively engage the intruders.

What constitutes the legally authorized response force is open to some debate. At fixed sites, where property lines are clearly defined, the control and protection of property is a traditional management function. Similarly, the protection of valuable goods in transit has also been a traditional function of the private sector. However, the use of military type weapons by industrial personnel has not been the province of industry. Such force has been reserved to legally constituted law enforcement bodies and the military.

However, local law enforcement bodies may not have sufficient capability to effectively counteract some of the upper limit guideline threats being postulated by NRC. Federal forces may also not be available. Thus, in the ultimate sense, industry may be forced to provide its own highly-trained, effectively armed custodial force. Thus, a fifth custodial responsibility may well be to provide increased echelons of physical security which are keyed to the capability of external response forces to meet credible threats.

Such an undertaking by industry may require legislative changes which clearly define the legal rights and liabilities of such industry security systems. If severe response forces, in addition to engineered security systems, are prescribed by government regulation, we would prefer that duly constituted and licensed forces provide this service; however, the case of industry providing this service under acceptable conditions of legal authority and liability protection and licensing by government agencies is in my opinion an acceptable alternative. Such licensed forces must be federally trained and must be well versed and able to counteract those classes of threats judged as credible or necessary to protect against.

There are still practical limitations on the extent to which industry can be expected to materialize the full scope of a sophisticated safeguards system which may be judged as proper to protect material under its custody. For example, the coordination of assistive and recovery forces and the establishment of a national communications net and command center for materials in transit is best done with government involvement. Recovery of stolen material and the apprehension of those guilty of diversion or sabotage is the responsibility of duly constituted law enforcement bodies.

2. Leadership

Industry has a unique leadership role to play in safeguards. It is the responsibility of industry to make safeguards a practical reality. This is particularly true for safeguards at fuel cycle facilities. Industry can exert positive leadership by establishing practical and workable systems that meet both the letter and spirit of the regulations. We must continually examine and demonstrate our capabilities against quantified threats. We must seek innovative and creative solutions that truly meet the postulated threat, so that our effectiveness is rightfully and convincingly our own. In this regard, the definition of postulated threat guidelines is of concern to industry, and industry will need to participate with NRC and governmental agencies in defining the essential protection policy and guidelines.

It then follows that we must also give more attention to designing effective safeguards features into new facilities. We are convinced that "built in" safeguards are, in the long run, the best way to establish the credibility and effectiveness the public expects industry and goverment to display.

We further believe that a government-industry partnership is essential in evaluating various alternatives and improved safeguards measures. We favor an industrial "proving grounds" approach where new concepts can be tested and modified in a practical environment. ERDA and NRC recently extended these challenges to industry and I strongly recommend that we in industry accept and meet these challenges in a responsive and constructive way.

3. Credibility

Another important responsibility of industry concerns the establishment of credibility. At times in the past, our credibility has been damaged by our own accounting numbers. Despite the limitations of measurement uncertainties, we are still judged on our materials accounting performance.

Unfortunately, accounting practices do inherently reflect statistical variances resulting from practical as well as technical limitations on the precision of measurement. A negative deviation is often distorted by the press to mean a diversion or theft has occurred or in principle may have occurred. We believe strong accounting methods are justified and should be continued and even improved—the economic value of the fuel materials justify this level of capability to detect a potential loss. However, primary reliance against diversion will need to be shifted to physical security systems which preclude successful diversion. The shift in philosophy also needs to be adapted on a worldwide basis for other national systems as well.

INDUSTRY'S VIEWS

In viewing the safeguards problem today, proper perspective is most important. The perspective is different depending on the time scale required for solutions. As stated earlier, the quantity of plutonium readily accessible today in the U.S. commercial reactor fuel cycle is very small. Although costly delays are being encountered in securing best economics in the LWR fuel cycle now due to delays in resolving the GESMO issues, time still exists in this area to proceed to orderly solutions in a prudent fashion. This is also true for the safeguards requirements applicable to the longer-range breeder program.

Although the reality of an immediate threat at any postulated level can be debated, the fact remains that even if a theft did not occur, the blackmail potential from a false report of diversion is sufficient in itself to warrant a closer look at safeguards adequacy. In the long run, commercialization of plutonium and closing of the back end of the light water fuel cycle in the best economic fashion may not occur unless a strong safeguards program is developed now.

1. Ultimate Solution

The ultimate solution lies in the thorough deliberation afforded by the generic environmental review of plutonium recycle now planned in GESMO. Safeguards must be quantified in terms of risks and costs; the postulated threat guidelines must be defined and the protection against them developed. The costs of additional safeguards will be high, but they are offset by a large margin by the benefits accruing from recycle. The safeguards issues are complex and the thorough study and debate required will take more time than some of us would like. But the long-range resolution cannot be artificially forced; it must move ahead in a deliberate, methodical fashion in an open but constructive forum.

2. Immediate Concerns

At the same time, the immediate concerns must be addressed. In meetings earlier this month between ERDA, NRC, and industry, particularly those involved in government programs, a joint industry-government undertaking has been proposed to implement safeguards alternatives which are responsive to an enhanced spectrum of threat scenarios. These studies will proceed in parallel with the GESMO proceedings. The objective of the joint studies is to provide the highest assurance through confident and demonstrable capabilities to prevent, detect and respond to attempted thefts or diversion of strategic special nuclear materials.

3. A New Approach to Safeguards Regulations

I agree with Ken Chapman's remarks at the Phoenix AIF fuel cycle meeting in which he called for a switch from the traditional regulation by procedures to regulation by objective. Such a concept has often been called for by industry spokesmen and is a refreshing approach. Although it may be a more difficult concept to license and inspect for compliance, it gives the licensee the flexibility in choosing between equivalent alternatives and to make choices which are best for his own situation, including economic factors.

In the aforementioned meetings with industry, this approach has been proposed in the particular context of safeguards. Design basis threats and performance criteria have been postulated for industry's comment and planning. The concept introduces the idea of "performance requirements plus demonstrable capabilities equals adequacy." The proposed details of the systems and procedures to meet the performance criteria are left to the licensee with review for adequacy by the NRC. Demonstration of performance will be tested by both the licensee and the NRC inspectors.

The performance requirement approach puts a new burden on each licensee possessing strategic special nuclear material. The licensee must establish a safeguards system which demonstrably meets the NRC's objectives and which is specific to his unique situation. He can no longer rely only on regulations from the regulatory agency.

4. Specific Views

I would like next to discuss specific views on some of the safeguards concepts. I do not offer these as representing a consensus among my industry colleagues; indeed, under the new proposed approach it is not necessary that a consensus prevail.

a. Access Limitations

The first concept on which I would like to present views is access limitations. To limit or reduce accessibility to SSNM by special means is obviously of importance in preventing theft or diversion. In the area of transportation, which is often cited as the weakest link in the total safeguards system, several concepts have been proposed, particularly in the area of transporting plutonium between the reprocessing and the mixed-oxide fuel fabricator. One of the recent studies on this subject is a report by an AIF study group on Technical Options for Plutonium Safeguards.

The location of mixed oxide fabrication plants in close proximity or adjacent to a fuel reprocessing plant in integrated fuel cycle facilities (the co-location option) would substantially reduce or even eliminate the transportation of concentrated plutonium over long distances. To us, a company which is a mixed-oxide fuel supplier and has plans for reprocessing, this is an acceptable option. But other options should not be ruled out. For example, we view secure ground transportation for plutonium in the mixed oxide forms as an acceptable alternative to co-location.

We do not consider it essential to transport concentrated plutonium forms between reprocessing plants and mixed-oxide fabrication plants. A blended product of uranium and plutonium oxides, as low as 7 percent plutonium by weight, is acceptable to us. Blending makes the amount of material to be diverted larger, more difficult to divert and complicates, extends and makes more costly the process in fashioning a workable nuclear device. It is prudent in our opinion to utilize secure transportation as a complementary system.

The concept of "spiking" has been suggested as a means to deter or prevent theft or diversion of plutonium. We do not favor this concept; the disadvantages far outweigh any safeguards gains. Spiking, certainly at lethal levels, may also create risks to employees from potential inadvertent exposures. Present nuclear power plants are not designed to receive, unpack, inspect and store spiked fuel, and fuel fabrication plants would require substantial modification to shield employees from the radiation. Remote handling and shielding to protect against potential lethal doses is expected to be much more complex and severe than that which would be required to handle nonspiked plutonium from either an exposure problem or a safeguards deterrent and the benefits are incrementally marginal in our view.

The use of remotely operated, partially automated process lines for plutonium processing and fabrication starting at the plutonium nitrate conversion process in the fuel reprocessing plant and extending through to the fuel assembly of mixed-oxide fuel bundles in the fuel fabrication plant is warranted in our opinion as a design option in new facilities. Such a step would not only reduce the accessibility of plutonium to inside diversion threats, but would also minimize occupational radiation exposure to employees. Complete hands-off, automated, remote production lines should be viewed as an ultimate design target which would provide added assurance potential against theoretical diversion by insiders.

b. Physical Security

Physical security and material control must be the first line of defense in a total safeguards system. As stated earlier, one must be able to assure with the highest confidence that SSNM has not been lost or diverted, even when considering the statistical nature of accounting systems.

For physical protection at fixed sites, the following basic capabilities should be in place: 1) prevention of unauthorized access of personnel and materials to material access areas and vital areas; 2) prevention of unauthorized removal of SSNM materials; and 3) detection, reaction, and countering of any attempts at unauthorized access or exit.

The system should have redundancy so that no single failure can defeat the system. Redundancy per se, is not sufficient and system elements should also have the feature of independence such that a strategy that can defeat one redundant measure will not defeat the second measure. Obviously, true and complete independence is a difficult technical challenge. However, there are a number of techniques now available that are useful in building those features into the system. These include sophisticated remote admittance systems, weapons and explosive detectors, SSNM portal monitors for personnel and vehicles, perimeter alarms, intrusion alarms, motion detectors, tamper-proofing devices, and multiple interlocks.

c. Materials Control and Accountability

Although we believe that physical security and material control are the first lines of defense in a total safeguards system, the traditional role of special nuclear material accountability must be retained as a complement to security and material control in detecting abnormalities in material mass balances, in providing assurance that other safeguards measures are effective and as an important tool in managing valuable materials. LE-MUF requirements should be consistent with the state of the art, but eventually reliance on accountability as the prime safeguards tool will not be sufficient as plutonium throughputs increase.

"Real-time" accountability is favored only in those parts of the plutonium fuel cycle where the material may be susceptible to diversion and only when demonstrated hardware is available and practicable. Nondestructive assays may never be as exact as destructive assays, and thus, the traditional measurement systems must be retained for the highest accuracy and precision. Real time systems employing nondestructive assay devices have value principally as a rapid overcheck and for prompt detection of loss events.

A "controlled vault" concept which is currently under development at Sandia has merit, we believe, and the concept should be extendable to the plutonium processing and fuel fabrication lines. In simple terms, this concept involves vault intrusion sensors, on-line material storage sensing devices, physical monitoring of entry and exit of materials, and tri-party, independent approvals to move materials. The approvals are more than administrative in that they require concurrent physical actions by a member of the security force, by a member of the accounting group and by a member of the operating group. This concept not only provides a high degree of physical control over the material but frustrates the scenarios in which one or two knowledgeable insiders are used to perpetuate the diversion or theft. Computerization of the concept is an ultimate development control.

INTERNATIONAL ISSUE

It is becoming more apparent that safeguards is an international problem rather than a purely domestic concern. An effective domestic safeguards system would appear to present less than optimum gains unless there were equally effective safeguards in the rest of the world.

The U.S., as a prime advocate and negotiator of the Nonproliferation Treaty designed to limit the spread of nuclear weapons, supports the IAEA safeguards. The IAEA has the responsibility of carrying out safeguards under the Treaty. The IAEA's task is to assure through its verification activities that significant quantities of nuclear materials have not been diverted from peaceful purposes. Protection against diversion by individuals within a country is the task of the national safeguards authority. The U.S. also is a strong supporter of effective national safeguards systems including the use of physical protection.

Industry, both at home and abroad, can greatly assist the cause of international safeguards by actively cooperating with the IAEA in its verification activities. Success of IAEA verification will be heavily dependent on industry's ability to present materials in verifiable forms and, in some cases, on our ability to incorporate IAEA surveillance and containment monitors in our plants. Industry should also support our government's view that other nation's physical security systems be equivalent or better than U.S. systems.

SUMMARY

By way of summary, I have endeavored to present an industry view on our responsibilities and limitations in the area of safeguards. I tried to distinguish between those protective activities which are traditionally within our province and those which are best done by the government.

We favor the alternative of finishing the GESMO review with full industrial and public participation as the means of providing a firm basis for future actions.

The use of deadly force to protect material and the possibility of maintaining military level combative capabilities for safeguards are complex issues. I have given my company's views on measures which could constitute an acceptable posture.

I have expressed the views of my colleagues as well as my personal views on specific safeguards concepts and protective measures. These measures correctly joined and implemented can provide effective safeguards. Industry can provide effective, adequate and credible safeguards for plutonium even to including, if necessary, protection against the extreme threat of attack by a well-trained and well-equipped paramilitary force.

Industry has an important and unique role to play in making effective safeguards a practical reality. Industry has the experience and self-interest for the task of implementation. We must often remind ourselves of the international nature of the safeguards problem and that it is not feasible to treat our domestic problems in isolation of the nuclear world in which we live.

Finally, we endorse extraordinary security measures in association with concentrated plutonium and highly enriched uranium. We endorse these measures as precautionary and as still one more echelon of protection against an already extremely small potential risk. There is always the danger that such precautions can be deliberately distorted by some as an admission of an area of risk to the public which has not been properly managed by industry and government. The communication of perspective is important in these early years of nuclear industry growth and we all share in the responsibility for effective communication to the public. I do not believe that the possibility, or even the probability, of distortion by a small minority should distract us from a continuing policy of conservatism, prudence, and quality-oriented execution in developing this very important energy fuel.

What Really Counts

(cont. from page 1)

would be most constructive if papers presenting different points of view, based on thoughtful analyses could be brought out at the same time, but considering the amount of free manpower available (and that is a very high percentage per man in the INMM), this does not appear to be very practical. So, we will have to perform the studies and issue the reports as inspiration and ambition strike various of our members.

Inasmuch as a substantial part of the membership work for NRC or ERDA, it will be essential to insure that their official neutrality is clearly protected. The safeguards committee is sensitive to this issue and to the fact that there are other intelligent INMM members who may quibble about their analysis or disagree, to some degree, with their conclusions. My guess is that the public will be more likely to respect an organization which admits that it still has arguments about how to handle a complex socio-technological subject such as safeguards, than one which attempts to convince the world of its omniscience. The low-enriched uranium safeguards study represents a lot of discussion, difficult analysis and tedious redrafting. It is educational, whether or not you agree with the specific conclusions. That is what really counts.

Proposed Real-Time Data Processing System To Control Source & Special Nuclear Material (SS) At Mound Laboratory

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SUMMARY

The SS Acountability System has been designed to provide accountability of all SS materials by unit identification and grams. The existing system is a gram-accountable system. The new system was designed as a result of a request by the Accountability Department to incorporate unit identification into an ADP (Automated Data Processing) System.

Unit identification requires that any quantity of SS material must have a unique identifying number assigned to it. The material will be recognized by this number as long as it remains accountable.

In addition to providing a unique identification number, the proposed system also records all transactions performed against a particular unit of accountable material. This requirement prevents error and provides a rapid means of locating any missing material. It also demands that a high volume of input data enter the system. Therefore, the system has been designed to allow this information to be input quickly, easily and correctly via CRT (Cathode Ray Tube) terminals at the time the transaction is performed.

Input data will typically consist of the following information:

1. Source of the material (its unit identification).
2. Amount of material being moved.
3. Isotopic content of this material.
4. Type of material.
5. Health Physics number of the person moving the material.
6. Account number from which the material is being moved.
7. Unit identification of the material being moved (if all material is not moved).
8. Health Physics number of the person receiving the material.
9. Account number to which material is being moved.
10. Acceptance of the material by the receiver.

A running inventory of all material is kept. At the end of the month the physical inventory will be compared to the data base and all discrepancies reported. Since a complete history of transactions has been kept, the source and cause for any discrepancies should be easily located.

The discrepancies are held to a minimum since errors are detected before entrance into the data base.

The system will also furnish all reports necessary to control SS Accountability. These reports may be requested at any time via an accountability master terminal.

All paper work has virtually been eliminated. However, if desired, hard copies may be produced near the terminal or at the main computer.

DEFINITION OF TERMS

ACCOUNT—The physical location of the material—where the work is performed.

CPU—Central Processing Unit (IBM 360/50 computer).

DATA BASE—A method of storing information centrally, allowing access by all qualified users and suppressing redundant information to a minimum.

741 FORM—A document which contains all necessary information concerning shipment of SS materials, identification, weights and destination.

MBA—Material Balance Area—a convenient grouping of various accounts, generally by building, but has no physical significance.

MTR—Material Transfer Report—A record of transfer of SS material into and/or from an account.

PROJECT—The purpose which the material is to serve.

REAL TIME PROCESSING—Immediate processing of actions by a computer which stores and/or returns the results of such an action to a user within a relatively short time after an event has occurred—usually within a few seconds.

UNIT IDENTIFICATION—A unique designation assigned to any discrete quantity of SS material which will enable exact recognition any time after its creation. (A number is definitely required.)

DETAILED DISCUSSION OF THE PROPOSED SYSTEM

Mound Laboratory presently operates under a gram-accountable system. At the end of each month the account is reconciled by manually comparing material received, material moved from the account, and material still resident in the account. Mathematically:

Material Received—Material Transferred = Material-On-Hand

Each container within the account is physically located and the material contained is determined, either by direct weight or an assay. The material in each container is summed and the total compared to material on hand. The difference being the MUF (**M**aterial **U**naccounted **F**or).

Statistical limits have been determined for the allowable MUF within an account. If this value is exceeded, the account is considered to be out of control. The account is shut down until the MUF is satisfactorily explained.

A typical operation, producing a theoretical P-item is outlined in Fig. 1. The 1500 grams received are first split into three containers of 500 g each. 75 g of material is removed from each container and processed into a P-item. In this example, just prior to inventory, processing stopped at an intermediate step and P3 was not produced, but its material had been withdrawn from the 500 g container. Consequently, this material was not included in the physical inventory, resulting in an unacceptable 75 g MUF.

The custodian and his (her) people must stop work and begin a physical search for the missing material. It could be a P1 or a P2, since their weights equal 75 grams, or the 75 grams could represent **several** missed items which total 75 grams.

The missing material will be located, but will probably require several days of searching and re-examining records to find it. In this case, the material will be located in the intermediate stage.

The system failed because it was impossible to trace the flow of material in, through and out of the system. The present system could not be adapted to handle Unit Identification.

Material is received into the Laboratory via the 741-Form and moved into the Receiving Account and onward to the Analytical Account. Here the material is analyzed and then passed to the operating accounts. The transfers are recorded on the MTR Form. Differences between actual analysis and the received analysis are moved out of the system to the 310 Account (a null account which is not accountable).

Within each account, work is performed and the material is split, requiring a Unit Identification for any quantity processed. Material also passes from one account to another and is recorded on the MTR.

Unit Identification, as used in the proposed system, required that all transactions against a particular Unit Identification be recorded. These transactions will be recorded on a data base as shown in Fig. 3.

A transaction will take place every time a unit changes weight. A Unit Identification must be created for the material removed and the value of the donor unit must be changed to its new weight.

The type and extent of the information needed at each transaction is described in Fig. 4—Transaction Information.

Now examine the same system as used in Fig. 1—Gram Accountable System, converted to Unit Identification and automated to be stored in the data base. This converted system is shown in Fig. 5—Unit Accountable System. The same processes occurred. Every time material was removed from a container, a new Unit Identification was created and the value of the donor unit changed to reflect its new weight. The transaction was stored in the data base. Again, Unit #7 was not reported on the physical inventory: it was left in some intermediate stage. The physical inventory is compared to the data base and it is reported immediately that Unit #7 was not on the physical inventory, its weight is 75 grams, and the MUF is 75 grams. The missing item has been immediately identified. Furthermore, the computer tells us that Unit #7 came from Unit #4 which came from Unit #1. It can also tell us who created Unit #7 (from the personal ID received when it was created).

If necessary, this parent-daughter relationship can be traced directly back to the entrance of the original material into the plant.

It soon became obvious that such a system would require an enormous amount of paper work if it used a conventional card input system. A survey of the number of such transactions per day showed it formidable. Fig. 6—Transaction Survey, summarizes the findings.

Therefore, due to the need to be able to generate unique Unit Identification numbers and to provide timely output and to relieve the user of a vast amount of paper work, a real-time, on-line processing system was proposed.

The goals of the system are as follows:

1. Provide unique identification for each sample.
2. Provide ready identification of any missing or non-identified items.
3. Monitor all transactions to assure correct input to the system (EDITING).
4. Produce all reports necessary to adequately describe the system. Report and flag all discrepancies.

Basically, a real-time system consists of a terminal (an input device) connected to a CPU (computer) at another location. Information can be sent to the computer, processed, and the results returned to the terminal within a matter of seconds (probably 10 seconds). The system being proposed for installation at Mound Laboratory is shown in Fig. 7—Mound Laboratory Real-Time Processing System.

A mini-computer will be located at **P**lutonium **P**rocessing and **S**emi-**W**orks Buildings. This will act as the controller for the terminals and will be in communication with the main computer (IBM 360/50). Each mini-computer will also have auxilliary disk storage. This will allow the system to continue to function if the main computer goes down. During down time, transactions coming from the terminals will be stored on the disk until the main computer is again available, at which time all transactions stored on disk will be passed to the main (host) computer and the data base updated.

The terminal essentially replaces the transaction from (Fig. 4). When a request has been properly keyed, a form will appear on the screen (Fig. 8—CRT Display) and the user will simply fill in the blanks.

In the example, Fig. 8, SS Account #056 is creating a new unit. He has been asked to enter the parent unit ID from which the material will come.

The cursor on the screen indicates where to enter the characters. When the parent unit ID has been entered, an edit routine will activate and check to be sure it exists, **i.e.**, is it real? If not correct, an error message will display and the user will repeat the entry. When correct, he will next enter the grams of materials to be moved to the new unit identification. At this point, an edit routine will test to see if the parent contains enough material to make the transfer. If not, an error message displays. If correct, the user continues keying element, isotope, ratio, account numbers, **etc.**

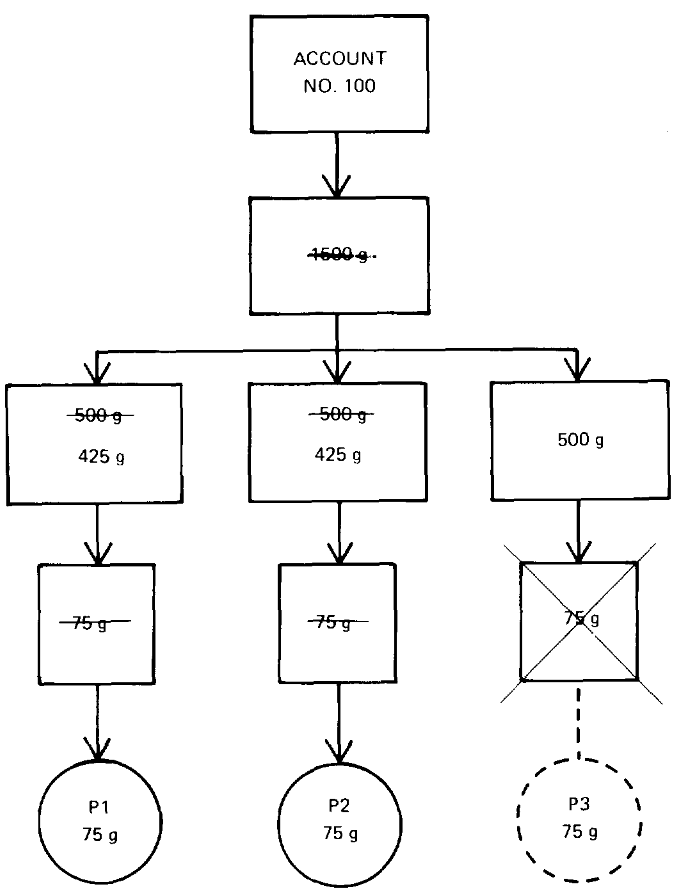
In the event the material is being moved from one account to another, the custodian of the receiving account must signify acceptance of the material. Conventionally, this is done by signature. In the real-time system, the custodian will be called to **his** terminal to key in a classified code indicating his acceptance. If he is not available, the transaction will be temporarily stored and completed when he becomes available and can accept the transfer. (Note: This eliminates the MTR). If a 'hard copy' of this transfer is desired, it can be printed at the host computer or on a hard copier.

Actually, the only paper to enter the system will be the incoming 741. Any outgoing 741 can be printed by the computer.

It should be pointed out that these are not "dedicated" terminals. Any terminal can be used to input data to any other system. Of course, the terminal would eventually be impacted if it attempted to handle too many independent systems. The remedy to this situation would be more terminals.

There are several "spin-offs" available from the SS Accountability System. Fig. 9 shows a criticality monitoring system. It is the same account as used in Fig. 1 and Fig. 5. As material moves into the account, a special program activates and determines if the material is fissionable and whether the criticality limit for that account is being approached. It can be programmed to sound an alarm or prevent the transfer of such material (by issuing a warning and not accepting the transfer).

The real-time system is scheduled to be implemented at Mound Laboratory in FY 77, beginning with the Plutonium Processing Building, where the majority of transactions occur. The balance of the Laboratory will be brought into the system in FY 78.



INVENTORY RESULTS

	Book		Physical
MTR-100	1500 g	C1	425 g
		C2	425 g
		C3	425 g
		P1	75 g
		P2	75 g
Total	1500 g		1425 g
MUF			75 g

FIGURE 1 – GRAM-ACCOUNTABLE SYSTEM

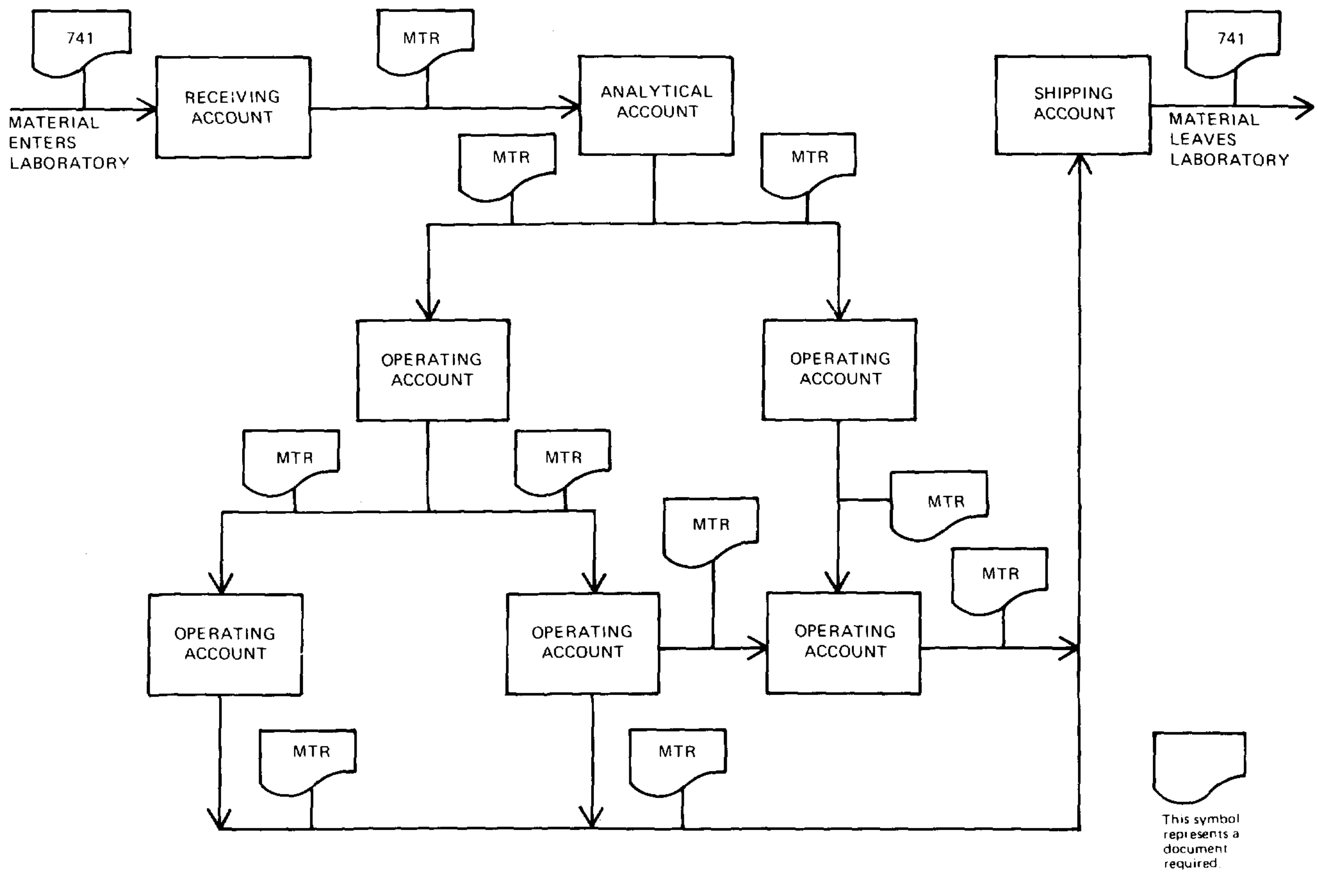


FIGURE 2 – SIMPLIFIED FLOW OF MATERIAL AT MOUND LABORATORY

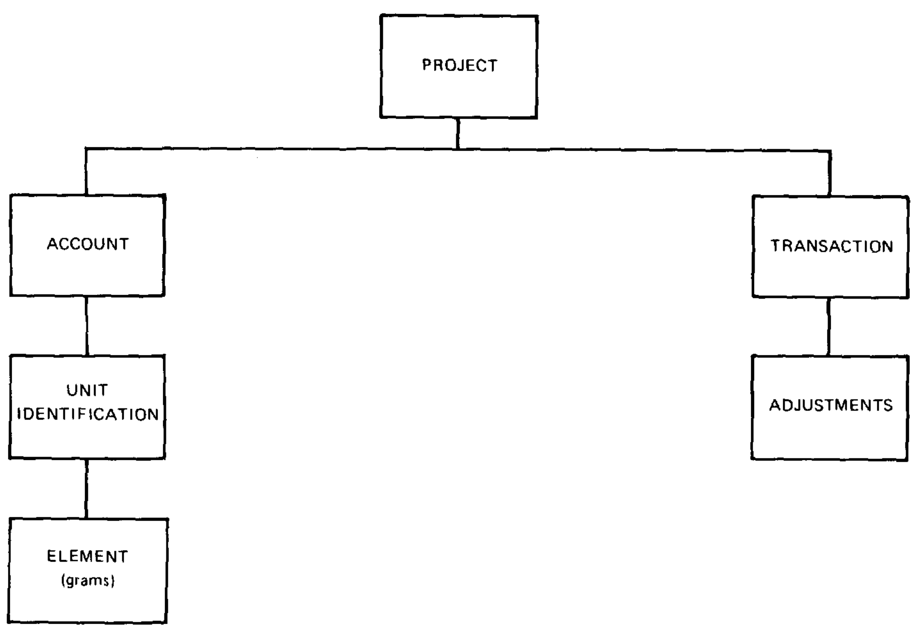


FIGURE 3 – DATA BASE STRUCTURE

THIS SECTION MUST BE FILLED IN SECURITY CLASSIFICATION	FOR DOCUMENT CONTROL USE
☐ UNCLASSIFIED ☐ CLASSIFIED* *Must Be Signed by Authorized Classifier	Document No.
	Pages / Date
Category:	Doc. Control Signature
Authorized Signature / Date	Requestor's Signature

(CLASSIFICATION STAMPS)

MTR No.

SS MATERIAL TRANSFER

Transferred By:	Date	Accepted By	Date
Building	Room	Building	Room

TRANS	UNIT IDENTIFICATION SW/R FORMAT XXXXX–XXXXXX–XX–XXXX PP FORMAT XX–XXX–XX (blank ^)	DATE HOURS	FROM ACCOUNT	TO ACCOUNT	SS ID	MT'L. TYPE CODE	IN/OUT AGCY. CODE	REF. ID	REFERENCE	ELEMENT WEIGHT	RATIO (100%)	ISOTOPE WEIGHT	WATTS

Remarks:

Footnotes:

MRC ML 5986

SS IDENTITY

10	Depleted Uranium	60	Enriched Lithium
20	Enriched Uranium	70	Uranium 233
40	Plutonium-242	81	Normal Uranium
44	Americium-241	82	Neptunium-237
45	Americium-243	83	Plutonium 238
46	Curium	85	Helium-3
47	Berkelium	86	Deuterium
48	Californium	87	Tritium
50	Plutonium-239	88	Thorium

TRANSACTIONS

- A Move to New Account Location On Site
- B Reinstate Closed Unit
- C Cleanup
- D Shipping Receiving Adjust.
- E Adjust Weight Measurement
- F NOL (Normal Operating Loss)

SS ID	ELEMENT TOTALS	ISOTOPE TOTALS

DISTRIBUTION UNCLASSIFIED

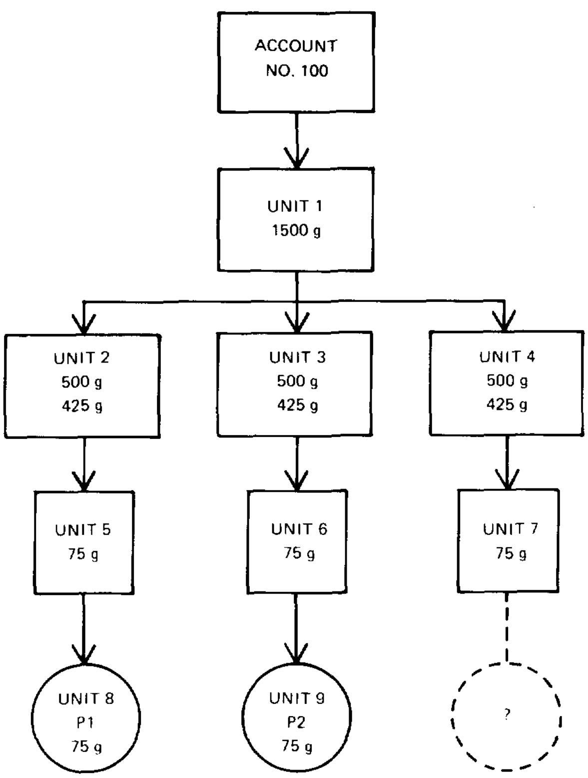
White	SS Representative
Yellow	Receiver
Pink	Sender
Goldenrod	Production Control

DISTRIBUTION CLASSIFIED

1A DeVer
2A
3A
4A

(CLASSIFICATION STAMPS)

FIGURE 4 - Transaction Information



INVENTORY RESULTS

	Computer Data Base		Physical
Unit 1	1500 g	0 g	0 g
Unit 2	500 g	425 g	425 g
Unit 3	500 g	425 g	425 g
Unit 4	500 g	425 g	425 g
Unit 5	75 g	0 g	
Unit 6	75 g	0 g	
Unit 7	75 g	75 g	
Unit 8	75 g	75 g	75 g
Unit 9	75 g	75 g	75 g
Total		1500 g	1425 g
MUF			75 g

FIGURE 5 – UNIT ACCOUNTABLE SYSTEM

Date	No. 1	No. 2	No. 3	TOTAL
7	253	253	262	768
8	237	237	96	570
9	130	130	121	381
10	257	257	88	602
11	214	214	81	509

AVERAGE TRANSACTIONS PER HOUR BY BUILDINGS

Date	No. 1	No. 2	No. 3	TOTAL
7	32	32	33	96
8	30	30	12	72
9	17	17	16	48
10	33	33	11	76
11	27	27	11	64

FIGURE 6 – TRANSACTION SURVEY

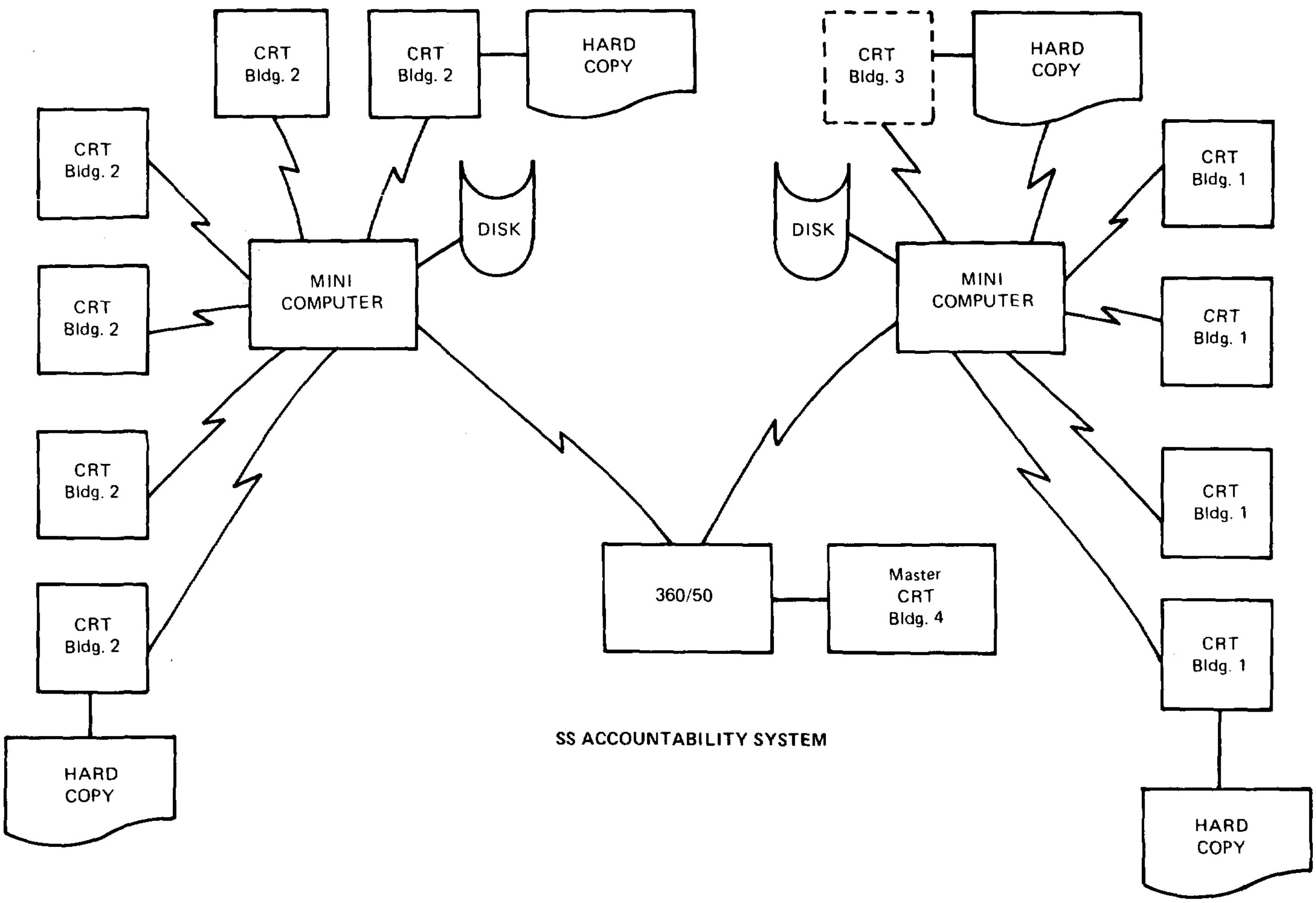


FIGURE 7 – MOUND LABORATORY REAL-TIME PROCESSING SYSTEM

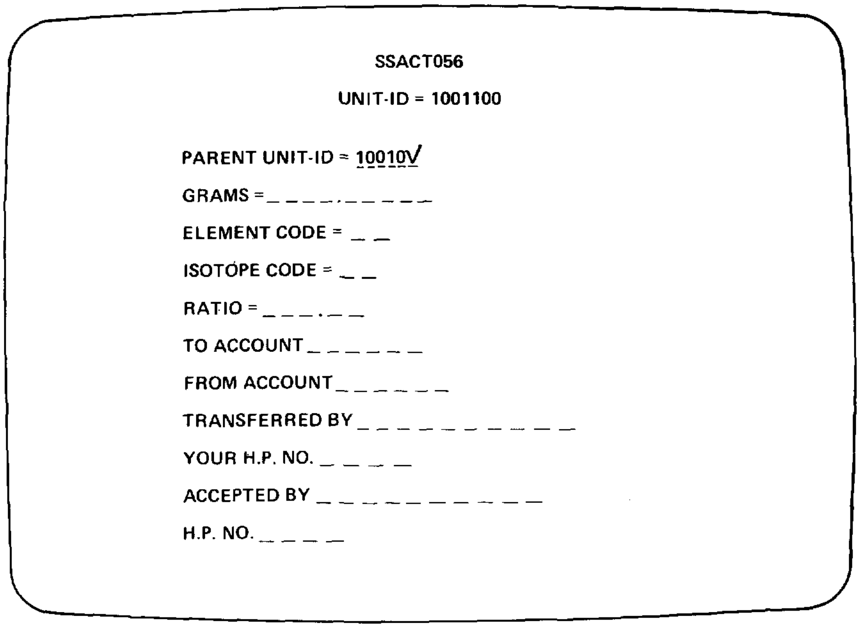
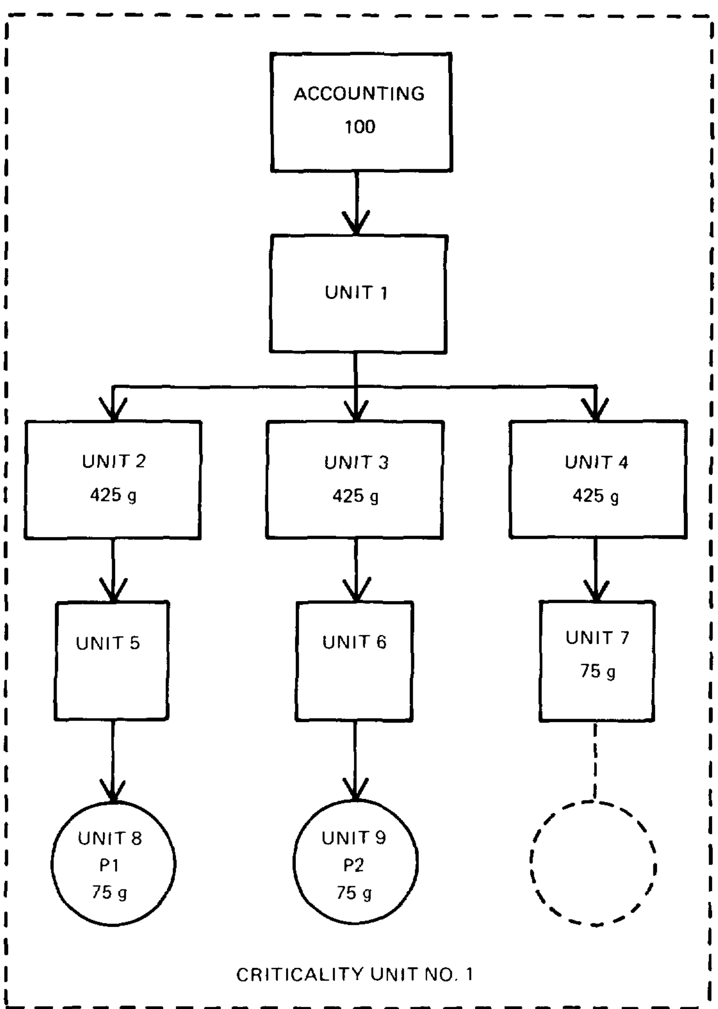


FIGURE 8 – CRT DISPLAY



CRITICALITY LOG

Computer Data Base

C.U. No. 1	LIMIT	1500 g
Unit No. 1		0 g
Unit No. 2		425 g
Unit No. 3		425 g
Unit No. 4		425 g
Unit No. 5		75 g
Unit No. 6		75 g
Unit No. 7		75 g
Unit No. 8		75 g
Unit No. 9		75 g
Total		1500 g

FIGURE 9 – A CRITICALITY MONITOR SYSTEM

Rounding Errors in Weighing

John L. Jaech
Exxon Nuclear Co., Inc.

Introduction

The weighing operation is of key importance in accounting for nuclear materials. Although measurement errors associated with material transfers and with physical inventories are often dominated by errors in sampling and/or determination of element concentration, as opposed to errors in weighing, yet it is important to maintain close control on this latter source of error.

In recognition of the importance of this measurement operation, a rather lengthy ANSI standard was recently published devoted entirely to problems in mass calibrations [1]. Only brief mention of rounding errors is made in the standard, and the topic is dealt with primarily from the point of view of bias introduced by rounding with little attention given the effect of rounding error on measurement precision. In an earlier publication [2], the author dealt with this problem. However, the formulas given in this reference assume that rounding is not too severe, i.e., the rounded data are assumed implicitly to be grouped into at least four cells.

The ANSI standard [1] advises that the rounding error be small relative to the inherent scale imprecision. This condition does not always exist, however, nor is it always warranted except that it simplifies the statistical estimation procedures. At a given measurement point, a scale may round data to the nearest 20 grams, say, either because that is as close as the scale can be read by an operator during routine operation, or possible because the electronic readout indicator automatically rounds to that degree. The inherent scale precision may be such that repeated measurements of a given item may tend to give the same rounded result most of the time. Analysis of the resulting data by the usual statistical methods can give a misleading indication of the scale precision and/or accuracy.

This article addresses itself to the estimation of the precision and bias of a scale, using known standard weights, when the data grouping is "coarse" due to the presence of a rounding error that is large relative to the measurement imprecision. Although the problem is treated from point of view of the measurement operation, it should be apparent that the statistical model is appropriate for other data sets whenever grouping is coarse due to rounding.

Example

It is instructive at this point to present some typical mass calibration data for which the data grouping is coarse because of rounding. Two scales were calibrated by weighing known standards (10 kg, 25 kg, 50 kg). For each standard, 45 weighings were made over a period of three days. Weights are rounded to the nearest 5 grams on Scale 1 and to the nearest 20 grams on Scale 2. The calibration data are given in Table I.

Table I
Scale Calibration Data

Standard					
10 kg		25 kg		50 kg	
Wt.(g)	Freq.	Wt.(g)	Freq.	Wt.(g)	Freq.
Scale 1					
9995	8	24995	5	49990	15
9990	37	24990	39	49985	14
		24985	1	49980	16
Scale 2					
10020	1	25020	19	50020	43
10000	44	25000	26	50000	2

Assume, initially, that the effects of rounding error are ignored and calculate the bias and random error standard deviation for each of the six data sets. These results will later be compared with those found when rounding error is properly taken into account.

Table II
Average and Standard Deviations for Table I Data

Case	Average(g)	Estimated Bias(g)	Standard Deviation(g)
Scale 1: 10 kg standard	9990.89	-9.11	1.93
Scale 1: 25 kg standard	24990.44	-9.56	1.79
Scale 1: 50 kg standard	49984.89	-15.11	4.20
Scale 2: 10 kg standard	10000.44	+0.44	2.98
Scale 2: 25 kg standard	25008.44	+8.44	9.99
Scale 2: 50 kg standard	50019.11	+19.11	4.17

The Model

For a given scale-standard combination, let x_i be the observed weight for the i^{th} weighing. The model is written

$$x_i = \delta + \eta_i + \beta_i \qquad (1)$$

where δ is the population mean (in the case of the 10 kg standard, say, δ-10 is the scale bias in that range),

η_i is the random error of a single weighing, and β_i is the rounding error. It is assumed that η_i is selected at random from a normal distribution with mean zero and variance σ_η^2. The rounding error, β_i, lies in the interval $(-\Delta/2, \Delta/2)$, where Δ defines the degree of rounding. For example, for Scale 1, Δ is 5 g and for Scale 2, it is 20 g.

Estimation of δ and σ_η^2 Assuming Errors are Uncorrelated

At first glance, it would appear that the estimation problem is very simple. It seems reasonable to calculate the sample mean, $\bar{x}$, and the sample variance, s^2, and apply the following equations:

$$\hat{\delta} = \bar{x} \qquad (2)$$

$$\hat{\sigma}_\eta^2 = s^2 - \sigma_\beta^2 \qquad (3)$$

where σ_β^2 is the rounding error variance. For a uniformly distributed random variable, it is well known that σ_β^2 is equal to $\Delta^2/12$. Thus, the estimates of σ_η^2 for the example data, using (3) are given in Table III. The estimates of the biases are the same as in Table II.

Table III
Estimates of Scale Precisions
Using Equation (3)

Case	$s^2(g^2)$	$\sigma_\beta^2(g^2)$	$\hat{\sigma}_\eta^2(g^2)$	$\hat{\sigma}_\eta(g)$
Scale 1: 10 kg standard	3.7374	2.0833	1.6541	1.29
Scale 1: 25 kg standard	3.2071	2.0833	1.1238	1.06
Scale 1: 50 kg standard	17.6010	2.0833	15.5177	3.94
Scale 2: 10 kg standard	8.8889	33.3333	-24.4444	Undefined
Scale 2: 25 kg standard	99.7980	33.3333	66.4647	8.15
Scale 2: 50 kg standard	17.3737	33.3333	-15.9596	Undefined

It is seen that 2 of the 6 estimates of σ_η^2 are negative. This is because the rounding error variance (σ_β^2) is large relative to the weighing error variance (σ_η^2), and because, in fact, η_i and β_i are correlated in this instance. Thus, equation (3) is not a valid estimating equation unless σ_β^2 is small relative to σ_η^2.

It is pointed out in passing that σ_β^2 in equation (3) is the familiar Sheppard's correction applied to grouped data when estimating the variance [3]. In that more general context, Sheppard's correction is not valid when the data grouping is coarse. Equation (3) is also given by the author in [2]. It, and Sheppard's correction in the more general context, should only be applied when the data are grouped into more than 3 cells.

Correlation Between η_i and β_i

Consider the correlation between η_i and β_i. This is best illustrated by a simple example. For a 10 kg standard weight, say, suppose that a given scale were very precise relative to the rounding error of 5 g such that 5 actual weights before rounding were, say, 9999.2 g, 9998.6 g, 10001.3 g, 10000.2 g, and 9999.0 g. Then, assuming δ = 10,000 g (scale unbiased), the 5 values of η_i are -0.8, -1.4, 1.3, 0.2, and -1.0 respectively. Now with rounding to the nearest 5 g, the 5 recorded weights would all be 10,000 g, and the respective β_i would be 0.8, 1.4, -1.3, -0.2, and 1.0 respectively. Thus, $(\eta_i + \beta_i) = 0$ for all i, and they are perfectly negatively correlated in this example. That is, the correlation coefficient between η_i and β_i is -1 or, alternatively, the covariance between η_i and β_i is $-\sigma_\eta\sigma_\beta$, or $-\sigma_\eta^2$ in this example since $\sigma_\beta^2 = \sigma_\eta^2$.

This example is a limiting case in that all observations are at one value, or grouped into one cell. It should be apparent that it is not possible to estimate σ_η^2 in this situation other than to put some upper bound on it; any value of σ_η up to about 1 g would be likely to produce all observed rounded weights of 10,000 g.

Consider a more general case in which η_i and β_i are not perfectly correlated, but neither are they independent. Suppose that for a 10 kg weight and rounding to the nearest 5 g, a scale with δ = 9998 g has σ_η = 2 g. Then, the following data might be generated.

Table IV
Simulated Data to Illustrate
Correlation Between η_i and β_i

η_i	β_i	x_i	η_i	β_i	x_i	η_i	β_i	x_i
-1.77	-1.23	9995	-2.96	-0.04	9995	3.28	-1.28	10000
-3.22	0.22	9995	-1.35	-1.65	9995	-0.74	-2.26	9995
0.28	1.72	10000	3.02	-1.02	10000	3.51	-1.51	10000
2.08	-0.08	10000	0.01	1.99	10000	1.53	0.47	10000
-1.59	-1.41	9995	-0.92	-2.08	9995	-0.21	2.21	10000
0.92	1.08	10000	-0.31	2.31	10000	1.14	0.86	10000
-0.26	2.26	10000	1.12	0.88	10000	-0.72	-2.28	9995
-1.31	-1.69	9995	0.41	1.59	10000	-1.20	-1.80	9995
-0.08	2.08	10000	1.25	0.75	10000	2.53	-0.53	10000
-0.23	2.23	10000	-5.29	2.29	9995	-1.41	-1.59	9995

Of course, only the x_i data are known, and not the individual η_i and β_i values. Of the 30 total observations, x_i = 9995 12 times and x_i = 10000 18 times. (These data will be analyzed later to obtain estimates of δ and σ_η^2).

A plot of β_i versus η_i is given in Figure (1). In this instance, the correlation coefficient between η_i and β_i is not -1 because the data are grouped into 2 cells rather than 1. Calculated statistics of interest are as follows:

(variance of η_i values): $s_\eta^2 = 3.8687$

(variance of β_i values): $s_\beta^2 = 2.6673$

(average of β_i values): $\bar{\beta} = 0.083$

(covariance between β_i, η_i values): $s_{\eta,\beta} = -0.1645$

(correlation coefficient): $r = s_{\eta,\beta}/s_\eta s_\beta = -0.051$

In this particular example, the correlation coefficient is close to zero. Its value is heavily influenced by the one point (-5.29, 2.29). If this point were deleted, then r would be +0.094.

This example is intended to illustrate the relationship between η_i and β_i. Of course, in application one does not know the η_i and β_i values, but only the observed x_i values. The problem is to use the x_i data to estimate δ and σ_η^2, keeping in mind the nature of the correlation between η_i and β_i.

Estimating Equations

The first steps in estimating δ and σ_η^2 consist in finding the sample mean and variance, designated by $\bar{x}$ and s^2 respectively. Then, from (1),

$$E(\bar{x}) = \delta + E(\bar{\eta}) + E(\bar{\beta})$$
$$= \delta + E(\bar{\beta}) \qquad (4)$$

since $E(\bar{\eta}) = 0$.

Also from (1),

$$E(s^2) = \sigma_\eta^2 + \sigma_\beta^2 + 2\sigma_{\eta,\beta} \qquad (5)$$

Then, moment estimates of δ and σ_η^2 are the solutions of the following equations:

$$\hat{\delta} = \bar{x} - E(\bar{\beta}) \qquad (6)$$

$$\hat{\sigma}_\eta^2 = s^2 - \sigma_\beta^2 - 2\sigma_{\eta,\beta} \qquad (7)$$

Now, for given δ and σ_η^2, values of $E(\bar{\beta})$, σ_β^2, and $\sigma_{\eta,\beta}$ can be calculated since β_i is a known function of η_i in this instance. The estimation procedure therefore consists of finding that set of values $(\hat{\delta}, \hat{\sigma}_\eta^2)$ such that equations (6) and (7) are satisfied. This is accomplished in a trial and error procedure involving the use of numerical integration over a number of intervals. A computer program, MERDA, has been written to accomplish this estimation. A program listing is available from the author upon request.

Application of Estimation Procedure to Previous Data Sets

The moment estimation procedure described in the prior section is now applied to the data of Table I, and also to those of Table IV. First, for the Table I data, the estimation results are given in Table V. For comparison purposes, estimates in which the rounding error is ignored, and also in which it is assumed to be independent of the weighing error are also shown.

For the constructed data of Table IV, it is known that the bias is -2.0 g and σ_η = 1.97 g. By the moment estimation method, estimates of these parameters are -2.08 g and 1.69 g respectively.

Table V
Moment Estimates of δ and σ_η
For Data of Table I

	Estimated Bias (g)			Estimated Precision (σ_η) (g)		
	Table II	Table III	Moment Method	Table II	Table III	Moment Method
Scale 1: 10 kg	-9.11	-9.11	-8.69	1.93	1.29	1.30
Scale 1: 25 kg	-9.56	-9.56	-9.40	1.79	1.06	1.56
Scale 1: 50 kg	-15.11	-15.11	-15.12	4.20	3.94	3.94
Scale 2: 10 kg	+0.44	+0.44	+2.68	2.98	Undef.	3.65
Scale 2: 25 kg	+8.44	+8.44	+8.74	9.99	8.15	6.56
Scale 2: 50 kg	+19.11	+19.11	+16.79	4.17	Undef.	4.01

Summary

When rounding error is large relative to weighing error, it cannot be ignored when estimating scale precision and bias from calibration data. Further, if the data grouping is coarse, rounding error is correlated with weighing error and may also have a mean quite different from zero. These facts are taken into account in a moment estimation method. A copy of the program listing for the MERDA program that provides moment estimates is available from the author. Experience suggests that if the data fall into four or more cells or groups, it is not necessary to apply the moment estimation method. Rather, the estimate given by equation (3) is valid in this instance.

References

[1] "Mass Calibration Techniques for Nuclear Material Control", ANSI N 15.18-1975, American National Standards Institute, Inc.

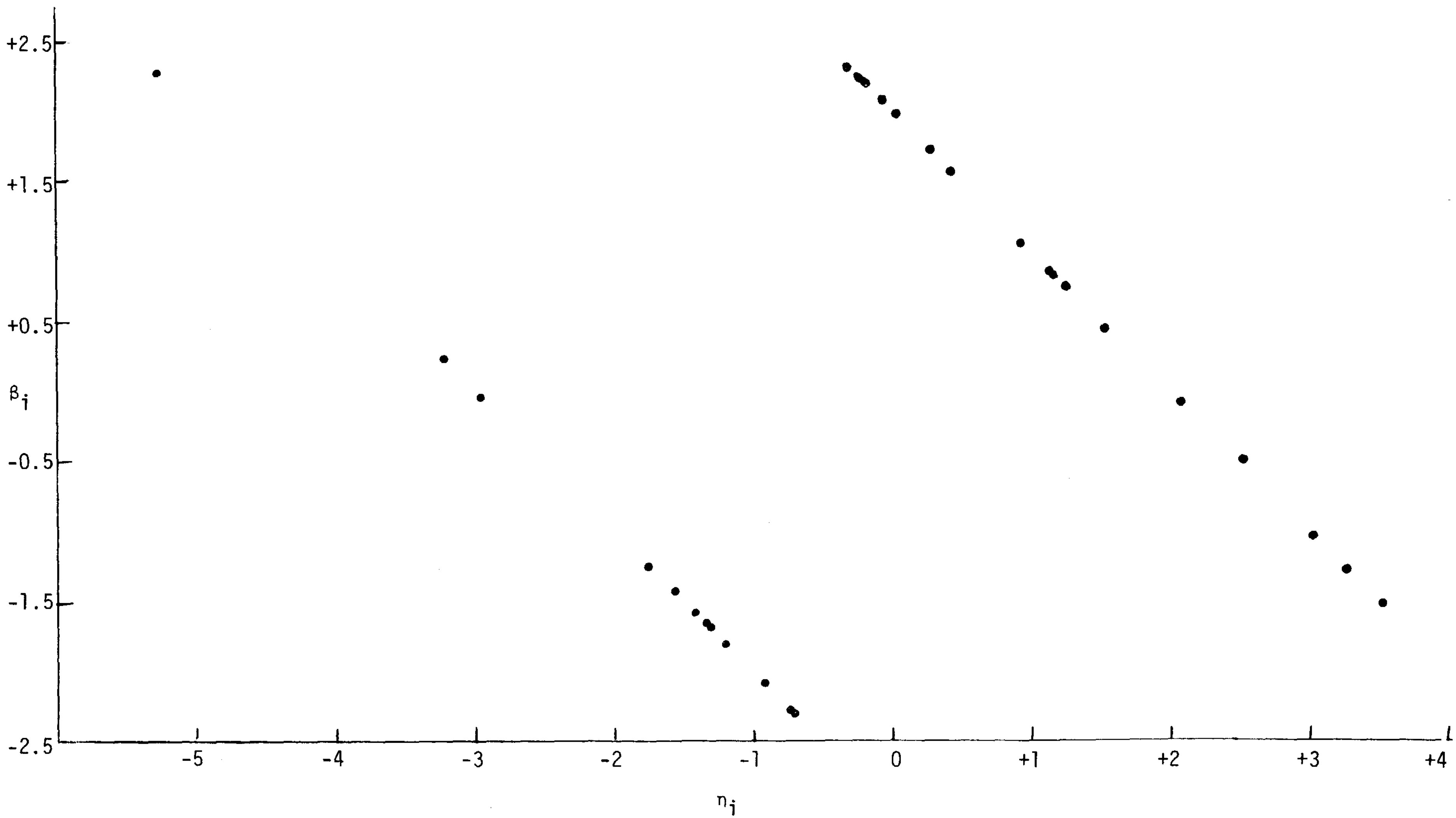
[2] Jaech, John L., Statistical Methods in Nuclear Material Control, TID-26298, U. S. Government Printing Office, 1973, p. 95-99.

[3] Cramer, Harold, Mathematical Methods of Statistics, Princeton University Press, Princeton, N.J., 1951, p. 361.

FIGURE (1)

β_i Versus η_i For

Table IV Data



Transmission Measurement Correction for Self-Attenuation in Gamma-Ray Assays of Special Nuclear Materials

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University of California
Los Alamos Scientific Laboratory

During the past several years, nondestructive assay (NDA) methods have become increasingly important in the measurement of special nuclear materials (SNM). Both active and passive methods have been vigorously exploited with much success in diverse applications, but among the various methods, passive gamma-ray assay is probably the most used at this time. Many applications of passive gamma-ray assay have been made in quality and process control, portal monitoring, inventory verification, waste management, and environmental monitoring. Frequently in such applications the self-attenuation of the naturally emitted gamma rays by the sample itself is significant and cannot be ignored. In fact, the central (and most difficult) problem in the NDA of bulk samples by passive gamma-ray spectroscopy is the correction of the sample self-attenuation. The difficulty arises from the rather low gamma-ray energies (typically 100 keV to 400 keV), the high mass attenuation coefficients of high-Z elements, the often unknown chemical composition of the sample, and sample volumes extending up to many liters. Quite often, in fact, samples are encountered for which passive gamma-ray assay for plutonium and uranium is impossible because the very large self-attenuation corrections required cannot be accurately made. Nevertheless, there are many cases and classes of material for which a careful passive gamma-ray assay is the most precise and accurate and the cheapest method for SNM determinations.

To exploit fully the potential of gamma-ray assay for those cases where it is applicable, as well as to identify clearly those cases where it is not, the Nuclear Safeguards Research Group at Los Alamos Scientific Laboratory (LASL) has for several years been working on the self-attenuation correction problem. It became apparent early that because of the severity of the problems in many plutonium and uranium samples, the usual calibration and attenuation correction methods involving direct comparison to standards or exploitation of prior knowledge of chemical composition are often not applicable. Determination of the sample linear attenuation coefficient (μ) by a separate transmission measurement with an external source has proven to be the most generally useful procedure. This paper briefly reviews the various procedures in use and presents some results of a detailed study of the transmission method of attenuation correction applied to the most important geometrical classes of assay samples, namely box-shaped and cylindrically-shaped samples. These classes include most of the distressingly large array of vials, bottles, cartons, boxes, cans, drums, crates, and barrels used for storing SNM.

GENERAL COMMENTS AND DEFINITIONS

We assume that the mixture of material to be assayed and matrix (everything other than the assay material) is reasonably uniform and that the particles of assay material are small enough to ignore self-attenuation within the individual emitting particles. In effect, this assumption states that the sample attenuation is characterized by a single linear attenuation coefficient, μ. Then knowing μ of the sample, the sample dimensions and the distance of the sample from the detector, it is possible to calculate the correction factor for the sample self-attenuation. Few closed forms exist for the correction factors and exact calculations must most often be done by numeric methods, but frequently it is possible to use an approximate analytical form of sufficient accuracy as discussed below.

The correction factor may be defined in several ways. Because assays are usually done by comparison to known standards of the same or nearly the same shape as the unknowns, the most generally useful form is the so-called correction factor (CF) with respect to the nonattenuating sample. Symbolically, the definition may be expressed as

$$CF = \frac{C(\mu=0)}{C(\mu\neq 0)} \quad (1)$$

where $C(\mu=0)$ equals the count that would have been obtained from the sample with no attenuation, and $C(\mu\neq 0)$ equals the actual count from the sample. $C(\mu=0)$, the quantity to be obtained in an analysis, is generally called the corrected count (CC) and is computed from the above definition, that is, $CC = CF \times C(\mu\neq 0)$, where CF is computed from the sample μ and the assay geometry, and $C(\mu\neq 0)$ is measured. Thus defined, the corrected count per gram of material assayed is constant, that is, the calibration curve is linear in terms of mass and corrected count.

Another useful correction factor form may be termed the correction factor with respect to a nonattenuating point (CF_p). Symbolically, this form is expressed as

$$CF_p = \frac{C_p(\mu=0)}{C(\mu\neq 0)} \quad (2)$$

where $C_p(\mu=0)$ equals the count that would have been obtained if the sample had been condensed to a nonattenuating point at the center of the sample, and $C(\mu\neq 0)$ equals the actual count from the sample, precisely as in the previous definition. This form of the correction factor is particularly useful when it is necessary to assay a large sample (such as a 55-gal drum) with respect to a small standard. If the sample μ and the appropriate dimensions are known, the two forms of the correction factor are equally difficult to compute; however, because it is of more general use, the rest of the discussion herein deals only with the correction factor with respect to the nonattenuating sample.

OUTLINE OF METHODS USED TO DETERMINE CORRECTION FACTORS

The various methods used in either finding or avoiding the attenuation correction will be recapitulated briefly.

Representative Standards. The oldest and perhaps still most used (and abused) method is that of avoiding the issue by using representative standards. In this procedure a set of standards is prepared as nearly identical as possible in size, shape, and composition to the unknowns, with varying concentrations of the material to be assayed. The standards are counted to prepare a calibration curve and the assay is accomplished by counting the unknowns and comparing the count directly to the calibration curve. This procedure will produce good results if (and only if) the unknowns and standards are sufficiently similar that the same concentration of assay material in each gives rise to the same sample μ and, therefore, to the same correction factor. In other words, at the same concentration of assay material, the exact same fraction of gamma rays must escape from both sample and standard. This method is only applicable in cases where the nature and composition of the assay samples are well known and unvarying as in the case, for example, with carefully prepared solutions.

Computation from Knowledge of Composition. A second method exploits previous knowledge of the chemical composition, mass, and shape to compute μ of the sample from which in turn the correction factor can then be computed. Sufficient prior knowledge to compute the sample μ does not necessarily imply that the assay result is known in advance. In many cases the assay material is a small and unknown fraction of the total sample mass and it is certain that μ is almost purely dependent on the matrix composition and mass.[1,2] When highest accuracy is not necessary and the required knowledge is available, this approach is useful.

Gamma-Ray Intensity Ratios. Another method of determining attenuation corrections, more discussed than actually used, involves measuring the relative intensity of two gamma rays of different energy emitted by the material under assay.[4] However, in general, μ of the sample for a given energy is not uniquely related to the intensity ratio, and again some prior knowledge of the nature of the sample is required. Furthermore, nature has not endowed all materials of assay interest with a pair of gamma rays of the appropriate energies. Nevertheless, the method has proved useful in particular cases, and it does have the potential for raising a warning flag when the assumption of reasonable uniformity is not met.[5,6]

Tranmission Method. A fourth and the most general method of obtaining the attenuation correction involves experimental determination of the sample μ directly by measuring the transmission through the sample of a beam of gamma rays from an external source.[1,2,7] This method requires no knowledge of the chemical composition of the sample, just the basic assumptions on uniformity and particle size. As such, it is the only practical way to proceed in the "black box" cases and is often the preferred method even when some knowledge of the sample composition is available, especially if the best obtainable accuracy is desired. The balance of this paper will be devoted to this method.

DETAILED CONSIDERATION OF TRANSMISSION METHOD

The sample transmission is defined as the fraction of gamma rays from the external source that pass through the sample unabsorbed and unscattered. From the fundamental law of gamma-ray attenuation, the sample transmission T is related to the sample μ by the relation $T = \exp(-\mu x)$, where x is the thickness of sample penetrated. Obviously, correction factors can be expressed either as functions of μ or T; however, because T is the measured quantity and the relationships are most conveniently graphed as functions of T, this parameter is used in the following discussions. It is assumed that T is measured normal to the center of the face of box-type samples and along a diameter passing through the midpoint of the axis of cylindrical samples. It is also assumed that the transmission is determined at the energy of the gamma ray used in the assay. The far-field correction factor for box-type samples has a simple closed form

$$CF = -\frac{\ln T}{1-T} \quad . \qquad (3)$$

The dependence of the CF(T) is shown in Fig. 1. Although not exact for near-field situations, this form is useful for assays where the distance to the detector from the face of the box is only ∿5 times the maximum dimension of the box. This is especially true in cases of large, somewhat heterogenous containers where a 10% error resulting from an approximate correction factor is much preferable to a ≥100% error resulting from neglect of the correction altogether. The discussion below with respect to cylindrical samples will help put the limitations in perspective.

No exact expressions for the CF of cylindrical samples can be written in terms of elementary functions. For the far-field case (cylinder radius and height negligible with respect to the distance to the detector), however, an expression exists in terms of Bessel functions and Struve functions,[8] but for near-field cases no exact expression of any form is known. The far-field case is conveniently taken as a reference case with which to demonstrate the general behavior of the CF for cylinders. Figure 1 shows the cylindrical far-field CF as a function of T as well as the far-field CF for a slab-type sample.

Note that for T<0.1, that CF∿log(T) applies for both cases. It is also noteworthy that because transmissions of less than 0.001 are very difficult to measure accurately, the range of readily accessible CF is about $1 \leq CF \leq 6$.

Because of the lack of exact analytical forms for near-field cases, much use has been made of approximate forms for cylindrical samples, the most useful of which has been

$$CF = k\,\ell n(T)/(T^k - 1) \qquad (4)$$

where k is a constant of value ∿0.8. This form is a slight modification of the exact far-field correction factor for a slab-type sample for which k = 1. A first-order approximation of the exact far-field form for the cylinder gives $k = \pi/4 = 0.785$, whereas empirical and numerical studies indicate k = 0.82 is better. Figure 2 shows the deviation from the correct far-field values of this approximate form for various values of k. For k = 0.82, CF is within 1-1/2% of the correct value for $0.01 \leq T \leq 1$ and within ±3% for $0.001 \leq T \leq 1$.

It appears that the value k = 0.82 is better than $k = \pi/4$ or k = 0.75 for far-field assays of cylindrical samples. However, the consequences of using an incorrect CF function over a restricted range of T and the relationship of the error in the computed CF to the error in the measured value of T should be explored. Assume that an approximate form with functional dependence on T,CF(T), has been used and that the correct function is $CF_o(T)$. The calibration constant is determined from a standard of transmission T_s and the unknown sample has transmission T_u. Next, let G be the unknown mass determined by using CF(T) and G_o be the "correct mass," that is, the mass that would have been determined from $CF_o(T)$. Algebraic manipulation then yields the relationship

$$\frac{G}{G_o} = \frac{CF(T_u)}{CF_o(T_u)} \bigg/ \frac{CF(T_s)}{CF_o(T_s)} \quad . \qquad (5)$$

Thus the ratio of measured to true mass depends not on the actual magnitude of the errors in CF(T), but only on the ratio of "used to true" CF ratios for the transmissions of the unknown and the standard. Figure 2 shows that for transmissions in the range $0.001 \leq T \leq 0.1$ the value k = 0.75 would give better results than k = 0.82 even though the absolute error in CF(k = 0.75) is greater over the range. However, if the range of transmission were $0.1 \leq T \leq 1.0$, the value k = 0.82 would be better. The best value of k to use for this approximate analytic form will depend on the range of T encountered, and a judicious choice may well reduce systematic errors by a few percent.

Now consider the fractional error in CF caused by a given fractional error in T. For the functional form, use $CF(T) = k\,\ell n(T)/(T^k-1)$. Then differentiating, we obtain

$$(dCF/CF)/(dT/T) = \left(\frac{1}{\ln T} + \frac{KT^k}{1-T^k}\right) \quad . \qquad (6)$$

Figure 3 shows this expression as a function of T for several values of k. Note that as T becomes smaller, and therefore more difficult to measure accurately, the fractional error in CF becomes smaller relative to the fractional error in T, thus compensating somewhat for the larger expected fractional errors in T. It should be emphasized that when only a small fraction of the gamma rays escape (small T and large CF) the sample, large fractional errors in the assay can result. A transmission measurement to determine the CF is the best way to proceed in such cases.

In the near field, cylindrical correction factors become functions not only of sample transmission, but also of the sample radius, height, and distance from the detector. A simple two-dimensional model is adequate to demonstrate the dependencies and is sufficiently accurate for much practical work. The model assumes a sample of radius R and zero height whose center is at a distance D from a point detector. The detector is in the plane of the now plane circular sample. In this model the CF is a function of T and the ratio D/R only, which means, for example, that given the same value of T, a sample of R = 1 cm with D = 10 cm has the same CF as a sample of R = 1 m with D = 10 m. Figure 4 gives the CF as a function of D/R for various values of T. These and all other near-field results were obtained by computer-executed numerical integrations. The essential point obtained from Fig. 4 is that the CF decreases as D/R decreases with the more drastic changes occurring for the smaller values of T. Remembering that the CF are with respect to the nonattenuating cylinder, the behavior just described can be seen qualitatively to be a consequence of the inverse square law. To show quantitatively the deviations from the far-field case as D/R decreases, the deviations are plotted in Fig. 5 as a function of T for various values of D/R. For D/R$\geq$50, the deviation from the far-field condition is less than 1% for T>0.0001. Therefore, D/R$\geq$50 can be regarded as the far-field condition for most purposes.

Obviously, no real samples are of zero height as assumed in the two-dimensional model, and the height of the cylindrical samples will influence the values of the CF. Numerical computations can again be performed for the three-dimensional case. Qualitative arguments show that the assumption of a point detector is good for nearly every case where the sample is at least several times the volume of the detector, and this assumption has been used in caluclations of CF for a cylindrical sample of finite height. It is of interest to get a qualititative understanding of how the CF for a cylinder of finite height varies from those of the corresponding two-dimensional case. Figure 6 gives the deviation for a cylinder whose height H is twice its diameter from the pure two-dimensional case for three values of D/R. The data quantitatively confirm what is qualitatively expected. The D/R>10 deviations from the two-dimensional limit are <1%. The deviations are greater for smaller values of T and for smaller values of D/R. Clearly, the deviations for given D/R also become smaller as H decreases relative to D.

CONCLUSIONS

When possible, a "far-field" assay geometry is preferred because of less stringent requirements of sample positioning and less dependency of the CF on the exact dimensions of the sample. Unfortunately, count rate considerations usually force the use of a near-field geometry to some degree. In any case, but especially in near-field situations, (D/R<10 for cylinders), it is best to use the CF values computed for that geometry. However, obtaining those values is often awkward because of the lack of analytic forms for CF(T).

Two reasonable alternatives are suggested. The first is to prepare a graph similar to Fig. 2 for the particular geometry in order to choose an approximate form (such as the one discussed herein) that will give adequate accuracy over the anticipated range of T. In doing so, it is important to remember that the CF(T) function may be in error in an absolute sense, but still provide adequately accurate assays over large ranges of T. The second alternative, useful when a computer does the analysis, is to store enough previously calculated CF values for the geometry in the computer to allow accurate interpolation. Although this paper deals with cylindrical and box-type samples viewed from the side, other configurations can obviously be dealt with in similar fashion.

Just a word about experimental standards is in order. In principle, a single standard will suffice if the proper selection of CF(T) has been made, but clearly, it is prudent to have two or more standards spanning the expected range of values of T. It should be emphasized that the standards need not have the same or even similar chemical composition as the unknowns inasmuch as the CF is dependent only upon the transmission value, sample shape, and assay geometry.

In all that has been done, high resolution detectors have been assumed so that only a negligible number of Compton scattered gamma rays are included in the full energy peak areas. Coherent scattering does introduce a rather fundamental limitation in that the measured transmission may not yield quite the correct effective μ for the sample. For large samples the effect may be $\sim$1%. Most often the sample heterogeneity will determine the accuracy attainable.

This paper has not discussed the hardware problems involved in the determination of the transmission and the intensity of the emitted gamma rays. Quality assays must include skillful data acquisition as well as proper treatment of the sample self-attenuation. Nevertheless, in frequently met cases neglect or improper handling of the self-attenuation correction can give rise to very large errors ($\geq$100%), which sloppy acquisition techniques can rarely equal, hence the emphasis of this paper on the sample self-attenuation problem.

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FIGURE CAPTIONS

1. Far-field correction factor for cylindrical and slab-type samples as functions of transmission.

2. Deviations from the correct far-field cylindrical correction factors of the approximate form CF(T) = k ℓn(T)/(T^k-1) for several values of k.

3. The differential change in the correction factor relative to the differential change in transmission for several values of k in the approximate form CF(T) = ℓn(T)/(T^k-1).

4. Near-field correction factors for the two-dimensional cylinder as a function of the ratio of the sample center-detector distance to the sample radius for various values of transmission.

5. Deviations as a function of transmission of the near-field correction factors for the two-dimensional cylinder from the far-field cylindrical correction factors. D/R is the ratio of the sample-center to detector distance to the sample radius.

6. Deviations of the three-dimensional cylindrical correction factors from the corresponding two-dimensional case for cylindrical sample whose height is twice its diameter. D/R is the ratio of the sample center to detector distance to the sample radius.

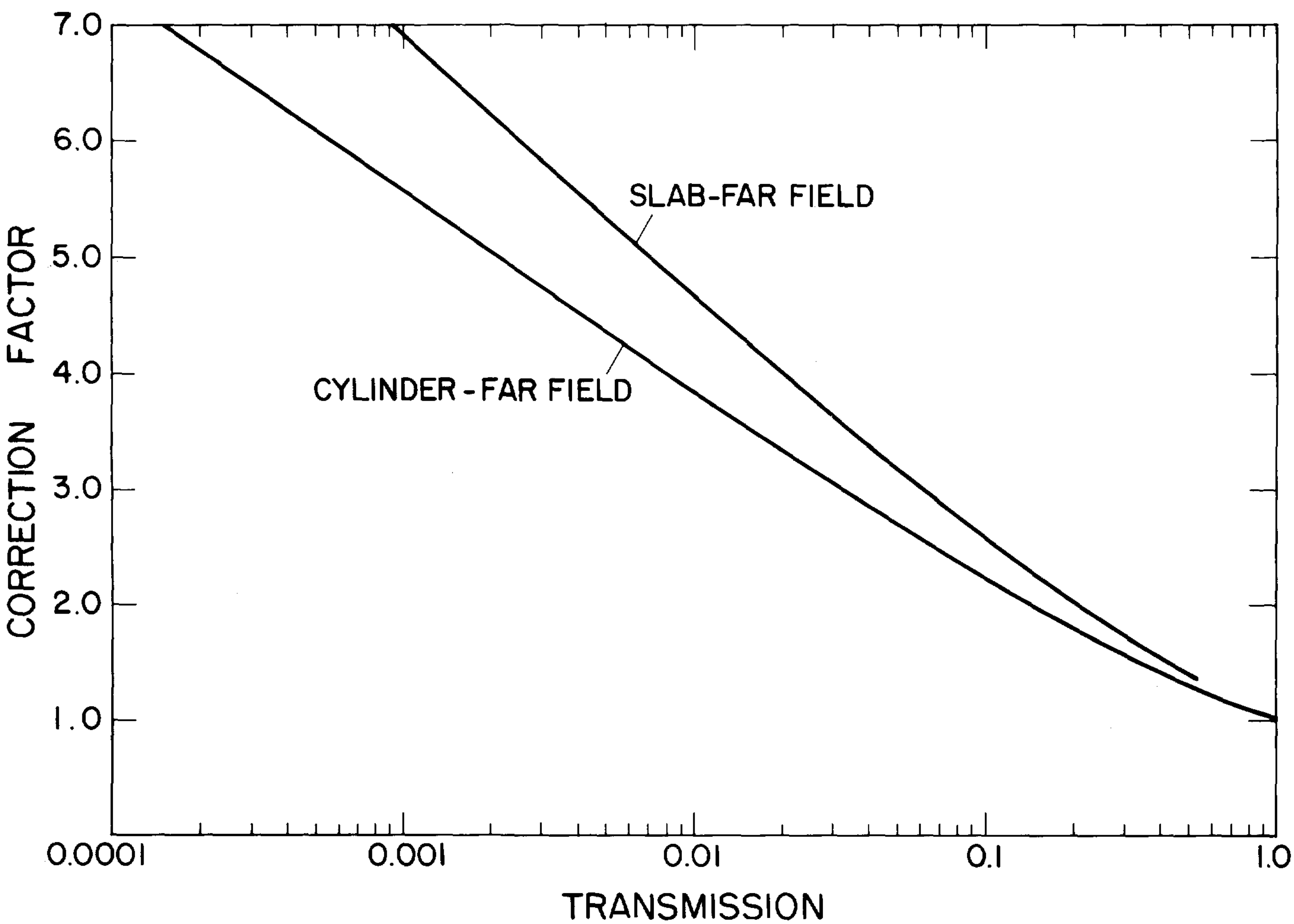
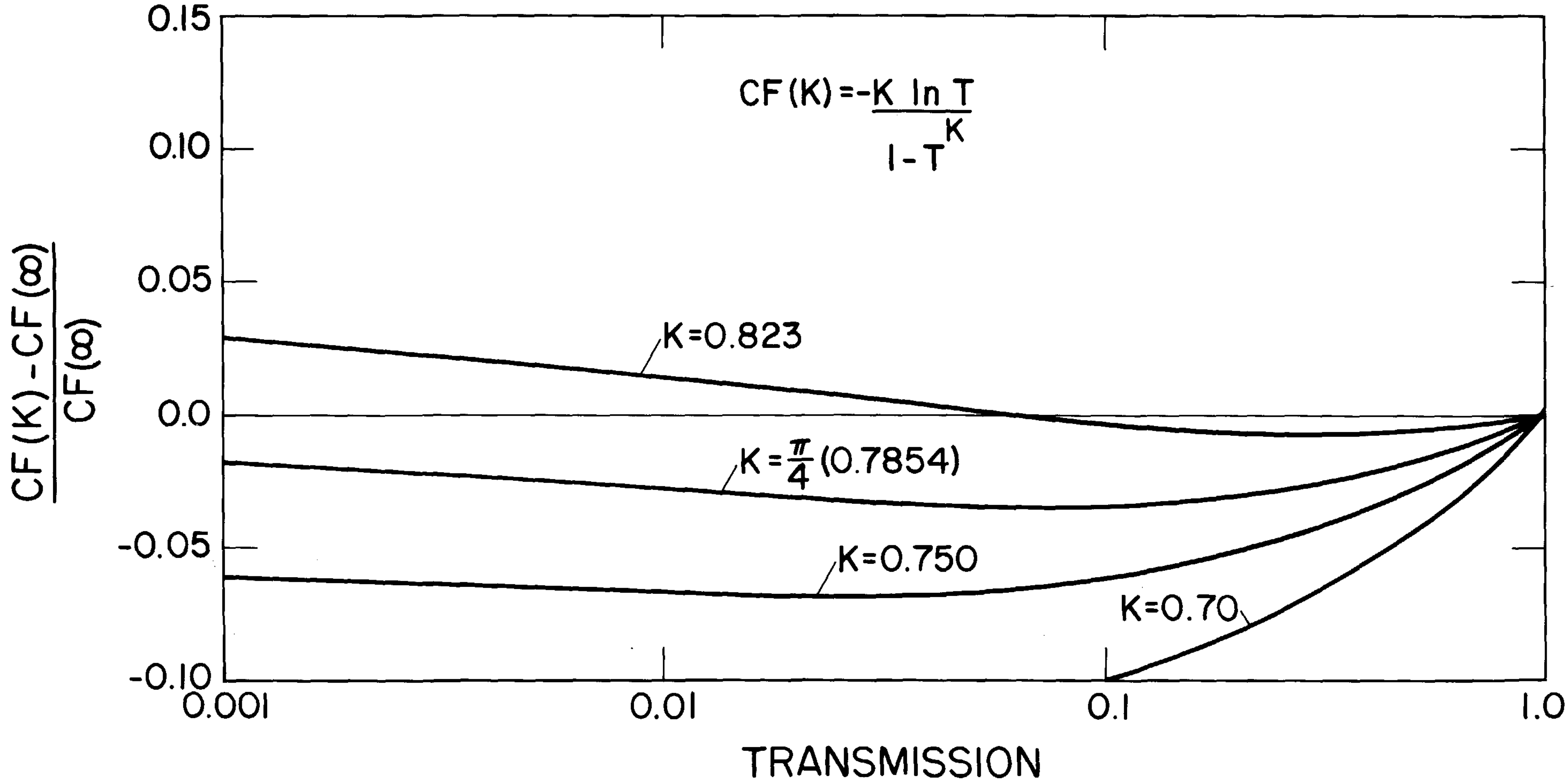


Fig. 1



0.15
0.10
0.05
0.0
-0.05
-0.10
0.001
0.01
0.1
1.0
TRANSMISSION
$\frac{CF(K) - CF(\infty)}{CF(\infty)}$
$CF(K) = \frac{-K \ln T}{1 - T^K}$
K=0.823
K = $\frac{\pi}{4}$ (0.7854)
K=0.750
K=0.70

Fig. 2

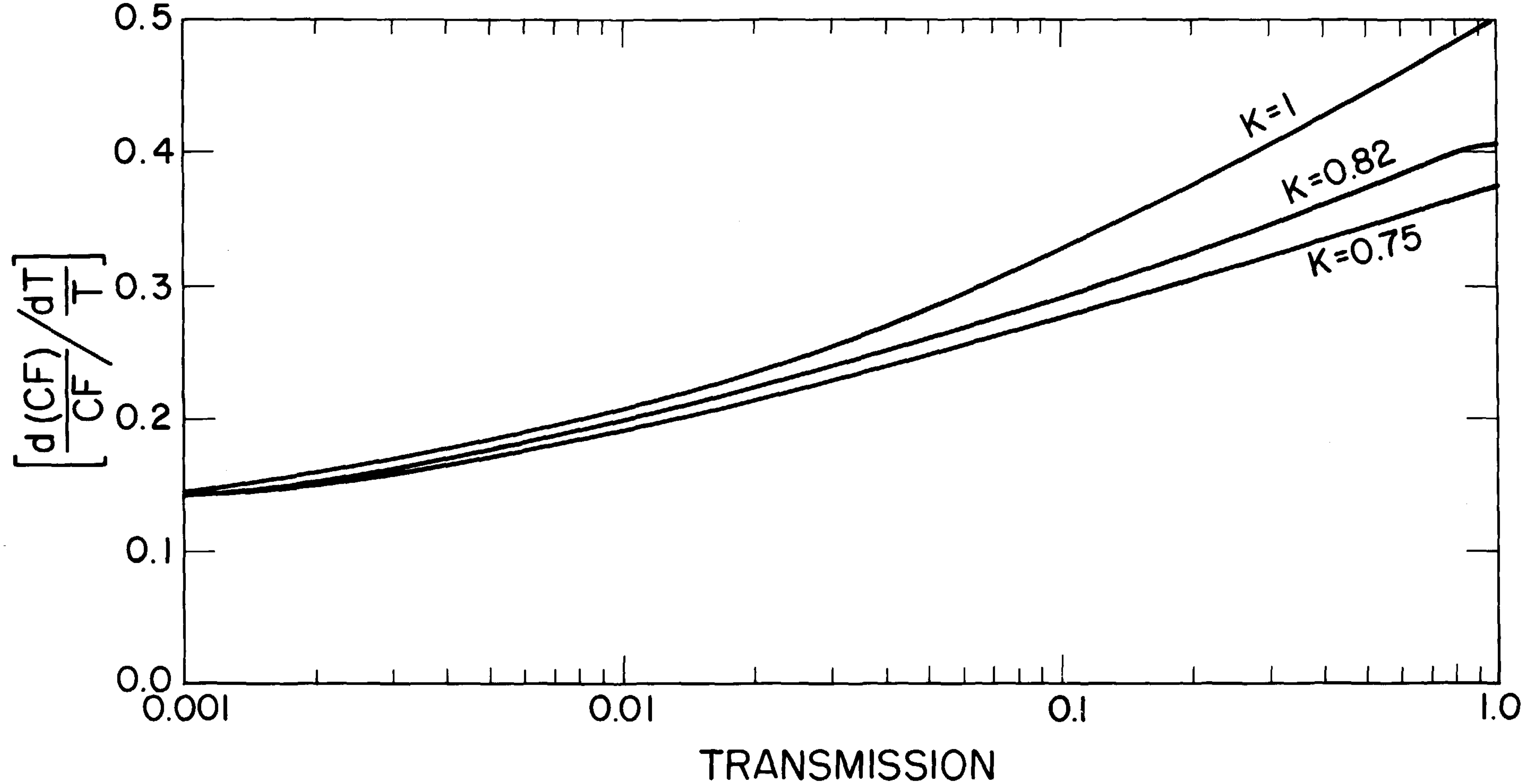

0.5
0.4
0.3
0.2
0.1
0.0
[d(CF)/CF / dT/T]
K=1
K=0.82
K=0.75
0.001
0.01
0.1
1.0
TRANSMISSION

Fig. 3

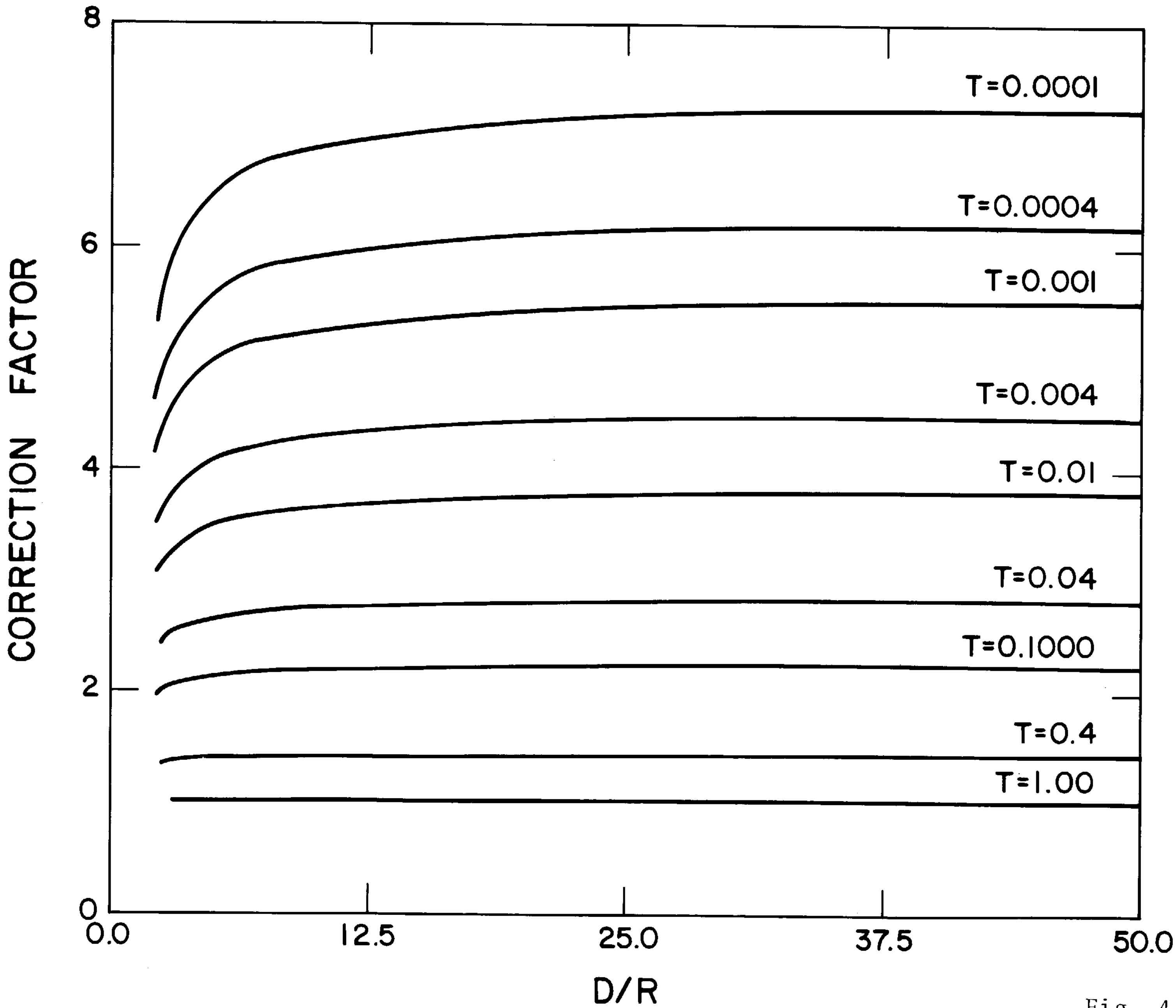

8
6
4
2
0
CORRECTION FACTOR
T=0.0001
T=0.0004
T=0.001
T=0.004
T=0.01
T=0.04
T=0.1000
T=0.4
T=1.00
0.0
12.5
25.0
37.5
50.0
D/R

Fig. 4

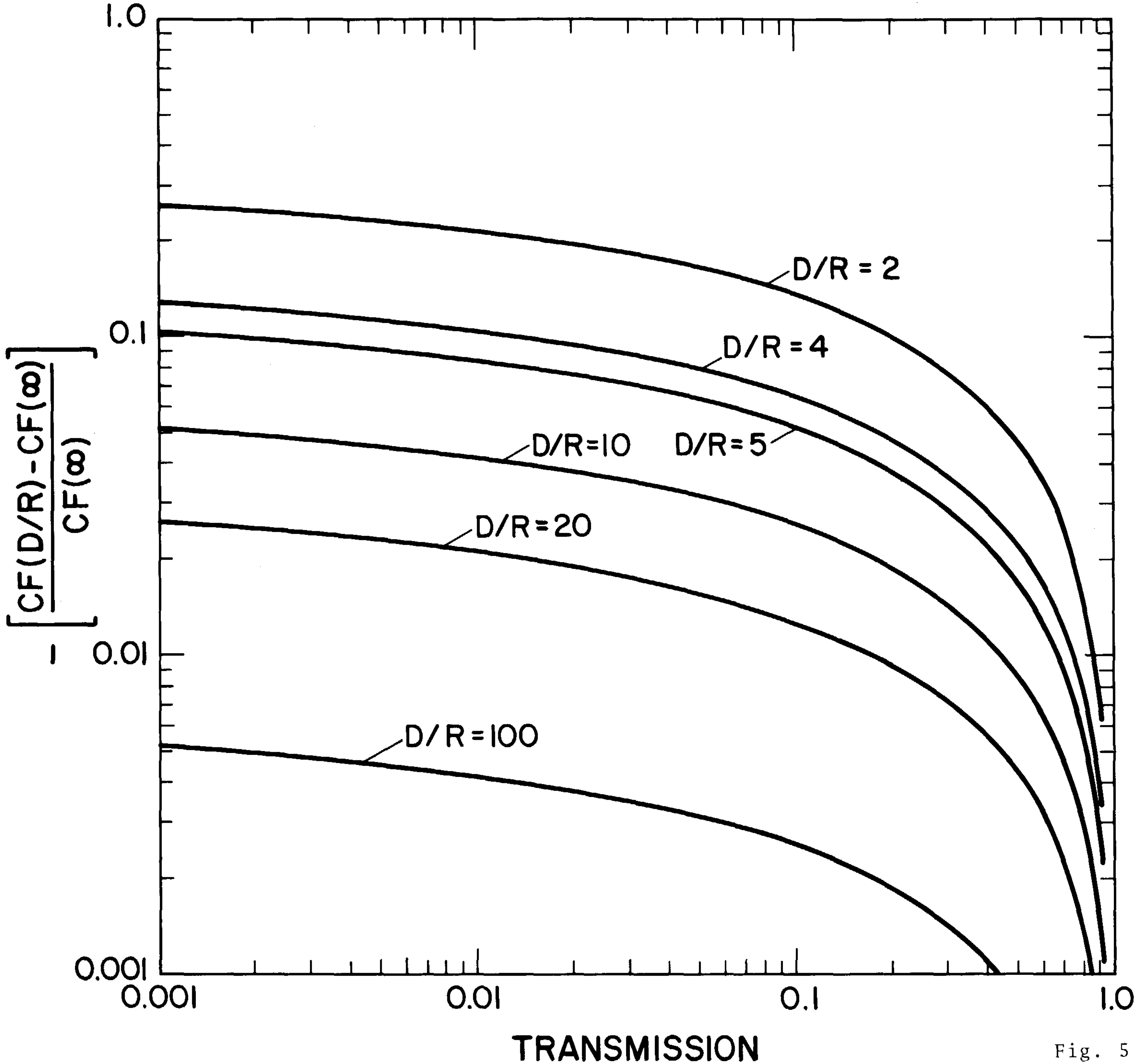

1.0
0.1
0.01
0.001
0.001
0.01
0.1
1.0
TRANSMISSION
$-\left[\frac{CF(D/R)-CF(\infty)}{CF(\infty)}\right]$
D/R = 2
D/R = 4
D/R = 5
D/R = 10
D/R = 20
D/R = 100

Fig. 5

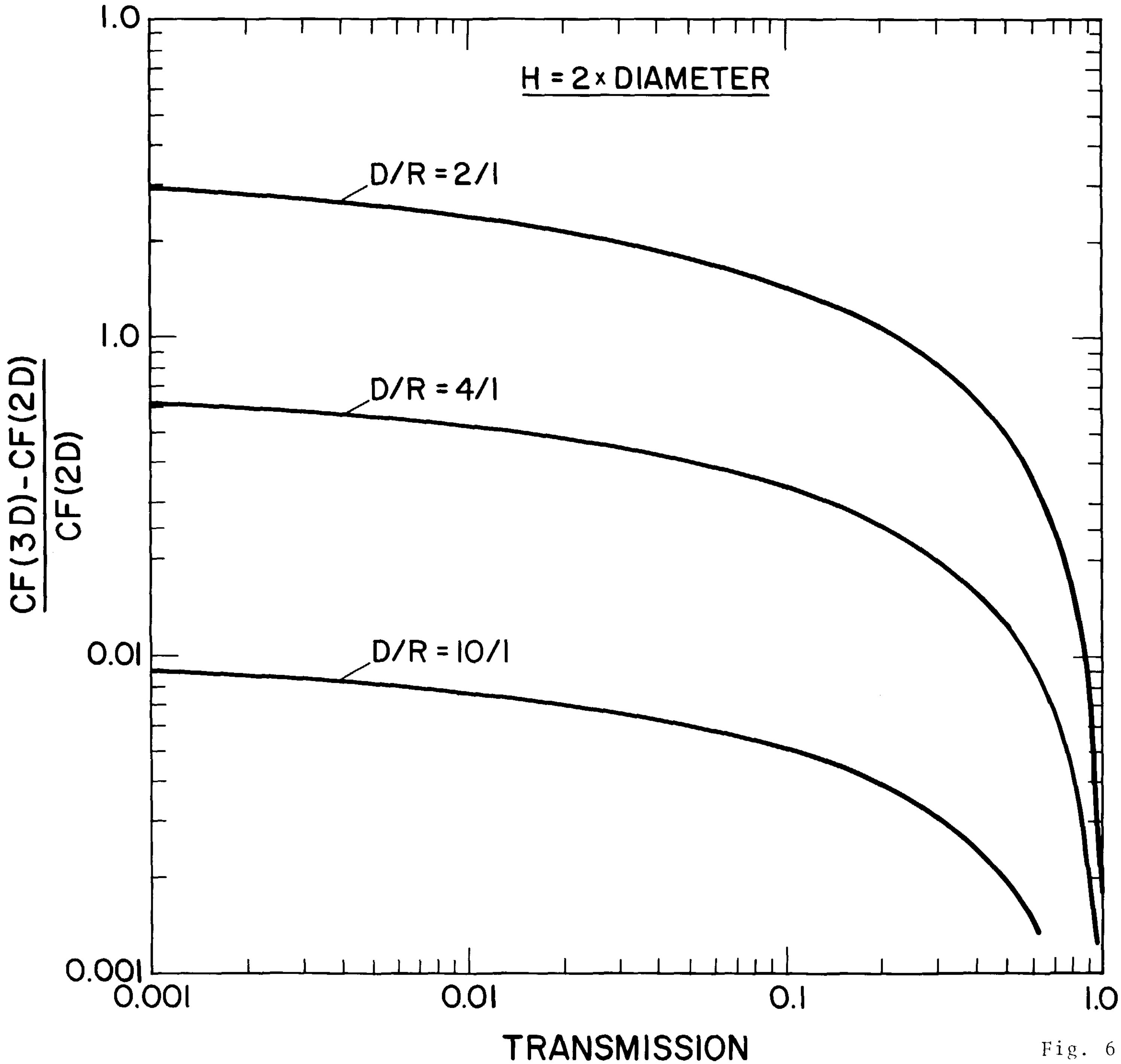

H = 2 x DIAMETER
D/R = 2/1
D/R = 4/1
D/R = 10/1
1.0
1.0
0.01
0.001
CF(3D)-CF(2D) / CF(2D)
0.001
0.01
0.1
1.0
TRANSMISSION

Fig. 6

INDEX OF ARTICLES (1972-1976)

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

NEW BOOK

Nuclear Reactor Fuel Elements

The Energy Research and Development Administration has recently published *Fundamental Aspects of Nuclear Reactor Fuel Elements* by **Donald R. Olander,** Department of Nuclear Engineering, University of California, Berkeley. We would appreciate your publishing a review or an announcement of this book which is written for the first-year graduate student in nuclear materials and for those involved in materials design and the performance of nuclear reactors for electric power production.

One of the critical areas on which economic viability of nuclear energy hinges is the performance of the ceramic fuel and of the metallic structural components of the core, both of which are subject to conditions of higher temperature and radiation fields. Research on the behavior of materials under such conditions is relatively recent, and this book applies this research to the practical problem of predicting the performance and longevity of reactor fuel elements.

The approach is analytic rather than descriptive. The aim is to make very clear the relation between a model of the performance of some feature of a fuel element and simple, basic physical principles with which the reader is familiar. This philosophy means that a number of standard, classical formulas that constitute the starting point for many fuel-element performance analyses are derived rather than simply presented. The ultimate purpose is to convey an understanding of the physical processes occurring in metals and ceramics which, when taken together, produce the complex irradiation behavior of a nuclear reactor fuel pin. No attempt has been made to provide a method for rational design of a fuel element.

The book is available as TID-26711-P1 from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161, for $16.25 ($18.75 foreign). 21 chaps., appendix, index, 624 pp., 8 1/2 x 11 in., paperbound, Library of Congress Catalog card number 76-6485 (CIP). Solution to problems given at the end of each chapter are available in a companion volume, TID-26711-P2. *Solutions to Problems,* 573 pp., 8 1/2 x 11 in., $13.50 ($16.00 foreign).

"Planning for the 1980 Census: What are your suggestions?"

The decennial census is a major national undertaking, and census data are widely used in many important government, private, and community programs. You have an important stake in the decennial census, both as a member of INMM and as an American citizen.

The Census Bureau is now actively working on plans for the 1980 census and important decisions have to be made in the relatively near future. For example, the full content of the basic census questionnaire must be determined by the spring of 1977 so that further preparatory steps can be accomplished successfully.

Although there are many constraints on the census in terms of what and how much information can be collected and tabulated, the Bureau believes that it is very important to obtain and review the recommendations of as wide a range of users and potential users of decennial census data as possible. The Census Bureau is therefore anxious to have the ideas of the members of INMM.

If you have any suggestions, questions, or comments on the 1980 census, please send them to: Director, U.S. Bureau of the Census, Washington, D.C. 20233.


Baston


Bingham


Dickeman


Jaech


Lowe


Parker


Reed

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Reilly

Waterman

Yolken

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New Radioactive Waste Facility Dedication Set

LOS ALAMOS, N.M.—Nuclear waste, unlike conventional garbage, cannot be flushed down a kitchen sink disposal unit or hauled off to the municipal dump.

The classic dilemma posed by the disposal of radioactively contaminated waste material is therefore being tackled on an accelerating scale by the Energy Research and Development Administration (ERDA) through programs such as the broad waste management research effort at the University of California's Los Alamos (N.M.) Scientific Laboratory (LASL).

Funding for LASL's waste management program is expected to be boosted from the current $1 million in fiscal year 1976 to about $4 million in fiscal 1977, with part of the money earmarked for the operation of a new radioactive waste Treatment Development Facility (TDF) that will be dedicated in Los Alamos August 19.

The new plant is the first ERDA facility dedicated solely to the study of waste management methods. It was constructed at a cost of $900,000 through ERDA's Division of Nuclear Fuel Cycle and Production. It's goals are to find safer, cheaper ways to reduce the volume and eliminate the combustibility of low-level contaminated waste from plutonium processing facilities.

Dr. **Thomas K. Keenan,** head of the LASL Waste Management Program, said the new facility will become the focal point of the Los Alamos program and will house a broad spectrum of waste handling research in its 10,600 square feet.

The search for suitable storage for high-level waste from nuclear reactors has been very well publicized. However, as Keenan points out, every item that is taken into a plutonium processing area must be regarded as contaminated and must be handled and disposed of accordingly.

"It is to this area that the new facility is dedicated," he says. "To look for the best and most economical ways of reducing the volume of low-level waste, stabilizing its chemical composition, and eliminating its combustibility."

In the last decade, ERDA's predecessor the U. S. Atomic Energy Commission (AEC), mounted an intensive study of radioactive waste disposal methods. One result was a 1973 directive that established new criteria for disposal of low-level contaminated waste.

The AEC established an upper limit of 10 nanocuries per gram (a measure of specific radioactivity) for immediate burial of such contaminated waste, and directed that all material containing more than this amount of radioactivity should be stored for eventual retrieval.

LASL scientists, as part of their waste management research, developed new techniques for accurately measuring the amount of radioactivity in contaminated trash. In other parts of the waste management program they are testing materials to determine those that will be best for storing waste, identifying the residue of waste coming from processing areas and looking for ways to cut down on the amount generated, and, with construction of the new TDF, they will search for safer, cheaper ways to reduce the fire potential of buried waste and evaluate methods for reducing waste volume.

Lee Borduin, who will head the day-to-day operation of LASL's new facility, says one of the findings of an AEC task force appointed to study the waste disposal problem was that incineration promised to be the best way to achieve the major goals of low-level waste handling.

The new facility will employ a conventional incinerator such as is used in many municipal disposal programs. It will be modified, however, to confine radioactivity and protect workers from contamination.

Borduin says the facility will handle up to 100 pounds of waste per hour, in a program designed to provide an economic comparison of this method of volume reduction versus other methods. The TDF is strictly a research and development facility, he points out, and results of the "figure of merit" economic comparison will be passed on to industry.

Typical low-level contaminated waste from LASL's plutonium processing areas includes rubber, paper, cardboard, wood, plastic, glass, ceramics, and metal.

Beginning in mid-1977, material generated in LASL plutonium operations will first be assayed for transuranic content (the amount of heavy elements, primarily plutonium, present in the trash), then shipped in sealed cartons to the new Treatment Development Facility.

Before being burned, it will again be counted for plutonium, scanned for metal objects with an x-ray machine such as is used on luggage at airports, then fed to the lower chamber of a dual-chamber incinerator by a ram feeder through a series of air locks.

Fired by natural gas burners, the lower incinerator chamber will reach a temperature of 1,500 degrees Fahrenheit. Small particles and hot combustion gases will rise to an upper chamber where the temperature will reach more than 2,000 degrees.