NUCLEAR MATERIALS MANAGEMENT

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Feature Articles

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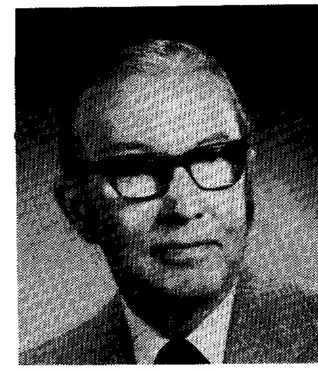
INMM Editorial



Dr. William A. Higinbotham
Brookhaven National Laboratory
Upton, New York

A Visitor's Impression of the Vienna Chapter–

During visits to the IAEA last fall and winter, I had the pleasure of attending four meetings of the Vienna chapter of our Institute.

The first fall meeting was a dinner meeting at a heurigen or wine-garden attended by 18 members, 13 wives and guests. Vince DeVito, Secretary of the INMM, gave an interesting talk about Institute affairs, anti-nuclear activities in the U.S., and plans for the centrifuge enrichment plant being constructed in Ohio. Peggy and I enjoyed the opportunity to get acquainted, and we sang a few songs before going home.

The Honorable Andre Petit addressed the second meeting in October. M. Petit is the French member of the Standing Advisory Committee on Safeguards Implementation (SAGSI) of the IAEA. He lived up to his reputation for being provocative. It was a stimulating talk and discussion.

The next meeting that I attended was, like the 2nd meeting, a luncheon meeting at a nice restaurant in the beautiful park that almost surrounds the UNO building. Since I was the featured speaker, I will only say that the members in attendance were kind and considerate.

The 4th event was most impressive. In the fall, the chapter sent out a notice inviting members to contribute papers for consideration for presentation at the forthcoming annual INMM meeting in San Francisco. From the contributed papers, six were selected for presentation at a symposium, held in a big auditorium in the UNO building, where the IAEA is located. Les Thorne, chairman of the Vienna chapter presided. The Canadian ambassador to the IAEA gave a very sensible introductory talk on the importance of international safeguards and on the challenge to the IAEA, after which the six papers were presented and discussed. The meeting lasted from 2 until after 5 p.m. A very large fraction of IAEA's safeguards personnel attended, as well as several officers and inspectors from Euratom.

This was a most impressive and inspiring performance. The papers were excellent. It is significant that this event had the support and the participation of the Deputy Director General for Safeguards, and the active participation of so many extremely busy Agency people.

The Vienna Chapter is healthy and effective. It has a number of unique advantages: a large group of safeguards experts in one place, members directly involved in international safeguards, and members from many nations who have an interest in discussing safeguards with each other.

Because IAEA personnel travel throughout the world to participate in meetings and to perform inspections, I look to them to encourage those engaged in safeguards in other countries to join the Institute so that we can become a truly international organization to promote cooperation on international and on national safeguards.

Personnel...

Dale A. Moul - CPP was admitted to the Bar of the State of Virginia on April 30, 1981. Mr. Moul is the Manager, Security Programs Division, NUSAC, Incorporated, a subisidiary of the Wackenhut Corporation. Mr. Moul earned a B.S. in Police Administration (Specialized in Industrial Security) from Michigan State University (graduated Magna Cum Laude), attended the University of California at Berkeley in the Master of Business Administration program, and received a J.D. degree in law from the University of Maryland Law School. While at MSU, Mr. Moul was a member of the MSU Honors College and Phi Kappa Phi National Honorary Society.

Mr. Moul is responsible for managing all of NUSAC's security services, which include the preparation of plans and programs for the physical protection of nuclear power generating plants, reprocessing facilities, fuel fabrication plants, engineering laboratory facilities, and other energy related facilities against acts of terrorism, sabotage and theft or diversion, as well as development of security programs for industry and government.

Darrell A. Hyde - of Union Carbide Nuclear Division and a major developer of NMMSS will leave Oak Ridge to join NUSAC effective May 1. Hyde was first associated with the U.S. nuclear program during the Manhattan Project in 1945.

Since 1964, he has been manager of development and operation and a consultant for NMMSS, the U.S. Nuclear Materials Management and Safeguards System, which provides information and analytical support for domestic and international safeguards. Hyde's professional assistance, consultation, and technical support to the Nuclear Regulatory Commission, the Department of Energy, the Department of State and the Arms Control and Disarmament Agency have contributed materially to the successful implementation of the Safeguards Agreement between the United States and the International Atomic Energy Agency. He has served as a consultant to the Commission of the European Communities in the Directorate of Euratom Safeguards and to the IAEA in the Department of Safeguards on the development and utilization of safeguards information support system.

At NUSAC, Hyde is a Project Manager in the Quality Programs Division and is responsible for design and development of material control and accounting systems, development of information systems, and assistance to the Security Division in the design, operation and maintenance of data accumulation and processing systems.

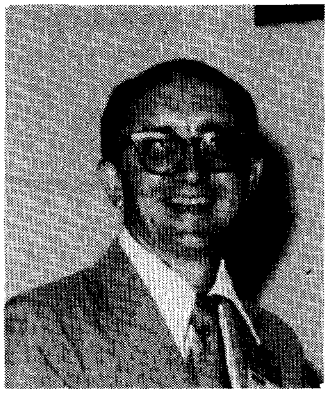
Hyde is a native of Robbinsville, N.C. and is married to the former Ruby Craft of Bryson City. They have two children; Lacy, an engineer with the Clinch River Breeder Reactor in Oak Ridge, and Susan, with the Tennessee Department of Human Services.

Dean D. Scott - was recently named manager of Safeguards at Battelle's Pacific Northwest Laboratories. Scott has 15 years experience in safeguards and nuclear materials control and was a senior engineer in the Safeguards and Materials Management Department at Westinghouse Hanford. Previously, he worked for the General Atomic Company, Babcock and Wilcox and AVCO Corporation.

In his new assignment, Scott will direct a staff who are responsible for managing, accounting and controlling all nuclear materials used by Battelle researchers. The former Safeguards Manager, Hank Henry, will be a consultant to Battelle following his retirement in April.

Battelle's Pacific Northwest Division, with laboratories at Richland, Seattle and Sequim, Washington, was established to perform research and development for industry and government agencies and to operate the Department of Energy's Pacific Northwest Laboratory. The Division is a component of Battelle Memorial Institute, the world's largest independent research institute. Other major Battelle research facilities are located at Columbus, Ohio; Frankfurt, West Germany and Geneva, Switzerland.

Chairman's Column



Gary Molen
E.I. du Pont de Nemours & Co.
Aiken, South Carolina

As we expected, 1981 has begun as a very active year. The Executive Committee, at its last meeting in Denver, Colorado, deliberated for three days over many important issues. Among some of the more important issues discussed was the role of the Institute as the Secretariat for the ANSI Committee N-14 "Standards for the Packaging and Transportation of Nuclear Materials." After much discussion and very helpful input from Bob Jefferson and Jim Lee, both of whom have been active in N-14 activities, the Executive Committee voted unanimously to accept the Secretariat. Accordingly, ANSI has been so advised. The Executive Committee also approved Jim Clark of NFS as the new chairman of N-14. Congratulations, Jim!

In other business conducted at the last Executive Committee meeting, the Committee heard an excellent report by Debbie McDaniel and Jim Hamilton on the physical protection workshop conducted at Charleston, South Carolina. Based on this report, I would strongly encourage those of you in the physical protection field to avail yourself at their next workshop. For more information on that subject see Tommy Sellers' article on the Physical Protection Technical Working Group. As you can see from his report this group is very active.

Based on a report by the Annual Meeting Committee, the program for the San Francisco meeting is shaping up to be another great meeting. A number of new things are being tried so I encourage you to get up to date on the plans for this very important meeting and begin to make your plans now to attend.

The Certification Board has now swung into high gear and they will be prepared to offer certification examinations to those who are interested. I urge you to look into this valuable and timely program. Along with the Certification Program progress we are continuing to offer special training courses in statistics and accountability. See Harley Toy's Education Committee report for more information.

The By-Laws and Constitution Committee has prepared amendments to the By-Laws and Constitution, which the Executive Committee has approved, dealing with graded membership. You'll be hearing more about this subject at the Annual Meeting when you will be requested to vote on these proposed changes.

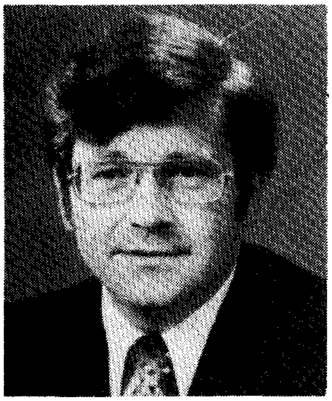
Who says there's no fun at an executive committee meeting? (Denver, April 1981)

INMM Executive Committee Meeting held in Denver, April 1981

As I pointed out in the last issue of the Journal, the Safeguards Committee continues to be quite active and very productive. Interested members of the Committee met with Bob Burnett of NRC and had a very informative and useful discussion on some proposed changes to the regulations governing the control and accounting of low-enriched uranium. Mr. Burnett has agreed to have similar meetings on a regular and routine basis. The intent of such meetings would be to provide a vehicle for the regular exchange of views between the NRC and the Institute and thereby improve the overall application of nuclear materials safeguards in the U.S. A similar type of dialogue is being explored with the U.S. State Department. Hopefully, the resulting discussions will help to improve the implementation of IAEA safeguards worldwide as well as in the U.S.

In closing, let me again appeal for more volunteers. We need your help and we want your input!

INMM Safeguards Committee Report



Robert J. Sorenson
Battelle Pacific Northwest Laboratory
Richland, Washington

The INMM Safeguards Committee met at Stouffer's Denver Inn on April 9-10, 1981. Attending the meeting were:

Jim de Montmollin	Charles Vaughan
Dick Duda	Gene Weinstock
Ralph Lumb	Bill Powers
Howard Menke	Bob Keepin
Roy Nilson	Bob Sorenson

A number of ideas which are under various stages of development are being actively pursued by the Committee. I'll report on just a few of the Committee's activities at this time.

Howard Menke held a meeting on February 26 in Washington, D.C. to review some proposed changes to the federal regulations which impact material safeguards. His working group has developed substantive comments and recommendations for the NRC on three proposed rule changes:

- "Proposed General Statement of Policy and Procedures for Enforcement Actions"
- "Protection of Unclassified Safeguards Information"
- "Periodic and Systematic Review of Regulations"

A subcommittee has been established with Dick Duda as chairman to channel information between the U.S. safeguards community and international safeguards working groups. While the government and national laboratories may already be doing this, industry in particular is not. Because the INMM is a professional society, it provides an opportunity for all the various segments of the safeguards community to discuss and comment on the activities of these international working groups. The Safeguards Committee believes that inclusion of all the segments of the safeguards community has been missing. Dick Duda will develop and plan the activities of this subcommittee and enlist members over the next few months.

Charles Vaughan convened an ad hoc working group on March 24 to formulate a position paper for proposing changes to the requirements for low enriched uranium. The meeting was held to prepare for the April 15 dialog meeting between the NRC and the Safeguards Committee. The working group was composed of Roy Nilson (Exxon Nuclear), Tom Bowie and Gary Kersteen (CE), Bill Powers (B&W), Howard Menke and Wilbur Goodwin (W), Wally Hendry and Charles Vaughan (GE), and Ralph Lumb (NUSAC). The Committee proposes changes in the regulations regarding multiple MBA's, inventory frequencies, in-plant transfer documentation, tamper-safing, and LEID. The proposal was extensively reviewed by the entire Safeguards Committee during the Denver meeting.

The Safeguards Committee met on April 15, 1981 with Robert F. Burnett and some of his staff from NRC's Division of Safeguards. It was a very fruitful meeting where a number of ideas were exchanged and a healthy dialog ensued. During the meeting, the Committee presented its recommendations to the NRC for changing some of the regulations for low enriched uranium at bulk handling facilities. We were very pleased with the presentation and its reception by the NRC and are optimistic that some very beneficial changes in the requirements will be forthcoming. Bob Burnett has agreed to have further meetings with the INMM on a regular basis, starting as quarterly meetings. The next meeting is tentatively scheduled for July.

Other topics discussed during the meeting were the NRC's impression of the recent IAEA inspection of Exxon Nuclear's low enriched fuel fabrication plant, the possibility of disseminating "lessons learned in the materials safeguards area" to the INMM and the safeguards community, the NRC's reaction to the Committee's comments on three recently proposed rules, and the proposed MC&A reform amendment.

News Release

Nuclear Generated Electricity Surpasses Oil in U.S.

Official 1980 data released by the Department of Energy showed that for the first time in history, U.S. utilities have generated more electricity with nuclear energy than with oil. While nuclear power generation dropped last year by 1.6 percent (as a result of post-TMI modification requirements), the use of oil fell amost 19 percent, and overall electrical generation increased by 1.7 percent.

A summary of the contributions of the various energy sources to the U.S. electrical supply in 1979 and 1980 is shown in the following table.

U.S. ELECTRICAL GENERATION

Source	1980 Billion kwh	1980 Percent of Total	1979 Billion kwh	1979 Percent of Total
Nuclear	251.1	11.0	255.2	11.4
Coal	1,161.6	50.8	1,075.0	47.8
Oil	246.0	10.8	303.5	13.5
Gas	346.2	15.1	329.5	14.7
Hydro	276.0	12.1	279.8	12.4
Other	5.5	0.2	4.4	0.2
Total	2,286.4		2,247.4	

Constitution and ByLaws Committee Report

Roy G. Cardwell
Union Carbide - Nuclear Division
Oak Ridge, Tennessee

Graded Membership Approved by Executive Committee

The joint report of the Ad Hoc Committee on Graded Membership, chaired by R.D. Smith, and the Constitution and Bylaws Committee recommending the establishment of new membership grades and classifications and other changes was accepted and approved by the Executive Committee at the Denver, Colorado, meeting in April. The INMM is indebted to R.D. Smith for the excellent job of writing the graded membership proposal.

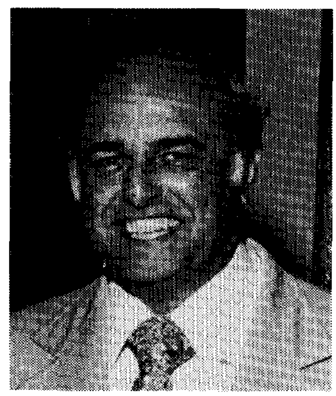
The proposal redefines the classification of Member, Student Member, and Emeritus Member and creates the new grades of Senior Member and Fellow and the additional classification of Honorary Member. "Corporate" membership would be replaced with "Sustaining" membership - open to any company, government agency, or other collective group which "shares the objectives" of our Constitution.

As an interesting note, INMM has one Life Member, officially designated by the Executive Committee several years ago. She is Ella Werner, our first Journal Editor (then a newsletter) who now lives in Sarasota, Florida.

Other changes to the Constitution and Bylaws approved by the Executive Committee include the reinsertion of the word "management" in referring to the "safeguards and management" of materials. Many Members strongly protested the replacement of "management" with "safeguards" in the last revision; and on reconsideration, the Committee felt neither term in itself completely encompassed our purpose and that both should be included. Other sections affecting admission, dues, resignation, expulsion, and reinstatement were also changed or expanded to make them better defined and understood. We are grateful to Hal Walchi of Westinghouse and H.W. Norton of the University of Illinois for their extensive comments which aided our effort.

All changes are incorporated in the Constitution and Bylaws and require membership approval by written ballot. These ballots will be prepared for delivery to Members attending the Annual Meeting in San Francisco and for mailing to all others after that date.

Report of The Awards Committee



Ralph F. Lumb
NUSAC, Inc.
McLean, Virginia

The Awards Committee is pleased to announce the selection of a paper entitled "A Conceptual Design of a Magnetic Tape Seal System" by Houng Y Soo, a graduate student at the University of Washington under the supervision of Professor Norman J. McCormick, as the best student paper submitted for presentation at the 22nd Annual Meeting of the Institute of Nuclear Materials Management.

This student award carries an honorarium of $500, provides for all expenses associated with travel to and subsistence in San Francisco during the meeting, and includes honorary membership in the Institute for the year 1981-82. Mr. Soo joins an illustrious group as the fourth winner of the Institute's Student Award.

The Awards Committee has also selected a member of the Institute to receive the Distinguished Service Award. He has indeed had an illustrious career in Safeguards and has made a significant contribution to the profession. He will be honored at the annual business meeting of the Institute to be held in San Francisco in conjunction with the 22nd Annual Meeting, July 13-15, 1981. In addition to the Distinguished Service Award and the Student Award, Merit Awards will also be disseminated at the business meeting.

News Release

Reprocessing Not Considered To Be A Viable Commercial Activity

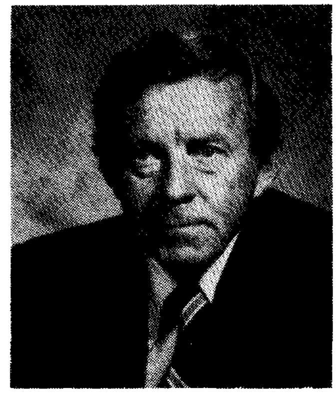
Utility and nuclear supply company representatives attending a Department of Energy sponsored meeting concerning nuclear fuel reprocessing universally agreed that reprocessing is not currently a viable commercial activity. Raymond G. Romatowski, Acting DOE Undersecretary, chaired the April 23, 1981 meeting which was held at the Department's Germantown, Maryland facility.

Representatives of the industry's private sector, approximately 30 percent representing utilities and service companies accounting for the remainder, were advised that the meeting had been convened to obtain individual viewpoints regrding reprocessing and that additional discussions and meetings would take place.

Reasons cited for the belief that reprocessing is not a commercially viable activity at this time, nor in the foreseeable future, included the unpredictability of the Regulatory licensing process, inability to predict future national policy changes, lack of a comprehensive Federal plan and guidance for energy growth, and the current financial uncertainties.

A consensus of attendee views indicates agreement that reprocessing is important to the national interest, the Barnwell Nuclear Fuel Plant should be maintained by the Federal government, and the utility representatives reiterated their support for a Federal away-from-reactor storage program.

Education Committee Report



Harley L. Toy
Battelle Memorial Institute
Columbus, Ohio

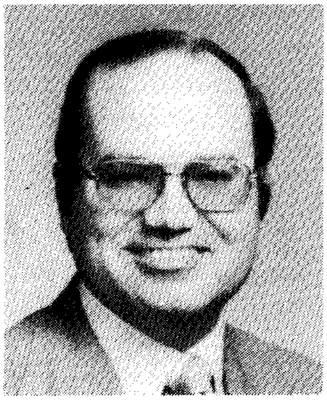
Upcoming Education Committee activities include the formal presentation of two courses in the early fall. During the week of September 14, John Jaech will present his *Selected Topics Statistics Course* at Battelle's Columbus Laboratories in Columbus, Ohio. (John Jaech enjoys Columbus in the fall in that it affords the opportunity to catch an OSU football game.) Response to date indicates that we may have to restrict the course to twenty attendees.

In October, Shelly Kops will present his *Accounting and Auditing of Nuclear Materials* course at Oak Ridge, Tennessee, on October 26-30, 1981. The course will be presented at the Holiday Inn in Oak Ridge. Shelly will be assisted by Roy Cardwell and Paul Korstad of the Pacific Northwest Laboratories. Roy Cardwell will serve as local host and coordinator for the course. The Accounting and Auditing course represents our second venture into presenting formal course offerings on a regional basis. You will recall that last November, Shelly, along with Cal Solem and Paul Korstad, presented the course in Richland, Washington under the sponsorship of the Pacific Northwest Chapter.

Your Education Committee continues to respond to public requests for general background information on safeguards and the nuclear industry in general. Requests for information on our organization and safeguards come in to Secretary DeVito who forwards the requests to the Education Committee for action. As Vince will attest, such requests are coming in on a regular basis. Our thanks to AIF for furnishing certain educational materials in responding to the numerous requests. Such requests, which come from high school, college students, and other organizations points out the country-wide recognition the INMM has achieved. We feel this is a most important activity and the Education Committee will continue to be active in this public relations and educational area.

Your Education Committee welcomes any and all comments regarding the current educational programs. We need your help and participation.

Membership Committee Report



J.E. Barry
Gulf States Utilities
Beaumont, Texas

Saluting Jim Patterson

As we welcome more new members to the INMM, we also acknowledge those that have served long and well. James P. Patterson is such a man. Recalling over twelve years of membership in the INMM and his being perhaps the last Certified Nuclear Materials Manager (#75 issued June 1974) under our earlier certification program, Jim has submitted his resignation from the Membership and Education Committees and from the INMM effective June 30, 1981. This year his job assignment in USNRC, Region III will have taken him from materials safeguards control and accounting activities into emergency preparedness and later into environmental monitoring and confirmatory measurements.

Expressing his pleasure for the past years of the professional association and meetings enjoyed through the INMM, he extends best wishes to our organization as a positive force for safeguards of nuclear materials. Obviously and rightly we extend our thanks to Jim for his past efforts on behalf of the INMM and for his part in the responsible development of nuclear power, which he will continue to play.

As noted in our last report, this committee is designating regional responsibility to its members. Members should look to them for faster response and support on membership-related matters. Jim Lee has agreed to do this with regard to the Southeastern United States. Requests for committee representation have been sent to the Pacific Northwest United States and Japan Chapters. By the next report we hope to announce not only these, but a representative for the Midwestern United States.

During the April Executive Committee Meeting, the membership committee was charged with the responsibility to report on the status and views of the membership which we will be seeking to establish through questionnaire during May and June.

The following nineteen individuals have been accepted during the period January 16, 1981 through April 15, 1981. To each, the INMM Executive Committee extends its welcome and congratulations. New members not mentioned in this issue will be listed in the Summer 1981 (Volume X, No. 2) issue.

Benson N.C. Agu, *Senior Officer,* International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria 2360/2087

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Gene L. Benjamin, *Senior Planner,* UNC Nuclear Industries, Box 490, Richland, Washington 99352, (509) 376-3513

Gregg W. Dixon, *Training Consultant,* International Atomic Energy Agency, P.O. Box 100, A-1400, Vienna, Austria 2360/1812

Abdul Fattah, *Safeguard Inspector,* International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria 2360/1953

Sandra D. Frattali, *Safeguards Standards Analyst,* U.S. Nuclear Regulatory Commission, Office of Standards Development, Mail Stop NL 5650, Washington, D.C. 20005 (301) 443-5903

Alexander M. Ironside, *International Atomic Energy Agency,* P.O. Box 100, A-1400, Vienna, Austria 2360/1854

William J. Jacobi, *Director, Security Systems Division,* Teledyne Systems International, 19601 Nordhoff St., Northridge, California 91324, (213) 886-2211

James E. Jones, *Engineer,* Ontario Hydro, 700 University Ave., Toronto, Ontario, Canada M5G 1X6, (416) 592-6930

Robert E. Kerr, *Head Technical Services, Department of Safeguards,* International Atomic Energy Agency, Vienna, Austria 2360/1879

Frantisek Klik, International Atomic Energy Agency, P.O. Box 200, Vienna, Austria 2360/1900

Daniel Frank Marcinkowski, *Safeguards Specialist,* Rockwell International, P.O. Box 800, Richland, Washington 99352, (509) 373-1933

Daniel Charles Poteralski, *Supervisor,* Florida Power & Light Company, P.O. Box 529100, Miami, Florida 33152, (305) 552-3390

David Anthony Rakel, *Senior Research Physicist,* Monsanto Research Corp., Mound Facility, T-226, Miamisburg, Ohio 45342, (513) 865-4203

John Kelly Shaffer, Jr., *Engineer-Advanced Safeguards Development,* Allied-General Nuclear Services, P.O. Box 847, Barnwell, South Carolina 29812, (803) 259-1711, ext. 694

John M. Shields, Jr., *Manager, Security & Material Control,* Babcock & Wilcox, NM&MD, 609 Warren Avenue, Apollo, Pennsylvania, 15613, (412) 842-0111

Arthur B. Shuck, *Vice President,* Profitect, Inc., 734 Forest Street, Winfield, Illinois 60190, (312) 668-8998

Donald Sumner Thurman, *Safeguard Inspector,* International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria, 2360/2060

Dennis DeWayne Wright, *Principal,* Technical Security Associates, Inc., P.O. Box 1233, Cherry Hill, New Jersey 08034, (609) 268-9500

Book Review

E.V. Weinstock
Brookhaven National Laboratory
Upton, New York

"The Detection of Fissionable Materials by Nondestructive Means"

The Detection of Fissionable Materials by Nondestructive Means, *by Rudolph Sher and Samuel Untermeyer II* (American Nuclear Society, Le Grange Park, Illinois, 1980; 286 pages, $49).

If the publication of textbooks and other scholarly works is a measure of the maturity of a field of knowledge, then nuclear safeguards must be coming of age. In recent years, since the publication of Ralph Lumb's pioneering book (1960), we have seen works by John Jaech (1973), by Jim Lovett (1974), and by Rudolph Avenhaus (1977), and now we have this pretty little monograph by Professor Rudolph Sher, of Stanford University, and Dr. Samuel Untermeyer II, of the National Nuclear Corporation, a manufacturer of safeguards instruments.

A monograph, according to my dictionary, is a book, article, or paper written about a single subject. In this case, as the title says, the subject is the detection of fissionable material by nondestructive means, which therefore includes nondestructive assay but is somewhat broader. Among the other topics covered are quality-control measurements, portal monitors, health-physics survey instruments, radioactive spiking, and the statistical analysis of problems arising in a number of nondestructive applications.

The work is not a treatise - that is, it is not an exhaustive treatment of the subject. Rather, it touches lightly on each topic, sometimes devoting only a few sentences to it, but it hits the high spots, provides enough information to enable the reader to make at least a preliminary selection of the appropriate instrument for his application, and lets him know where to find more detailed information, through the key references at the end of each chapter. This approach has certain advantages and disadvantages. The chief advantage is the great breadth of coverage it permits in a work of modest length, but the penalty is that there is little room for derivations of mathematical relationships, so that sometimes the physical meaning and limitations of the expressions are not apparent.

After a brief introduction explaining the need for methods for the nondestructive detection of fissionable material, the origin and characteristics of the radiations used are reviewed. The material in this chapter is treated at just the right level to enable the reader to understand how the radiations are produced and which circumstances favor the emission of one kind over another. Much useful data on nuclear reactions, the characteristics of fission, x-rays, matrix reactions, and heat generation are reproduced. In fact, the data tabulations and graphs presented throughout the book are one of its strong points, and will save the harried researcher much time that would otherwise be spent in searching the literature for them.

Nuclear radiation detectors are surveyed in the next chapter. There are some good summaries of the differences between the various kinds of detectors, but I found the explanation of pulse conditioning requirements and of the action of detector electronics to be unclear; for these topics the reader would be well advised to consult one of the standard texts on radiation detectors, listed in the references. The chapter ends with a discussion of the properties of that elegant and powerful nuclear detection technique, coincidence counting. The authors have obviously done their homework quite thoroughly here, even noting a misprint that appears in one of Tsahi Gozani's important contributions to this subject, in which he elucidated the mathematical relationships governing multiple coincidence counting.

The meat of the book is in the next two chapters, which are devoted to passive and active techniques, respectively. To name a few topics, the former covers the assay of uranium and plutonium by gamma-ray detection, using both low resolution (NaI) and high resolution (Ge, Ge(Li) and Si(Li)) detectors, passive fuel-rod scanners, enrichment meters (the discussion here includes one of the few derivations in the book), portal monitors, calorimetric assay of plutonium, and neutron-coincidence well counters. The treatment of the last topic is relatively detailed, not surprisingly, since one of the authors has written a well-known report on the subject. Naturally, most of the topics are covered in considerably less detail, as may be deduced from the number of techniques or instruments (I counted over 25) and the length of the chapter (51 pages, include many figures, tables and references). Nevertheless, a good job is done of presenting the main advantages and limitations of passive detection techniques.

These limitations can be overcome by resorting to active techniques, but as is made clear, at the cost of increased expense and complexity. Despite these drawbacks, an impressive number of techniques and devices have been developed over the years, mainly at the Los Alamos National Laboratory but also at several other laboratories. As in the previous chapter, a convenient classification scheme enables the reader to pick his way through the thicket with relative ease. A short list of some of the less familiar topics will give an idea of the coverage: fluorescent x-ray analysis, reactor reactivity measurements, lead slowing-down spectrometers, neutron resonance absorption, neutron radiography, and activation analysis. The reader won't learn from the text precisely how to do all these measurements, but he will learn the basic principles and where to look for more information. As an amusing aside, one of the references is to a private communication from one of the authors, but whether to himself or to his collaborator is not stated.

I do have one complaint of a non-technical nature about these two chapters. Almost all the photographs of commercially available instruments are of those manufactured by the National Nuclear Corporation, despite the availability of at least some of these types of instruments from other manufacturers. No doubt this was the most convenient course for the authors, but in a situation like this it would have been better to lean over backwards to avoid even a hint of favoritism.

The rather specialized topic of radioactive spiking of fissionable material is next taken up. The treatment is based on an unpublished Brookhaven report. The idea of adding lethal quantities of some radioactive agent to nuclear fuel goes back a long way, and, like many bad ideas, is revived every few years. The version of spiking discussed here, however, is the less objectionable one of adding just enough of the spikant to enhance the detectability of the material.

The final chapter is devoted to the statistical problems encountered in various nondestructive-assay and quality-control measurements, and was written by John Jaech, an eminent authority in the field who is also the author of the standard reference on the application of statistics to safeguards. The subject matter ranges from the more-or-less standard treatment of the propagation of errors to a complex analysis of the statistics of pellet-scanning in fuel rods. Among the more important topics covered are those of instrument calibration, tests for outliers and normality, and inter-laboratory comparisons. The reader should be forewarned that, in order to fully understand the treatment, since only one or two results are actually derived, it would be best if he had some prior background in statistics, or, at least, a familiarity with its jargon; for example, the terms "significance levels," "autocorrelation," and "standardized normal variate" are used without defining them, and, although covariance is defined mathematically, its significance is not explained. On the other hand, each analysis is accompanied by a detailed numerical example illustrating the application of the method. All in all, the chapter is extremely useful to anyone engaged in safeguards measurements. In particular, I liked the emphasis on the importance of systematic, as opposed to random, error; it is surprising how many people still think that a measurement can be improved indefinitely simply by repeating it over and over.

The volume concludes with an appendix containing an excellent and comprehensive table of properties of the heavy-element nuclides: decay properties, fission properties, important cross sections, etc.

Reading the book was a pleasure. In contrast to some of the works reviewed here in the past couple of years, it is exceedingly well written in a simple, straightforward, expository style. Its appearance is also most attractive: the diagrams and graphs are well drawn and reproduced, the tables are legible and nicely organized, and the typography is easy on the eyes.

In short, this is a book of which its publisher, The American Nuclear Society (a pity it wasn't the INMM), can be proud. It is an excellent introduction to an important branch of safeguards, and belongs on the shelf of every person interested in nondestructive measurement.

This article is reprinted with the permission of the Seattle Times

A 'Convert' To Nuclear Power Attacks Some Common Fears

by Marcia Terry
Seattle Free-Lance Writer and
Technical-Writing Consultant

I have changed my mind about nuclear energy. Two years ago, I sympathized with those opposing nuclear-power plants. Today I sympathize more with the people inside the plants - the ones presumed to be immoral by the protesters outside.

It was months before anyone could convince me that nuclear energy had its place. There were a lot of myths to dispel - myths often perpetuated by newspaper and TV reports.

Now, after studying the issue, I am appalled at the assumptions that I once held and that many nuclear opponents hold today. These assumptions are generally based more on fear than on facts.

I have left political and economic considerations off the list in order to concentrate on the putative dangers of nuclear power. I'm convinced that nuclear energy has gotten a bum rap.

Let's look at my old assumptions one by one to see how many turned out to be true:

-*All radiation is man made.* This is terribly false. Radiation existed in the universe and on earth long before man showed up. Our food is radioactive, our homes are radioactive, even our bodies are radioactive!

-*All radiation is bad.* Like any gift of nature, radiation can be dangerous. But it can also provide wonderful benefits - to see how a bone is broken, to heal a goiter without surgery, to kill cancerous cells. Radiation is a necessary by-product of a process that allows us to produce large amounts of energy without environmental pollution.

-*The stuff coming out of nuclear plant cooling towers is loaded with horrible contaminants.* I probably got this idea from looking at too many anti-nuclear cartoons. What is that stuff? Condensed water vapor - the same thing clouds are made of. Because most of the water flowing through the reactor's cooling system never comes in contact with contamination, it never becomes contaminated.

-*A nuclear power plant can explode like a bomb.* People are really nervous about this one, but it can't happen. In order to produce a nuclear device that explodes, the fissionable material must be at least 90 percent pure. The fuel in a commercial reactor is about 3 percent pure!

-*We should all live in mortal fear of the "China Syndrome."* The China Syndrome makes good copy and stirring movies, but how probable is it? The Rasmussen Report, published in 1975 at the request of Congress, concluded that it was 1,000 times more likely that an American would die in a hydroelectric dam failure than in a nuclear power plant disaster. Some people have discredited the Rasmussem Report as overly optimistic, but it would have to be off by a factor of 1,000 before I'd start losing sleep over the China Syndrome.

-*Radiation can "get you" from miles away.* It can only "get you" from miles away if radioactive particulate material travels that far. Radiation dissipates so much with distance that you can halve your dosage by doubling your distance from the source. To be irradiated, you must be very close to a radiation source which emits particles (alpha and beta) that are absorbed into the air after a few feet, or close enough to an insufficiently shielded source of more penetrating types of radiation (gamma and neutron) for enough time to receive a significant dose. Anything suitable between you and the source (a concrete wall, a paper bag, your clothing) will act as a shield against radiation.

-*A radiation leak from a nuclear power plant can wipe out a whole city.* An atomic bomb can do that, but it's not easy to do with a radiation leak. First, something must go wrong with the reactor's cooling system. Second, the emergency core-cooling system has to fail. Third, the concrete containment (about 4 feet thick) must fail and release a cloud heavy with contamination. Fourth, a temperature inversion has to hold contamination close to the ground in lethal amounts. Fifth, a good wind has to blow the whole mess over a population center with pinpoint accuracy and disperse lethal doses to individuals.

A cloud of that sort could contain some pretty nasty things, like the one from Three Mile Island. But even the local resident closest to that accident would have received more radiation exposure if he'd had one or two medical X-rays.

-*You never want to come within miles of what Ralph Nader calls the most toxic substance known: plutonium.* Plutonium is pretty vile, but to call it the most toxic substance known ignores botulism and diphtheria toxins. They are hundreds of thousands of times more toxic in the blood stream; while lead arsenate is about ten times more toxic.

And as for a safe distance, that depends on whether the plutonium is sealed from the atmosphere. Because plutonium emits alpha particles, a sheet of paper is sufficient to protect you from the radiation, but there is a danger if you breathe plutonium into your lungs. Once the particles are in your lungs, they can be very destructive, planting the seeds for future cancer cells. Even so, the menacing particles can be cleansed from the body by an antidote which removes all heavy metals.

-*If we shut down all nuclear power plants, we'd wipe out the primary source of high-level radioactive waste.* Not so. The primary source in the U.S. is still the military - 99 to one. Less than 1 percent comes from commercial reactors. Furthermore, much of the "waste" could be turned into additional energy if the government allowed reprocessing of spent fuel - there's a significant amount of potential energy left when it comes out of the reactor.

-Nuclear energy is the least desirable energy form environmentally. This assumes that the radiological hazards of nuclear energy are so great that they outweigh the fact that nuclear energy is produced without significant air or water pollution. There are cleaner ways to produce energy - solar, wind, geothermal and hydropower. But even hydropower, so important in the Northwest, supplies only about 2 percent of the nation's energy needs. These sources are good for small-scale production, but are not appropriate on a larger scale.

That leaves thermal energy, by far the largest producer of electricity in the U.S. For it, we rely on natural gas (the cleanest - it gives off only carbon dioxide when burned); oil (carbon dioxide and sulfur dioxide); coal (carbon dioxide, sulfur dioxide, and a residue of ashes), and nuclear power.

Coal fly ash frequently contains radioactive elements as well as other non-radioactive, cancer-causing particulates. Estimates indicate that the amount of radioactivity in coal fly ash could exceed the radiation emitted by a nuclear-power plant by as much as 400 percent (still not a huge amount of radioactivity, by the way).

-I was safe from radiation on a camping trip with my Coleman lantern. I never suspected that my Coleman lantern contained radioactive materials, but the bulk mantle is impregnated with a thorium compound that intensifies the light. How radioactive is it? If you stood in front of it for one hour, you would receive about 400 times more radiation than from standing at the boundary of a nuclear-power plant for one hour.

What other ordinary things are radioactive? Well, there's the soil, building materials (granite more than brick, and brick more than wood), food, people (your body uses a radioactive isotope of potassium), and certain types of glass. Cosmic radiation bombards the earth from outer space, so you increase your radiation exposure with altitude - Denver is about twice as radioactive as New Orleans. Also, you get a dose of radiation whenever you go up in an airplane.

-No nuclear energy plants are justified on earth. In other words, "Don't confuse me with the facts, I've already made up my mind." Never mind that the nuclear industry has one of the cleanest records of any industry (no radiation injuries or deaths to the public in more than 410 reactor-years' experience). Never mind that many hazardous chemicals (dioxins, for example) have no half lives and remain toxic forever. Never mind that nuclear energy could lessen our dependence on foreign oil.

-Anyone who has anything to do with nuclear energy production is not to be trusted. I expected the worst when I went to meet people in the nuclear industry. Imagine my surprise when I met intelligent, articulate individuals as concerned about the environment and their families as any anti-nuclear people I'd ever met.

As for credibility, I discovered that many of my questions couldn't be answered by nuclear amateurs. They had to be answered by someone who at least had been inside a nuclear plant. I also discovered that the scientists who are so "sharply divided" on the issue didn't study the same subjects. Anti-nuclear scientists tend to be chemists, zoologists, neurologists. Few have training or experience in nuclear physics or nuclear engineering.

-Media reports have their fingers on the facts relating to nuclear energy. I discovered the hard way that this wasn't true. The popular literature differs wildly from the technical literature, and it was a long time before I could sort out the political issues from the technological issues. Furthermore, the concepts are difficult for a non-scientist to grasp.

My conclusion: It was easier for reports to find out how people felt about nuclear energy than to find out how it actually worked. It was also easier to condemn nuclear energy in that last 20 seconds of a news broadcast than to explain how it worked.

So how can a citizen learn enough to grasp the basics without spending two years hunting down books on the subject and pestering nuclear engineers? One simple way to learn more about nuclear energy is to take advantage of the excellent free exhibits and tours of the Trojan nuclear plant near Rainier, Ore.

Another way is to contact an organization called Energy Advocates (P.O. Box 3242, Seattle, WA 98114). This group is dedicated to exploring all forms of energy and conservation alternatives.

After all, as I learned over the past two years, a misunderstood danger is always more frightening than an understood danger.

News Release

IAEA To Supply Safeguards To Three NRC-Licensed Nuclear Facilities

The International Atomic Energy Agency (IAEA) has selected three commercially-owned nuclear facilities, licensed by the Nuclear Regulatory Commission, for application of safeguards under the United States/IAEA Safeguards Agreement.

In 1967, the United States volunteered to have IAEA safeguards applied to all major U.S. nuclear activities with the exception of those having direct national security significance. This offer was made to encourage the widest possible adherence to the Treaty on the Non-Proliferation of Nuclear Weapons, by demonstrating to other nations that they would not be placed at a commercial disadvantage by application of safeguards under the treaty. The offer also was a manifestation of U.S. support of the international safeguards system and demonstrated the U.S. belief that IAEA safeguards would not interfere with peaceful nuclear activities.

Following formal negotiations between the U.S. and the IAEA, the international agency's Board of Governors approved the proposed agreement on September 17, 1976. It then was submitted to the U.S. Senate which gave its advice and consent to ratification as a treaty on July 2, 1980. The provisions of the agreement entered into force on December 9, last year.

The facilities to which IAEA safeguards will be applied are Exxon Nuclear Company, Inc.'s fuel fabrication plant at Richland, Washington; Portland General Electric Company's Trojan Nuclear Power Station near Prescott, Oregon; and Sacramento Municipal Utility District's Ranco Seco Nuclear Power Station near Sacramento, California.

Under the terms of the agreement, the licensees are required to furnish information about their facilities and submit reports accounting for the nuclear material they possess. In addition, IAEA representatives will conduct periodic inspections of the three facilities.

News Release

DOE Revises Its Spent Fuel Storage Program

The Department of Energy is reorienting its efforts to provide federal away-from-reactor spent fuel storage. Spent fuel storage program activities to support acquisition of interim storage facilities are being redirected to concentrate on the development of technology to increase utility storage capabilities.

The Department's offer to accept domestic and limited quantities of foreign spent fuel for storage and disposal was made in October 1977 as a result of President Carter's indefinite deferral of reprocessing and non-proliferation policies. However, Congressional authority to fully implement the policy was never obtained and the utilities have continued to rerack their at-reactor fuel storage basins to increase their storage. The Administration's decision to discontinue the Federal storage offer is based upon its efforts to establish clear and decisive nuclear energy policies and programs so that utilities and industry can provide the necessary facilities and services to manage their spent fuel.

DOE studies indicate that some utilities will require additional storage capacity beginning in 1986 assuming maximum density storage at reactors prior to that time. The Department will work with these utilities to explore solutions to their storage problems such as dry storage and storage of disassembled fuel elements. Department research and development on fuel element disassembly and rod storage will be completed in 1982 which would enable some utilities to further increase their storage capacity and delay the need for additional capacity. Dry storage techniques are also being developed by the Department which could supplement existing at-reactor storage. Although some utilities may still face a storage shortfall even with these new techniques, there are other approaches to their storage problems such as operation without full core reserve or transshipment of fuel until commercially provided storage and reprocessing facilities and federal waste repositories are available.

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REPORT ON USDOE / IAEA ADVANCED INTERNATIONAL TRAINING COURSE ON STATE SYSTEMS OF ACCOUNTING FOR AND CONTROL OF NUCLEAR MATERIALS April 27-May 2, 1981

Bernardino Pontes, International Atomic Energy Agency
C.R. Hatcher, G.R. Keepin and **T.D. Reilly**, Los Alamos
R.A. Schneider, Exxon Nuclear and **R.J. Sorenson**, Battelle-Northwest

An Advanced International Training Course on State Systems of Accounting for and Control of Nuclear Materials was held April 27–May 12, 1981 at Santa Fe and Los Alamos, New Mexico and at Richland, Washington. The course, sponsored by the U.S. Department of Energy in cooperation with the International Atomic Energy Agency, was developed "to provide practical training in the implementation and operation of a national system of accounting for and control of nuclear materials that satisfies both national and IAEA international safeguards objectives."

A total of some 70 participants (including course attendees, lecturers, and equipment demonstrators) took part in the 16-day course. Nations represented included Belgium, Brazil, Canada, Egypt, France, India, Iraq, Israel, Italy, Japan, Korea, Luxembourg, Malaysia, Mexico, Pakistan, Poland, Sweden, Switzerland, Taiwan, Turkey and Yugoslavia. Participants also came from the co-sponsoring organization - the IAEA in Vienna, Austria - and from the Euratom Organization of the Commission of the European Communities in Luxembourg.

The course was conducted by the University of California's Los Alamos National Laboratory, the Battelle Pacific Northwest Laboratory, and the Exxon Nuclear Company, Inc. The course staff included G. Robert Keepin, Course Director, Bernardino Pontes, IAEA Scientific Advisor, and Course Coordinators Charles Hatcher (LANL), Douglas Reilly (LANL), Richard Schneider (Exxon Nuclear), and Robert Sorenson (Battelle PNL).

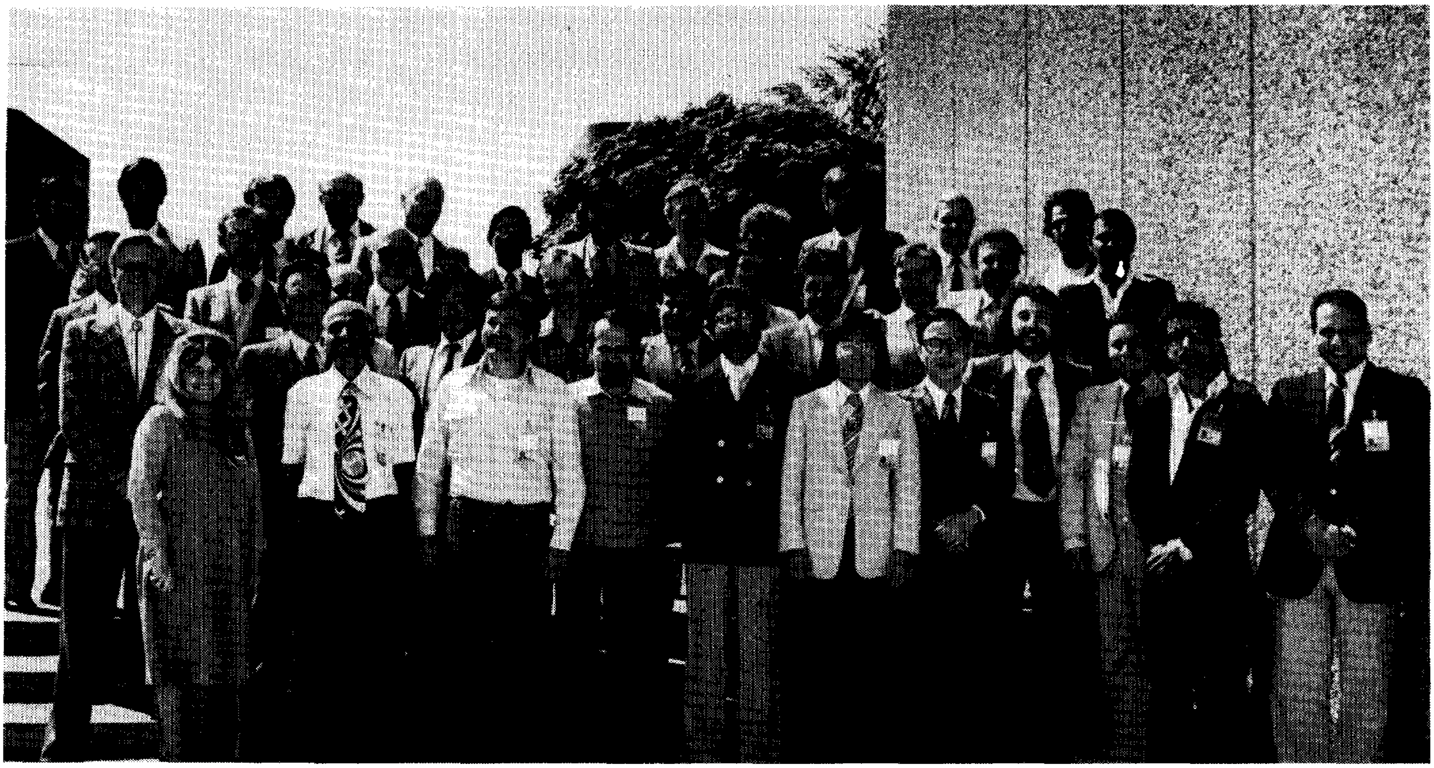
Major emphasis in the course was placed on the principles and practical methods used in establishing and operating nuclear material accounting and control systems at bulk-handling facilities - particularly LEU (low enriched uranium) conversion and fuel fabrication plants. Emphasis was also placed on the interaction between (1) facility safeguards, (2) national system (SSAC) safeguards, and (3) international (IAEA) safeguards.

Course attendees hold positions of major responsibility in technical research, operations, and technical management in nuclear material accounting and control organizations at both the facility and national levels in their respective countries. Most attendees had attended one or more of the basic SSAC courses previously offered by the International Atomic Energy Agency in 1977 in Vienna, in 1978 in the USSR, and in 1980 in Santa Fe, New Mexico.

The course lecture staff included safeguards experts from IAEA, U.S. Department of Energy, U.S. Nuclear Regulatory Commission, U.S. Department of State, Los Alamos National Laboratory, Battelle Pacific Northwest Laboratory, Exxon Nuclear Company, and Allied General Nuclear Services. The schedule of sessions and lecturers/instructors is shown in Tables I and II.

In the opening session on Monday, April 27, participants were welcomed by LANL Director Donald Kerr, DOE/OSS Director George Weisz, IAEA's Svein Thorstensen, and Exxon Nuclear's Roy Nilson. Course Director Bob Keepin then presented an overview of the course, including course objectives and course structure, together with a description of course components, materials, and facilities to be visited.

Following a review by John Boright, U.S. Department of State, of historical development and current trends in nuclear safeguards, the first major topic addressed at Santa Fe was the broad area of "State Safeguards Systems and the International Interface" (see Table I). IAEA safeguards experts Carlos Buechler and Svein Thorstensen first reviewed the IAEA requirements and guidelines for State Systems of Accounting and Control and then described the establishment and practical implementation of IAEA safeguards operations at a bulk-handling facility with special emphasis on a fuel fabrication facility. This was followed by an overview of state system requirements by Mike Smith and Ken Sanders of USNRC, taking as an example current US requirements and regulations governing nuclear material accountancy and control, as well as recent modifications to USNRC regulations to accommodate the implementation of IAEA safeguards in the US (10 CFR 75). The concept and role of the NRC's FNMC (Fundamental Nuclear Material Control) plan were discussed and typical na-



Participants in 1981 Advanced SSAC Course (photo taken May 4, 1981 at Richland, Washington). (l to r) Front Row: Diane Larson, USA; Subhash Purushotham, India; Porfirio Garcia, Mexico; Avraham Farchy, Israel; Muhammad Nawaz, Pakistan; Ah Auu Gui, Malaysia; Yi-Ching Yang, Taiwan; Arif Isyar, Turkey; Rifaat El-Shinawy, Egypt; Adel Al-Fayyad, Iraq; Hafiz Higgy, Egypt. Second and third rows combined: Darryl Smith, USA (partially hidden); Bob Keepin, USA; Yvan Capouet, Euratom, Luxembourg; Pierro Vanni, Italy; Bernardino Pontes, IAEA (partially hidden); Charles Hatcher, USA; Cheong Won Cho, Korea; Andrzej Pietruszewski, Poland; Jean Maurel, France; M. Akiba, Japan; Victor Dimic, Yugoslavia; Stanislaw Ciemniewski, Poland; Suror Mahmoud, Iraq; Ghulam Kibria, Pakistan. Fourth Row: Bob Sorenson, USA; Al Walker, USA; Gilbert Verstappen, Belgium; Svein Thorstensen, IAEA; Theodore Hurlimann, Switzerland; Chung-Lu Lo, Taiwan; Winston Alston, IAEA; Richard Olsson, Sweden; Valeria Leonardi, Euratom, Luxembourg; John Ellis, USA; Edwin MacKay, Canada; Rudi Roenick, Brazil.

tional safeguards system operations were described and explained from the standpoint of meeting both national requirements and IAEA international safeguards.

A panel discussion entitled, "IAEA-State System Interface" addressed a wide range of safeguards topics and helped to put in perspective the principles and actual practice of national safeguards systems on the one hand and the overlay of the IAEA international system on the other.

The second major topic area, "Safeguards Measurement Technology and Applications," was introduced with a survey of "traditional" measurement methods (chemistry, mass spectrometry, bulk measurements), and associated measurement standards. This was followed by a review of the newer techniques of nondestructive assay (NDA) and their applications in fuel cycle facilities. On Thursday, April 30, attendees visited the Nuclear Safeguards R&D facilities at Los Alamos for a tour and demonstration of NDA instruments and methods - both portable NDA instruments used by safeguards inspectors and the larger in-plant instruments typically used by plant operators and process personnel.

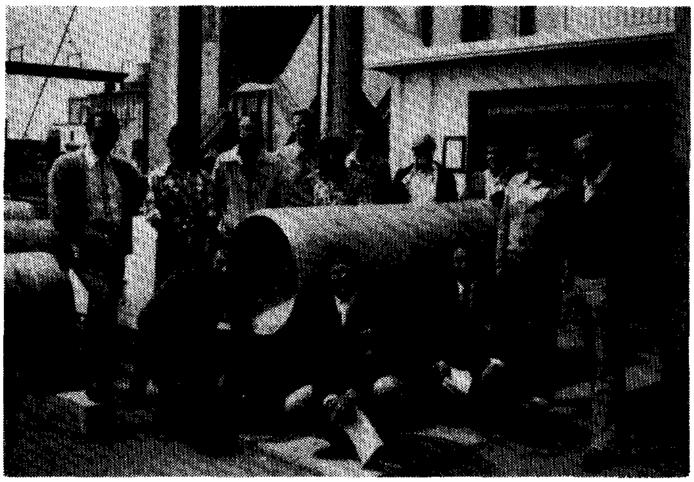
The final day at Santa Fe was devoted to the principles and practice of safeguards systems design and implementation. Modern near-real-time accountancy/process control systems were described and specific examples of operating in-plant systems given, together with a discussion of methods and criteria for evaluating the performance of advanced materials accountancy and control systems.

The Santa Fe portion of the course concluded with a review, discussion, and question-and-answer session covering the material presented during the first week of the course. Experts were made available for technical consultation and follow-up on special problem areas or topics of special interest to individual attendees.

The Richland portion of the course (see Table II) opened with a brief description and general plant tour of the Exxon Nuclear Fuel Fabrication Plant. It is noteworthy that this facility was selected by the IAEA for its first safeguards inspection in the United States under the terms of the US/IAEA agreement which entered into force in December 1980.

Following the Exxon Nuclear plant tour, the plant accounting system, key measurement points, safeguards criteria, and operating system characteristics were described and discussed. Lectures on the various measurement methods and techniques used at the Exxon Nuclear plant were alternated with numerous tours and demonstrations of plant measurement equipment - both conventional chemical analysis and nondestructive assay methods. Measurement control, sampling plans and statistical data analysis methods used at the plant were described in some detail, as were typical national system (NRC) inspection procedures for LEU fuel fabrication plants.

Course participants arriving at Exxon Nuclear plant.



Exxon Nuclear UF_6 Cylinder Weighing Scale

A mobile NDA safeguards measurement van was visited and operation of on-board equipment demonstrated. In connection with the Exxon Nuclear plant tours, on Saturday, May 9, course attendees had an opportunity to participate directly in the operation of a variety of in-plant analytical and measurement procedures in key process areas of the plant.

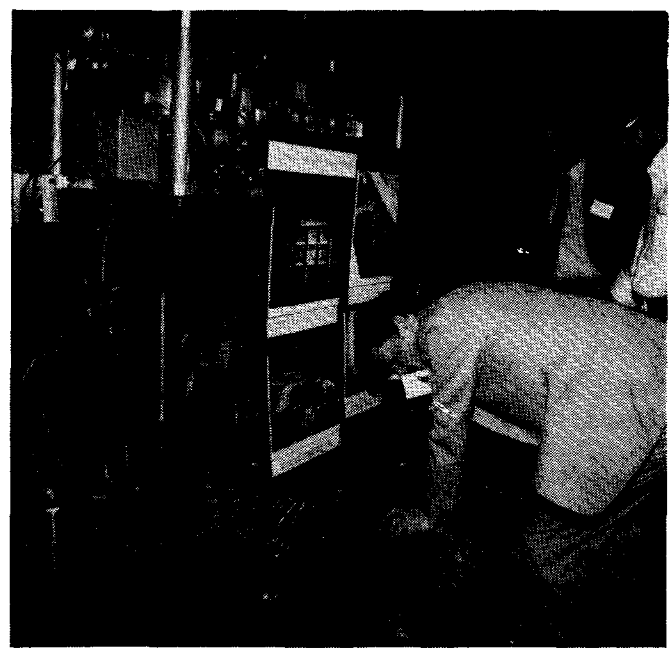
The Richland portion of the course culminated in a two-day workshop on safeguards systems design for a fuel fabrication plant. To permit maximum individual participation, students were divided into four subgroups for the design workshop. Based on data provided for a model LEU fuel conversion/

Kirk Galbraith describing the Exxon Nuclear Plant

fabrication plant, each subgroup (approximately seven students) worked on developing a FNMC plan for the model plant and made recommendations for establishing and implementing an appropriate measurement and accountability system.

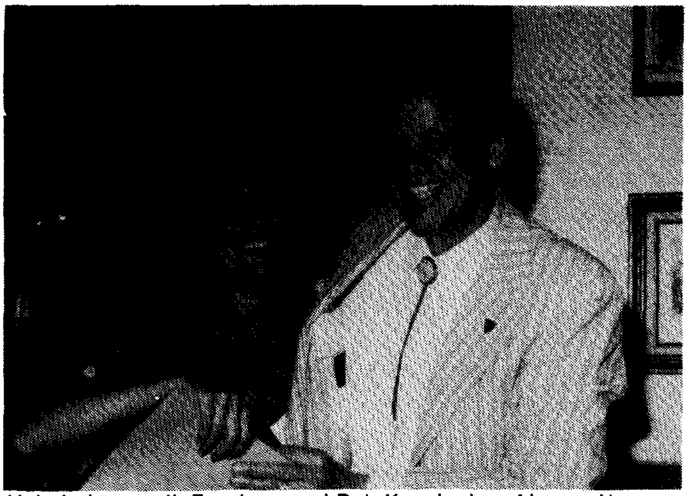
Following the workshop there was a plenary session of all attendees in which reports on the work and results of each design subgroup were presented by a "rapporteur" for each subgroup. The different subgroup designs were then compared and critiqued in an informal panel discussion involving full participation from both attendees and course instructors.

During the technical sessions and discussions it was recognized that certain professional biases and differences in viewpoint and approach to safeguards can arise quite naturally in the normal course of inspector/inspectee interactions - whether on the facility, the national, or the international level. In this connection it was pointed out that in recent years there has been significant progress toward better understanding and mutual appreciation between plant people on the one hand and safeguards people on the other. In some facilities, for example, in-plant test and evaluation programs of safeguards equipment have led to new awareness on the part of both plant operators



Using a Cerenkov radiation viewing device, Andrezej Pietruszewski inspects spent MTR fuel at the Los Alamos Omega West reactor

and safeguards technologists. Thus with more in-plant test experience, safeguards technologists have acquired a fuller appreciation that the cooperation and understanding of plant people are absolutely essential to effective in-plant implementation of new safeguards techniques and instrumentation. By the same token, many of the plant people who have had involvement with in-plant test and evaluation programs have become increasingly aware of the significant contribution that modern safeguards measurement equipment and systems can make to increased plant operational efficiency and production, and hence to good overall plant economics.



Valeria Leonardi, Euratom, and Bob Keepin, Los Alamos National Laboratory, in a lively discussion of the IAEA-EURATOM Joint Team Inspection Concept

The differences in viewpoint and approach to safeguards issues and problems taken by different facilities and nations were cited as positive evidence of the great need for consensus, international coopration, and standardization in the implementation of equitable, effective safeguards on both the national and international level. It was further noted that this need is an important underlying factor in the basic thrust and overall purpose of the ongoing series of international training courses on accountancy and control of nuclear materials.

In addition to the formal material presented, participants were able to exchange information and ideas with each other concerning the actual practice of safeguards in the different countries and organizations represented. These informal exchanges and contacts among responsible safeguards personnel from differing professional and cultural backgrounds provided significant additional benefit to both lecturers and participants. In connection with the overall thrust of the course, the hope was expressed that this advanced training course provided not only administrative and technical details of modern safeguards, but would help each participant, through their extensive interactions and deliberations throughout the course, to achieve a deeper insight and greater knowledge with which to undertake the task of implementing effective safeguards both in their own individual countries and throughout the international nuclear community.

During the Director's reception at the Los Alamos National Security & Resources Study Center, Donald M. Kerr, Los Alamos National Laboratory Director, chats with Piero Vanni, Italy; Jean Maurel, France; and Theodore Hurlimann, Switzerland

The published proceedings of the 1981 advanced course, including the full text of all lecture presentations, are available from the U.S. Department of Energy, Office of Safeguards and Security, or from any of the participating organizations.

TABLE I

PRESENTATIONS AT SANTA FE/LOS ALAMOS, NEW MEXICO

Welcome and Orientation–	
	D. Kerr, Los Alamos G. Weisz, DOE/OSS S. Thorstensen, IAEA R. Nilson, Exxon Nuclear
Session 1	**Introduction to Advanced SSAC Training Course -** R. Keepin, Los Alamos
Session 2	**Historical Development and Current Trends in Nuclear Safeguards -** J. Boright, US Department of State
Session 3	**IAEA Guidelines for State Systems of Accounting and Control -** C. Buchler and G. Hough, IAEA
Session 4	**IAEA Safeguards Operations at a Bulk Facility -** S. Thorstensen and L. Thorne, IAEA
Session 5	**National Safeguards System Requirements -** C. Smith and J. Partlow, US NRC
Session 6	**National Safeguards System Operations at a Bulk-Handling Facility -** C. Smith and K. Sanders, US NRC
Session 7	**Panel: IAEA-State System Interface -** J. Boright, US Department of State - Moderator C. Buchler and S. Thorstensen, IAEA J. Foley, Los Alamos; R. Nilson, Exxon Nuclear; C. Smith, US NRC
Session 8	**Survey of Chemical and Destructive Analysis Methods -** A. Hakkila, R. Gutmacher, and C. Thomas, Los Alamos
Session 9	**Survey of Bulk-Measurement Technology and Measurement Standards -** J. Ellis, AGNS
Session 10	**Elements of Non-Destructive Assay (NDA) Technology -** C. Hatcher and H. Smith, Los Alamos
Session 11	**Elements of In-Plant NDA Instrumentation Design and Implementation -** T. Canada, Los Alamos
Session 12/13	**Demonstration of NDA Instruments and Methods at Los Alamos -** D. Reilly and C. Hatcher, Los Alamos
Session 14	**Principles of Near-Real-Time Materials Accounting and Control Systems -** J. Shipley, Los Alamos
Session 15	**Example of an In-Plant Near-Real-Time Accountancy/Process Control System -** J. Ellis, AGNS
Session 16	**Performance Evaluation of Near-Real-Time Accounting Systems -** D. Cobb and J. Malanify, Los Alamos and J. Ellis, AGNS
Session 17	**Review, Discussion and Consultation with Technical Experts -** Los Alamos, Battelle, Exxon Nuclear and AGNS Staff

TABLE II PRESENTATIONS AT RICHLAND, WASHINGTON

Session 18	**Brief Descriptions of Exxon Nuclear Fuel Fabrication Plant** - K. Galbraith, Exxon Nuclear
Session 19	**General Plant Tour** - K. Galbraith and R. Schneider, Exxon Nuclear
Session 20	**Model Plant Key Measurement Points (KMPs)** - R. Schneider, Exxon Nuclear
Session 21a	**Basis of Accountability System** - R. Schneider, Exxon Nuclear
Session 21b	**Model Plant Accounting System** - M. Schnaible, Exxon Nuclear
Session 21c	**Model Plant Accounting System** *(continued)* - A. Kraft, A. McGinnes and E. Herz, Exxon Nuclear
Session 22	**Tour of Conversion Area** - K. Galbraith and K. Johnson, Exxon Nuclear
Session 23	**Measurement Methods Used at Plant** - R. Schneider, N. Wing and K. Johnson, Exxon Nuclear
Session 23a	**Bulk Measurements - Weighing and Sampling** - R. Schneider, Exxon Nuclear
Session 23b	**Analytical Methods Used at Plant** - N. Wing, Exxon Nuclear
Session 23c	**NDA Methods Used at Plant** - K. Johnson, Exxon Nuclear
Session 24	**Process Monitoring** - R. Brouns, Battelle
Session 25	***Demonostration of Measurement Techniques*** - D. Hill, K. Johnson, R. Sharp and R. Brinkerhoff, Exxon Nuclear
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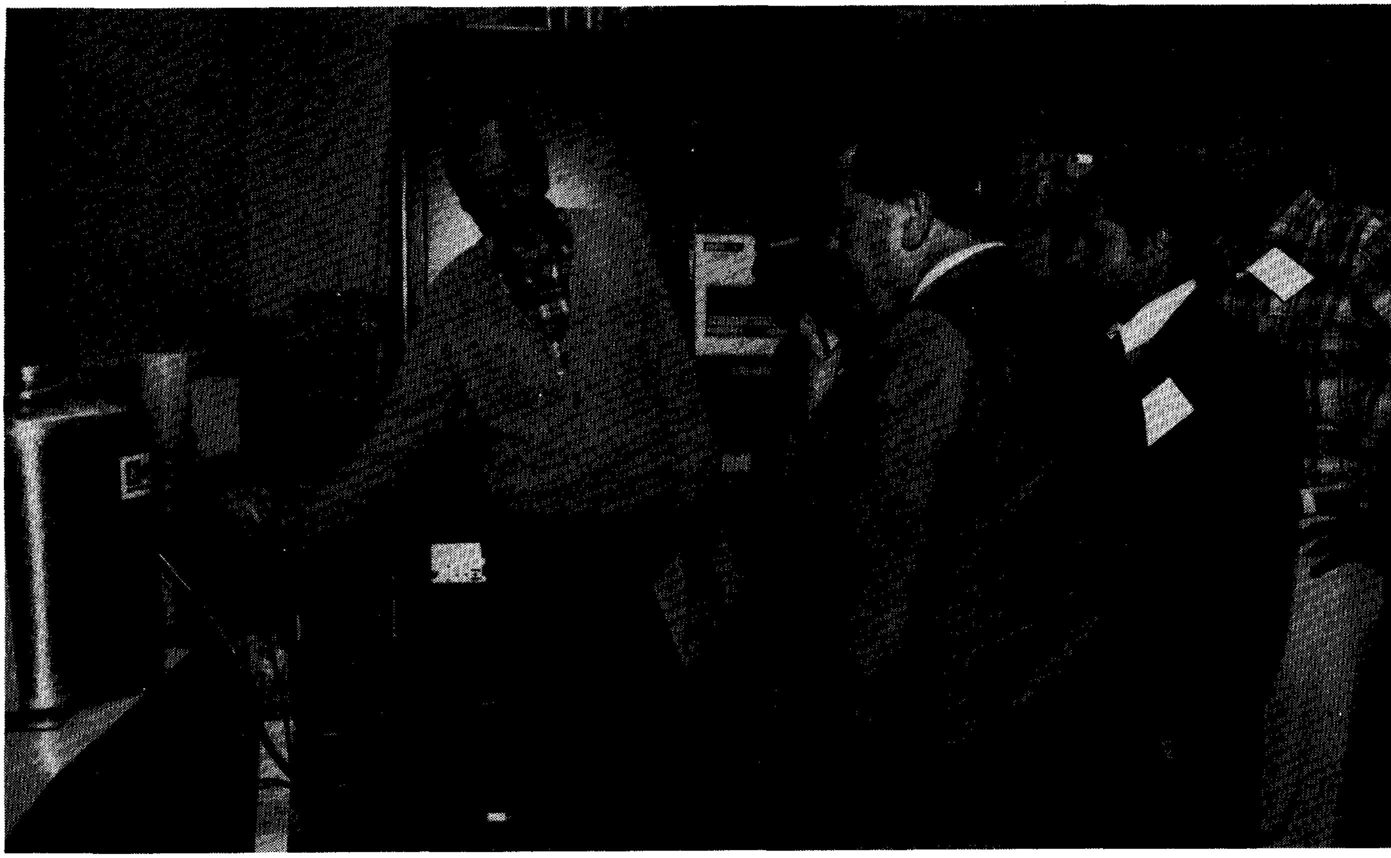
Session 41	**Panel Discussion: Comparison/Critique of Subgroup Reports** - R. Sorenson, Battelle, Moderator
Session 42	**Course Evaluation, Discussion and Wrap-Up** - Course Staff and Attendees

Merlyn Krick, Los Alamos National Laboratory, instructs attendees in the use of the High Level Neutron Coincidence Counter (HLNCC) for measuring plutonium.

Three course participants enjoy view of the Rio Grande at sunset from the deck of the Keepin home - Casa del Mirador.

Stanislaw Ciemniewski leads the group in singing "Finiculi Finicula" - in Polish! It was later sung in French, English, Spanish, and of course, Italiano!



Jack Parker, Los Alamos National Laboratory, demonstrates nondestructive assay instrument at the Los Alamos Safeguards R&D Laboratory.

John Boright, Department of State, moderates the panel on "IAEA State System Interface." Panelists are (l to r) Roy Nilson, Exxon; Charles (Mike) Smith, NRC; Carlos Buchler, IAEA; Boright, DOS; Svein Thorstensen, IAEA; and John Foley, Los Alamos National Laboratory.

Letter to Editor of SCIENCE

R.J. Sorenson
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Richland, Washington

INSTITUTE OF NUCLEAR MATERIALS MANAGEMENT
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February 10, 1981

Editor, SCIENCE
American Association for the
Advancement of Science
1515 Massachusetts Avenue N.W.
Washington, D.C. 20005

Dear Sir:

Subject: NUCLEAR FUEL ACCOUNT BOOKS IN BAD SHAPE, BY ELIOT MARSHALL, 221:4478(147), 9 JANUARY 1981

Our nation is facing an increasingly serious energy problem, the magnitude of which may not yet be clearly understood by everyone. The times call for the best analysis and discussion of our restricted energy options and the effects they have on the American public. The public needs the highest quality and most responsible reporting on this matter. In our opinion the article by Eliot Marshall, entitled "Nuclear Fuel Account Books in Bad Shape," did not measure up to this need. We were especially disappointed that such an article would appear in a technical publication of the caliber of Science.

To us the article seems to be written in a sensational style. It discusses a number of subject areas but does not tie them together so the reader can reach a sound conclusion. Rather than a coherent whole, it is really a smorgasboard of facts that may misrepresent what the people who were quoted were really trying to say. The reader is left with a feeling that something is wrong but the article does not help him understand the problem. It adds more confusion than clarity to what is happening. Since we believe it is important to try to be factual in discussing the nuclear energy option, we have prepared the following response to the article.

Statistical Checks

The author refers to the statistical checks as being meaningless. It seems to us that the alarms have truly sounded, indicating there are some problems in the system. The alarms are not meant to sound only if material is missing. They are also used to monitor the reliability of the material control and accounting (MC&A) system and they have told us that we have some problems with certain

plants--but not all plants. In most cases we have a good idea what the problems are.

Bad Bookkeeping

Throughout the first three-quarters of the article the author refers to accounting or bookkeeping systems that are sloppy and deficient. What we believe the critics mean is that there is a large uncertainty in the quantity of material located throughout the process. This is not a function of bookkeeping but rather of the ability to measure the material.

Limit of Error

The Limit of Error on Inventory Difference (LEID) is defined by the NRC in the published Code of Federal Regulations [10 CFR 70.15(a)(5)]. It is derived by propagating the errors involved in each measurement used to calculate the ID. (We assume one understands that every time a measurement of any kind is made, there are errors associated with that measurement.) While the definition is not as precise as some statisticians would like, it is being rather consistently applied throughout the NRC licensing and inspection process, and we do not think there is any confusion in the industry about its meaning. However, there is difficulty (and confusion) about how to determine the value of LEID.

ID Exceeds LEID

There are a number of reasons why the Inventory Differences (ID's) may exceed the LEID's much more than 5% of the time. An in-depth analysis of this problem would also require seeing how many licensees are involved, whether the same ones are inflating the problem repeatedly, etc. The table in the article is too general for drawing conclusions.

A common problem is that a licensee underestimates the LEID by underestimating the variances of the measurements that go into the ID numbers. The possible existence of bias in measurements is often neglected, causing sources of error to be omitted. Also, the method of propagating the variance of bias may be incorrect. Because of NRC pressure to drive down the LEID, unrealistic estimates of uncertainties may be derived, based more on measurement capabilities under the best conditions than on sustained performance under all conditions.

Because of the problems in estimating measurement uncertainties that combine to produce an LEID, a given calculated LEID may not always be expected to be exceeded by the ID 5% of the time under conditions of no loss. The 5% figure assumes that the individual measurement uncertainties are known quantities; this is simply not true in all cases since some uncertainties are difficult to estimate. In any given instance, the 5% purported value could certainly be much larger.

The "Page Rule"

The Page Rule the article refers to is not based on a statistical test; it is simply a percentage of the licensee's throughput. No one has ever argued that it is anything more than that. There are numerous alarms and decision

criteria in the business community that are not based on a scientific principle. Many people believe that the Page Rule needs to be replaced but no statistical test has emerged that has been uniformly endorsed. In modern licensed facilities there is some general support for a combination of LEID and CID, but as the article states, in some of the older plants this may not be achievable.

A factor the article did not mention is that the Page Rule penalizes the low throughput and helps the high throughput licensee. Using a percent of throughput, the small licensee must run his plant under tighter controls than the large throughput licensee. However, it is the large throughput plants that are having the serious problems and they need greater incentives to reduce the ID.

What is the Problem?

We believe the problem in most cases is simply some very old process lines and facilities that are not able to locate and accurately measure the quantities of nuclear material in the process. The problem can be expected when we continue to use older plants that do not accommodate good cleanouts and measurements of material in the process. We expect better safeguards performance from new, modern plants but we cannot expect it from some of the older ones. But that is true of any industry.

Conclusion

We can understand how difficult it is for writers to obtain precise and factual information on complex subjects such as nuclear materials safeguards. However, there are many ways to obtain this information and to have articles reviewed prior to publication. In these days when rational discussions with perspective are so important to us all, the American public needs serious journalistic efforts. We encourage you to provide such material to your readers; we believe it would be a service to them.

Sincerely,

Robert J. Sorenson
Robert J. Sorenson
Chairman/Safeguards Committee

News Release

West Valley Plant Is In The News Again

Recent publication by DOE of a major procurement for site management and technical services brings the Nuclear Fuel Services, Inc., West Valley Fuel Reprocessing Plant into the limelight again. The Request for Proposal describes a ten-year program requiring assumption of responsibility for site management and maintenance, including operation of those facilities necessary to keep the facility in a safe shut down condition. A major part of the program to be awarded is that involved in designing, constructing, operating, and decommissioning facilities for the solidification, interim on-site storage, and ultimate off-site shipment of the high level reprocessing wastes stored in tanks at the plant site. Estimated cost of the first six years of the program - up to the time operation of the waste solidification system is scheduled to commence - is $140,000,000. DOE is targeting a contract award by August 1981.

The West Valley Plant operated from April 1966 to November 1971, processing some 641 metric tons of uranium fuel and generating nearly 600,000 gallons of liquid, high level waste. Work was underway in the latter part of 1971 on modifications to the plant, and the plant was shut down in November to permit complete revamping of the process and ventilation systems in order to improve radioactive material control in the plant and to increase its capacity from a nominal one ton per day to 2.5 tons per day. As a result of a series of unfortunate decisions by the Nuclear Regulatory Commission, the cost of complying with NRC regulatory requirements imposed on the modified plant became excessive, and NFS announced in 1975 its intention not to reopen the plant and to withdraw from the reprocessing business. NFS has continued to occupy the site in a caretaker status since that time.

New York State was initially and remained a co-licensee with NFS under the plant operating license. A contract between New York State and NFS, which expired at the end of 1980, recognized the special status of New York State as part owner of the plant facilities (as well as owner of the plant site) and co-licensee; in the contract, New York State agreed to assume responsibility for the site, including the stored waste, at the end of the contract term or when NFS indicated its intent to discontinue operations at the plant. But times and institutional attitudes change. Within a few years after NFS announced its intent to withdraw from reprocessing, New York State was seeking relief from its commitment to assume responsibility for the stored waste.

Aided by public opposition to the plant, fanned by anti-nuclear groups in New York State who are reported to consider acceptable nothing less than return of the West Valley site to its pristine condition, and further assisted by a sympathetic Congress, New York State has concluded an agreement with DOE to take over responsibility for the site (but not ownership thereof). Under the terms of this agreement, DOE will be responsible for the operation of the site, and under the terms of legislation passed in the 96th Congress, will assume responsibility for the waste and will carry out a demonstration project at the site in which the stored waste will be solidified and packaged for transfer to a federal repository. This transfer is to be achieved as soon as feasible. Further provisions of the legislation include requirements for DOE to develop containers suitable for permanent disposal of the solidified waste, to dispose of low level and transuranic waste generated during the demonstration operations, and to decontaminate and decommission (1) the tanks and other facilities in which the high level radioactive waste solidified under the project was stored, (2) facilities used in the solidification of the waste, and (3) any material and hardware used in connection with the project.

News Release

E.R. Johnson Associates, Inc. Announces Appointment

E.R. Johnson Associates, Inc. (JAI), of Reston, Virginia announces the appointment of W.L. Lennemann and M.H. Singleton to senior staff positions.

Mr. Lennemann, a 31-year veteran of the nuclear industry, retired from the Department of Energy in 1980. Formerly he was Head of Waste Management Section at IAEA in Vienna, Chief of the AEC Chemical Processing Branch, Chief Metallurgist for the AEC Division of Raw Materials, and Chief of Technical Services for AEC Grand Junction Operations Office. Mr. Lennemann holds degrees in Chemical Engineering from the University of Nebraska (B.S.) and Illinois Institute of Technology (M.S.).

As Senior Technical Associate, Mr. Lennemann is involved in JAI's fuel cycle studies activity, with particular emphasis on reprocessing, spent fuel storage and waste management.

Mr. Singleton is a graduate of the U.S. Military Academy and the University of Michigan in Mechanical Engineering; he is also a graduate of the U.S. Army Command and General Staff College. He held numerous technical positions in the Army antiballistic missile program, including director of the technical staff and organizational elements of the Army's Ballistic Missile Defense Organization. He retired with the rank of Colonel.

As Senior Technical Associate, Mr. Singleton is JAI Project Manager on the U.S.-Japan Pacific Basin Joint Feasibility Study and is involved in physical security activities of the company.

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A Model For Absorption-Modified Multiplication Effects In The Assay Of HEU-Containing Powders In A Random Driver

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ABSTRACT

A model has been developed which describes the enhancement of the response, in a random driver, of a "stack" of highly enriched uranium of arbitrary height over the integral of the response of infinitessimal layers that would be produced solely by the interrogating sources which are external to the stack. The model has not yet been applied to containers filled to varying heights with powders, for which it was developed, but it has been used successfully to describe the response from stacks of uranium plates of varying heights and from a set of containers filled to a constant height with varying amounts of UO_2 in an Al_2O_3 matrix.

Introduction

In a recent paper with a similar title, Winslow and Bellinger [1] described a model tailored to the stacking of highly enriched uranium (HEU) plates in a random driver. The model permitted the reproduction of the enhancement of the response over the sum of the responses of individual plates. Since such plates are discrete items, the mathematics required the solution of a set of simultaneous equations equal to the number of plates in the stack. That is, it was supposed that the net response, C_i, from a plate at position i in the stack was given by

$$C_i = N_i + f(\ldots g^2C_{i+3} + gC_{i+2} + C_{i+1} + C_{i-1} + gC_{i-2} + g^2C_{i-3} + \ldots) \qquad (1)$$

Here, N_i is the response from a single plate at position i due to the interrogating sources in the driver external to the stack, and the remainder is the enhanced response due to sources in the stack. This second term was generated by supposing that, were there no absorption in the stack, the additional response at position i would be proportional, with proportionality constant f, to the total net response from the rest of the stack. Since there will be absorption within a plate, however, Eq. 1 was written by using g as the transmission coefficient of a plate.

In fact, the experimental work and, hence, the model development were done with five-plate units, rather than single plates, up to a full stack of 15 such units, or 75 plates. The values of N_i were found by measuring the response as a five-plate HEU unit was moved, one unit at a time, up through a stack of 70 depleted uranium (DU) plates. A plot of N_i vs i was referred to as the differential response curve. Then, for a stack of p HEU five-plate units, p equations derived from Eq. 1 must be solved for the p values of C_i which, when summed, give the total net response from the stack of p units. This sum, plus the background is to be associated with the observed gross count.

Values of $f = 0.09356$ and $g = 0.69822$ were determined by fitting at $p = 10$ and at $p = 15$ to a particular set of observations. The agreement with the observations at all other values of p was gratifyingly good, even though these were not least squares values of f and g.

It was suggested [2] that this method of modeling should also be applicable to powders. This paper is a report on the form the model takes for that application. The results have not been applied directly to powder data, but it will be shown that the model in the form to be derived here gives the same results for the plates as the previous discrete form.[1] It has also been applied to a set of containers filled to a constant height with varying amounts of UO_2 mixed into an Al_2O_3 matrix.

The Model

It was mentioned in the previous paper [1] that, for continuous powders as opposed to discrete plates, Eq. 1 becomes an integral equation. If C(x) is the response per unit height at height x, if N(x) is the response per unit height at height x due to the sources external to the stack, and if μ is the absorption coefficient of the material in the stack, Eq. 1 becomes

$$C(x) = N(x) + fe^{-\mu x}\int_0^x e^{\mu y}C(y)dy$$

$$+ fe^{\mu x}\int_x^h e^{-\mu y}C(y)dy \qquad (2)$$

for a stack of height h and a constant cross section. Here, of course, C(y) is the same function of y that C(x) is of x, and f has the units of reciprocal height. If C(x) can be determined, the total net response from the stack is, then

$$R = \int_0^h C(x)dx \qquad (3)$$

The first step is to find the differential equation satisfied by C(x). This is

$$\frac{d^2C}{dx^2} - m^2C = \frac{d^2N}{dx^2} - \mu^2N \qquad (4)$$

where

$$m^2 = \mu^2 - 2\mu f$$

and the form of the solution will depend on whether m^2 is greater than, or less than, zero. It will be discussed for $m^2 > 0$ and, then, the necessary changes for $m^2 < 0$ will be given. The solutions have been found for N of second order in x, corresponding to the form of the differential response curve of the previous paper. Not all the gory details of the derivation will be included here.

Let

$$N = a + bx + gx^2$$

where g will be a negative number and a, b, and g are known. Then the solution of Eq. 4 is

$$C(x) = C_1e^{mx} + C_2e^{-mx} + \alpha + \beta x + \gamma x^2$$

in which

$$\alpha = (\mu^2/m^2)a + 4\mu gf/m^4 \qquad (5)$$

$$\beta = (\mu^2/m^2)b \qquad (5a)$$

$$\gamma = (\mu^2/m^2)g \qquad (5b)$$

and C_1 and C_2 must be determined by substitution of C(x) and, equivalently, C(y) into Eq. 2. After this is done, Eq. 3 is applied with the result that

$$R = \alpha h + (\beta/2)h^2 + (\gamma/3)h^3$$

$$- K_+[2\alpha + \beta h + \gamma(h^2 + 2h/\mu + 4/\mu^2)] \quad (6)$$

where

$$K_+ = \frac{2f}{m}\,\frac{\exp(mh) - 1}{[\mu - m + (\mu + m)\exp(mh)]}$$

If $m^2 < 0$, this must be recognized in Eqs. 5 and

$$K_- = \frac{f}{\mu m}\,\frac{\mu\sin(mh) - m[1 - \cos(mh)]}{f[1 - \cos(mh)] + \mu\cos(mh) - m\sin(mh)}$$

replaces K_+ in Eq. 6. In K_-,

$$m = (2\mu f - \mu^2]^{1/2}$$

Application I

Equation 6 has been checked by using the previous plate data. These plates had an HEU thickness of 1/16 in., and each had a coating of about 0.002 in. Thus, each five-plate unit is taken to be 0.3325 in. thick, and is assumed to have a uniform absorption coefficient. This thickness will be called X. The differential response curve of the previous paper is, then, determined by Eq. 6 with h replaced by X and with different constants a, b, and g, derivable from a single set for a particular origin, but dependent on the origin for the stack of height X when it is at position i in the DU stack. Formally,

$$N_i = \alpha_iX + (\beta_i/2)X^2 + (\gamma_i(X/3X^3$$

$$- K[2\alpha_i + \beta_iX + \gamma_i(X^2 + 2X/\mu + 4/\mu^2)]$$

in which α_i, β_i and γ_i depend on i, and K is K_+ for h = X. In this way, the a, b, and g of N(x) for the origin used for the stacking of the five-plate HEU units can be related to the constants in the previous equation for N_i.[1] Having done this, the α, β, and γ required for finding R as a function of h, measured relative to a fixed origin, from Eq. 6 can be found for that data.

The values of μ and of f were determined by, again, fitting at the heights corresponding to 50 plates and to 75 plates. The results were $\mu = 1.07678$ in.$^{-1}$ and $f = 0.35539$ in.$^{-1}$. These can be compared directly though crudely, to the previous values of g and of f. If

$$0.69822 = e^{-0.3325\mu},$$

$\mu = 1.08036$ in.$^{-1}$. Very crudely, a value of f = 0.09356 per unit would correspond to 0.09356/0.3325 = 0.28138 in.$^{-1}$. If a weighted thickness is defined as

$$X' = \int_0^X e^{-\mu x}dx,$$

f = 0.09356 per unit would correspond to 0.09356 x 1.08036/(1 - 0.69822) = 0.33494 in.$^{-1}$.

When $\mu = 1.07678$ and $f = 0.35539$ are used in Eq. 6 to find the response at all the other heights corresponding to the addition of successive five-plate HEU units, the results are nearly identical to those obtained with the discrete form of the model; the only differences are that the present results are less by one count at 4 of the 15 points. Such differences are, probably, due to round-off errors.

Application II

As part of a special project, standards were made recently by mixing highly enriched UO_2 in various concentrations in an Al_2O_3 matrix and filling cylindrical containers with these mixtures to a constant fill height. The driver response to these standards has the same general characteristics as shown, for instance, by Foley and Cowder.[3] A rather long reach from the HEU plate data, accompanied by some crystal-ball evaluations of the absorption coefficients to be used, was made in an attempt to fit the observations on these standards. Since the attempt was more successful than might have been expected, it is believed it might be useful to lay out the long reach in some detail.

First, the changes in the form of the model are described. Up to now, the contribution to C(x) caused by sources elsewhere in the stack has been described as being a fraction, f, of the "signal" that arrives at x from elsewhere in the stack, and a single absorption coefficient was used. For the present application, it is assumed that, if k is the fraction of active material of absorption coefficient μ_0 mixed into inert material of absorption coefficient, μ, then

$$\mu = k\mu_0 + (1 - k)\mu_1 .$$

Similarly, the argument is made that, while some of the signal arriving at x from elsewhere in the stack is absorbed with the generation of new neutrons, some is scattered by the inert material. Thus, the coefficient of the integral terms in Eq. 2 is changed from f to $[kf_0 + (1 - k)f_1]$. Finally, if N(x) is the response of the active component caused by the sources external to the stack, as used to this point, it must now be replaced by kN(x). Here it is added that the application to these standards is eased by the fact that the observations on them were made at the same driver table height as for the HEU plates, and the uranium had the same enrichment for each.

The problem was set up so that the active material was UO_2 and the intert material was Al_2O_3. Thus, the absorption coefficients for these are needed, and N(x) must be found for a container of only UO_2. To work out the absorption coefficients, nuclear radii are used. There are various formulae for these; what was used here was

$$\rho = 0.2 \times 10^{-12} z^{1/3} \text{cm},$$

where z is the atomic number, taken from Rasetti.[4]

The value found here for μ for the HEU plates, 1.07678 in^{-1}, corresponds to 0.42393 cm^{-1}. Then the cross-section is this divided by the number of atoms/cc in uranium metal, and is found to be

$$\sigma_U = 8.96823\text{b}.$$

From this it is found that

$$\sigma_U/\pi\rho_U^2 = 3.50191 ,$$

and this ratio has been used like a universal constant. In this way, it is found that

$$\sigma_{Al} = 2.43301\text{b} ,$$

$$\sigma_O = 1.76025\text{b} .$$

With values of the numbers of atoms/cc of U and of O in UO_2 and of Al and of O in Al_2O_3, it is further found that

$$\mu_{UO_2} = \mu_0 = 0.77526 \text{ in}^{-1} ,$$

$$\mu_{Al_2O_3} = \mu_1 = 0.53279 \text{ in}^{-1} .$$

The ratio of the number of uranium atoms per unit volume in UO_2 to that in U metal is taken to be 0.51702. Were the containers used for the standards, 8-cm diameter cylinders, filled with HEU metal, they would contain 2356.85 grams per inch, while the plate stack had 1137.35 grams per inch. Thus, N(x) for the standards is found from that for the plates by multiplying by 2356.85 x 0.51702/1137.35, or 1.07138. No attempt was made to correct for differences in transmissivity.

The ratio, k, is that of the mass of uranium in the standard to that in the same container were it filled with UO_2. The height of the container was 4.2 in. Thus, from the characteristics of these standards and from the extensions of the plate results, as described above, all the necessary numbers are in hand except f_0 and f_1. These were determined by a single least squares determination of corrections to reasonably good starting values, the latter having been determined by trial and error, to be

$$f_0 = 0.33892,$$

$$f_1 = 0.43316 .$$

The results are shown by a plot of gross count vs k in Fig. 1, where the points are the observations and the curve was calculated from the model.

Discussion

The basic model as described by Eq. 2, which leads to the net count given by Eq. 6, is precisely equivalent to the one of the previous paper.[1] There has only been a straightforward translation from the use of layers of finite thickness to layers of infinitesimal thickness. To whatever extent the first one reflected the processes actually occurring in a column of HEU when actively interrogated in a random driver, the second does also. Thus, it is not surprising that, since the first one fits the results observed with a stack of plates of varying height, the second one does also [Application I].

Application II constitutes a more severe test. Five of seven parameters were derived by methods that might be questioned but, at least, that derivation was not influenced by the observations to which a curve was to be fit. Nevertheless, an excellent fit was obtained to the five observations by using them to determine only the remaining two parameters, f_0 and f_1.

The same numbers, derived for the 8-cm diameter container, have been used to generate the curves shown in Fig. 2, where the abscissa is mass of HEU rather than k. Here, curves a, b, and c are for fill heights of 3.0, 3.5, and 4.0 in., respectively. They show the count to be expected as the concentration of $HEUO_2$ is increased from zero to unity at these different fill heights, and emphasize the self-absorption part of the total process. Curve d, on the other hand, shows the response to be expected if pure $HEUO_2$ is loaded into the container to different fill heights; it emphasizes the multiplication aspect of the process. We have rough data which needs repetition, but which is good enough to use as support, for HEU_3O_8 mixed in an Al_2O_3 matrix, which bears out the general behavior shown in Fig. 2. It should be realized, of course, that the form of Fig. 2 will be the same for any particular maximum concentration. While curve d was drawn for k = 1, a similar curve could have been drawn for k = 0.5, say.

It is apparent from Fig. 2 that the effective multiplication decreases as the concentration increases. It is also clear that one needs only the appropriate data, not a model, to make this observation.

Results so far lend credence to a belief that the gross features of the model are sound, but some disclaimers are in order. There must be a certain amount of fortuity, or compensation, in the passage from the good fit obtained in Application I to that obtained in Application II. The equation used for N(x) in the latter was adjusted from that used in the former for the difference in the amount of HEU per unit height, but no account was taken of the differences in penetrability that should be expected. Similarly, as the concentration of UO_2 varied, N(x) was further adjusted, via multiplication by k, only for that change in mass per unit length and not for further changes that should be expected in penetrability.

The most worrisome problem is that a proper value for f_1 seems to depend on the height, h, which is contrary to the conception of its purpose. One can impose heights where N(h) remains positive, but obtain nonsensical negative counts at low values of k, though there is no such problem at low concentrations for lower values of h, with that same value of f_1. The problem only occurs in that range where the trigonometric solutions apply, so that even at k = 1, one could impose a value of f_0 which would lead to negative counts. This aspect of the model clearly requires further study.

While it is difficult to see how the model could be useful in field work, it shows promise of being useful in paper studies of effects to be expected under various conditions. It was mentioned that we have obtained data of the characteristics shown in Fig. 2. The model in its original form [1] showed that the dependence of response on the location of dummy plates in a stack of HEU plates could be expected to be that which was actually indicated within the statistical uncertainty. The use of a flat N(x) associated with the production of neutrons by spontaneous fission should make the model applicable to the passive response from plutonium. There may be other applications not yet seen by the author, who is grateful for the suggestion [2] that led to this paper.

References

1. G. H. Winslow and F. O. Bellinger, "A Model for Absorption-Modified Multiplication Effects in the Assay of HEU Plates in a Random Driver," Journal of the INMM, VIII, No. 3 (Fall, 1979).

2. M. S. Zucker and W. A. Higinbotham, private communication. This acknowledgement was carelessly omitted from Ref. 1.

3. See, for instance, J. E. Foley and L. R. Cowder, "Assay of the Uranium Content of Rover Scrap with the Random Source Interrogation System, Los Alamos Scientific Laboratory Report LA-5692-MS (August 1974).

4. F. Rasetti, "Elements of Nuclear Physics," Prentice-Hall, Inc., New York (1936).

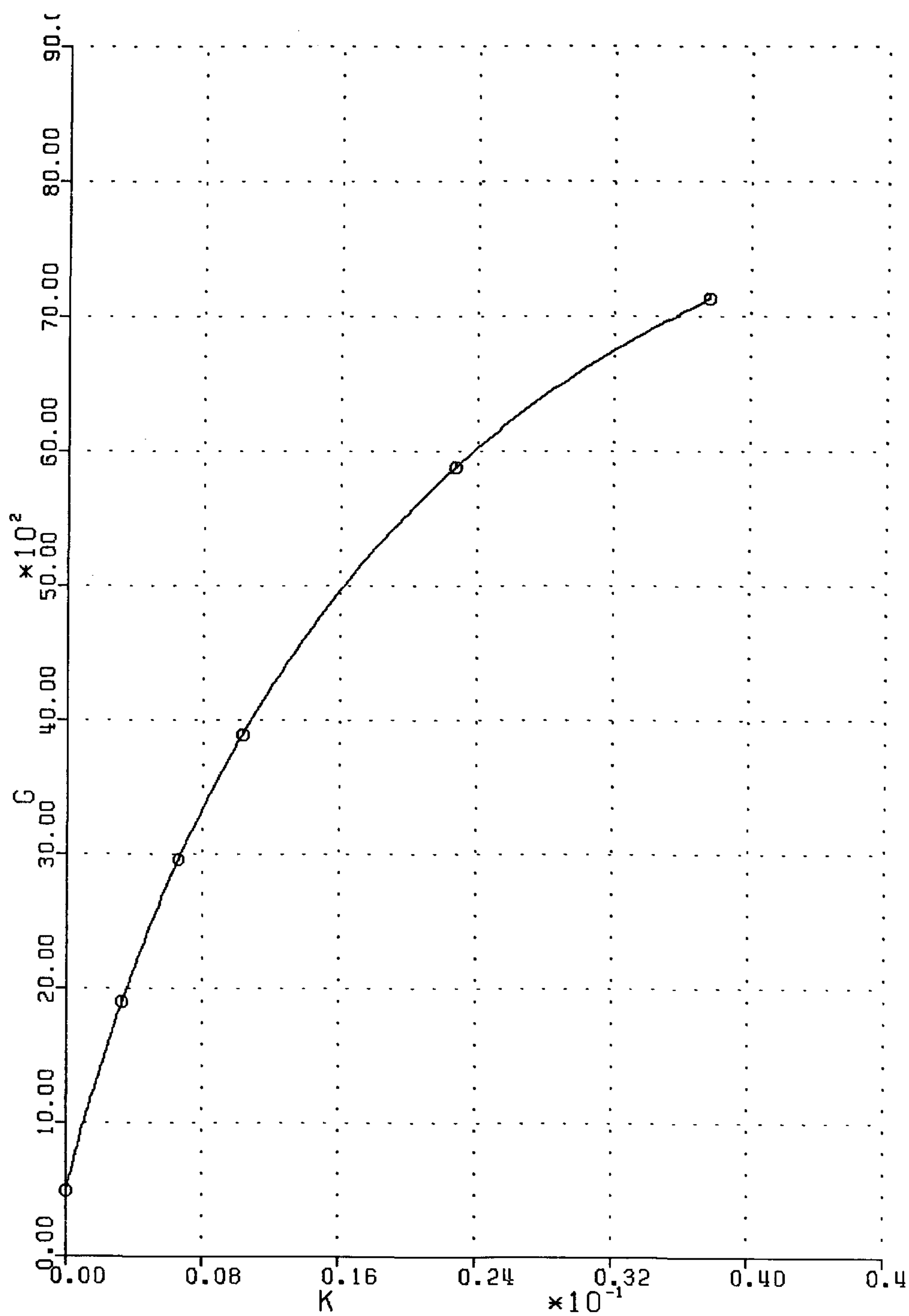

Figure 1

Fig. 1. Gross counts for samples of varying concentration at constant volume. The points are observations; the curve was calculated from the model after fitting at two of the observations.

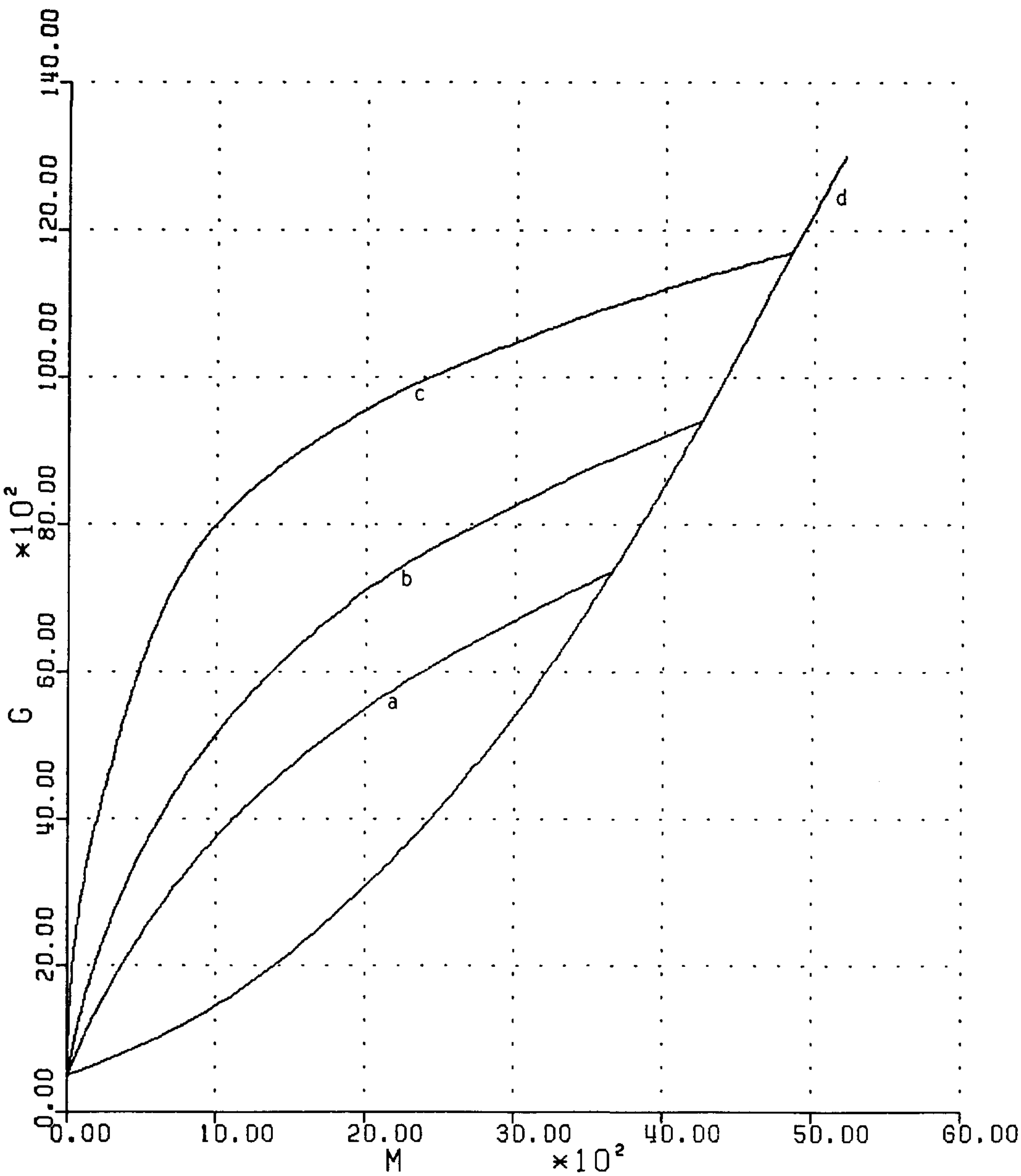

Figure 2

Fig. 2. Illustration of fill height-concentration relations. Curves a, b, and c for fill heights of 3.0, 3.5, and 4.0 inches, respectively, show the count to be expected as the concentration of $HEUO_2$ is changed from zero to unity at each fill height. The abscissa is the mass of HEU in the form of $HEUO_2$. Curve d shows the count to be expected for successive loadings of pure $HEUO_2$ and emphasizes the multiplication aspect of the process. The other curves emphasize the self-absorption aspect.

Demonstration Of Near-Real-Time Accounting: The AGNS 1980 Miniruns*

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ABSTRACT

During 1980-81 a series of minirun experiments is being conducted at the AGNS Barnwell Nuclear Fuels Plant. Each experiment consists of operating the second and third plutonium cycles continuously for approximately one week using natural uranium solutions. One of the main objectives of the miniruns is to demonstrate near-real-time acounting and control techniques in a large, modern reprocessing facility. The results of five of these miniruns during 1980 are reported.

I. BACKGROUND

Beginning in 1976, the Los Alamos Safeguards Systems Group selected the Barnwell Nuclear Fuels Plant as the baseline facility for a series of studies to develop concepts for near-real-time accounting (NRTA) in reprocessing plants.[1,2] These studies addressed the development and application of domestic and international safeguards at reprocessing plants.

The plutonium purification process (Fig. 1) received special attention because this is where separated plutonium solutions would be processed to the final, concentrated nitrate product. A reference NRTA strategy was developed that considered the plutonium purification process as a separate unit-process accounting area. This was accomplished by the addition of an on-line accountability measurement to the 1BP stream. Computer-based analysis showed that this reference strategy with hourly materials balances was both sensitive and timely in detecting diversion from the plutonium purification process.

In 1977 Allied-General Nuclear Services (AGNS), under the sponsorship of DOE, began the development and testing of a Computerized Nuclear Material Control and Accounting System (CNMCAS).[3] Initial work on CNMCAS involved the entire chemical separations line and focused on computerization of measurement, measurement control, and accounting procedures for "conventional" accounting. ("Conventional" accounting is the measurement of inputs and outputs for a materials balance area, coupled with periodic cleanout and physical inventory to close the balance.)

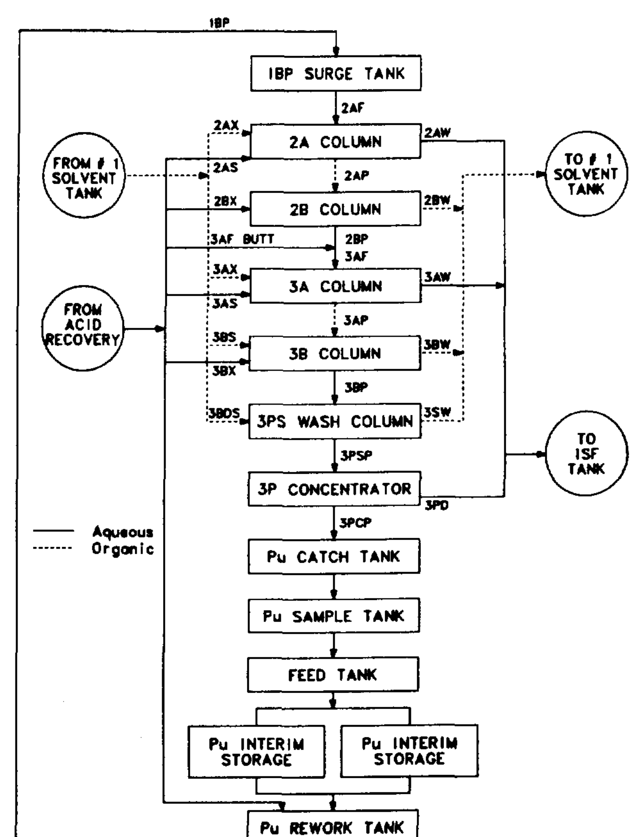

Fig. 1.
Minirun cycle: plutonium purification process.

*Work supported by the US Department of Energy.

Between 1977 and 1979, nearly 500 tonnes of natural uranium were cycled through the process and measured using CNMCAS. During this period, data from over 1790 batch measurements and 10 physical inventories were collected and analyzed. A summary of the results of these tests is presented in Table I. Significant improvements in conventional accounting were achieved in successive years, mostly as a result of adopting an electromanometer as the primary accountability tank measurement device and applying a vigorous computerized measurement control program.

As on-line measurement and computer capabilities improved, AGNS began to experiment using routine measurements of process variables to estimate the quantity of material in process. These experiments were initially conducted for the entire process, but by 1980 reduced funding required AGNS to find a less costly mode of testing. Because of the widespread and continuing interest in computerized nuclear materials control and near-real-time accounting methods, the minirun concept was devised. This concept involves cycling uranium solutions through the plutonium purification process in a closed loop, supported only by the solvent recycle system, the acid recovery/condensate recycle systems, and the process off-gas system.

II. MINIRUN DESCRIPTION

The minirun cycle (Fig. 1) consists of four pulsed-column contactors (2A, 2B, 3A, and 3B); one packed column (3PS); a product evaporator (3P concentrator); and seven product, feed, and blending tanks. Support systems include aqueous waste tanks, a waste evaporator and acid fractionator, a solvent surge and recycle tank, an off-gas system, and associated process and chemical distribution systems. This represents a good cross section of routinely used plant equipment for development of improved materials control and accounting methods.

A modified Purex solvent-extraction flowsheet is used with unirradiated natural uranium in place of plutonium for the tests. Uranium feed is provided by batch dilution and recycling of the concentrated (∿300 g/L) uranium product solution. Product batches are blended to 60 g/L and about 3M HNO_3 in the plutonium rework tank and batch transferred to the 1BP surge tank as needed. Feed to the process is continuously transferred from the 1BP surge tank to the 2A column at about 100 L/h.

TABLE I

CONVENTIONAL ACCOUNTING FULL-PLANT TEST RESULTS

Year	MTU Processed	ID[a]	LEID[b] (2σ)
1977	83	0.29% (241 kg U)	0.98% (813 kg U)
1978	82	0.04% (33 kg U)	0.28% (229 kg U)
1979	301	0.007% (21 kg U)	0.19% (572 kg U)

[a]ID = Inventory Difference. This is the difference between inputs and outputs after adjustment for beginning and ending inventory quantities. This quantity is also referred to as MUF or Materials Unaccounted For.

[b]LEID = Limit of Error of the Inventory Difference. This is the uncertainty of the materials balance for the inventory period.

Uranium is extracted into the organic phase and scrubbed with nitric acid in the 2A column. In the 2B column, the uranium is then stripped back into the aqueous phase using dilute HNO_3. An acid adjustment is made in line, downstream of the 2B column, and the above operations are repeated in the 3A and 3B columns, respectively.

Aqueous wastes (2AW and 3AW streams) are accumulated in a waste evaporator for the entire run period. Samples are taken from the waste streams every 8 h and analyzed for uranium to permit rough estimates of waste losses during the run. After the run, the accumulated acid wastes are measured to quantify the waste loss. Used solvent from the process (2BW and 3BW streams) is sent back to the solvent feed tank for recycle without treatment.

Product aqueous solution is scrubbed with diluent in the 3PS column to remove dissolved TBP, evaporated to 250-300 g/L in the 3P concentrator (the concentrator is operated in a continuous overflow mode), and collected in the plutonium catch tank. The product solution is then batch transferred to the plutonium sample tank, measured for product accountability, and moved to the feed tank. This material is then remeasured in the feed tank for input accountability and moved to one of the interim storage tanks to await reblending as feed in the rework tank.

The normal starting uranium inventory for each minirun was 400-500 kg. After attaining equilibrium, a "process holdup" (pulsed columns, lines, product evaporator) of about 70-75 kg of uranium was observed, with the remaining material distributed among product tanks. Waste losses from the minirun test loop varied from run to run. In full-plant operation, these minirun "waste losses" would actually be internal recycles and would not affect full-plant conventional materials balances.

III. EVALUATION OF MINIRUN DATA

Each run was seven days in duration, except for minirun number 5, which was five days long. Table II summarizes the purpose and activities of each of the five runs during 1980.

A. Conventional Accounting

Table III is a materials balance summary for the five miniruns based on conventional accounting. A total of 3340 kg of uranium was processed during the runs at a nominal rate of 150-200 kg of uranium per day. The cumulative ID for the five runs was 13.3 kg of uranium (0.4% of throughput) with a 2σ uncertainty of 11.7 kg (0.35%). Table III contains two types of materials balance data. The first type incorporates feed and product flow accountability measurements for the minirun cycle as well as beginning and ending inventory measurements. The second type of materials balance is based solely on beginning and ending inventories and any uranium solution added to the minirun system. The first type of balance is representative of actual process conditions, whereas the second type provides confirmatory data based on measured additions of uranium to the minirun test loop.

The relative percent values for ID and LEID are higher than those for the 1978 and 1979 full-plant test results (Table I). This is due in part to the fact that minirun waste losses, which are normally difficult to measure precisely, were relatively large. As a result, waste measurements degraded the minirun overall materials balance performance.

The first minirun was very erratic in terms of system/column operation. Inventory data showed a considerable loss of organic solution from the minirun system, which was caused by column upsets and overflows. The materials balance data reflect the quantities associated with this loss. Subsequent runs finally recovered most of this material, indicating that the "missing" organic was probably distributed as undetected layers on peripheral minirun storage tanks.

B. In-Process Inventory Determinations

During the course of the five miniruns, about 1000 in-process inventory determinations were made at the rate of one per hour. Figure 2 is a summary of a typical in-process inventory determination, which includes liquid level, solution density, temperature, and solution composition data for each process vessel. Volumes and total uranium contents are calculated for each vessel and summed up to give the total measured inventory. This total is subtracted from the total system inventory (which is either the current difference between accumulated inputs and outputs or the current total inventory of uranium in the minirun loop) to give an unmeasured inventory (UMI). This UMI was not zero in the minirun tests because raffinate waste losses and line holdups were not measured or estimated. The UMI values were monitored to detect unauthorized removals and to explain significant changes in the data.

Figures 3, 4, and 5 are UMI vs time plots that were generated for run numbers 1, 3, and 5 as part of the data evaluation effort. It is evident from these plots that improvements were achieved in the stability of the data with each successive test. A number of factors contributed to this improvement. First, run number 1 was most unstable because a continuous in-line dilution system was used for the feed. A batch-blend system was adopted for succeeding runs, and the stability of the system was greatly improved. Second, the data reflect fluctuations caused by the initial inhomogeneity of each feed batch. In the future, an estimated value will be used for the uranium concentration until tank mixing is complete. Third, partially plugged dip-tubes caused erroneous readings when not corrected. This problem was overcome by installing purge-air humidifiers on the troublesome dip-tubes. Also, following run number 3, several pressure transmitters were tied into an automated calibration system in which the calibrations of process instrumentation were periodically compared to corresponding readings of a high-precision digital manometer.[4] This modification alone reduced the uncertainty of level and density readings by almost an order of magnitude.

C. The Pulsed Columns

Under normal process conditions it is not possible (or at least not very convenient) to measure the in-process inventory of nuclear material in the pulsed columns. However, estimates of the in-process inventory can be obtained if timely flow and concentration measurements are available on the column inlet and outlet streams.

TABLE II

1980 MINIRUN DESCRIPTION

Number	Purpose	Special Test Activities
1	Shakedown	- Program debugging; - Column inventory experiment
2	Shakedown/baseline run	- Accumulation of steady-state data
3	Announced diversions (all parties informed of diversion timing)	- 17 abrupt (batch) diversions ranging from 5 kg of uranium to 0.25 kg of uranium - 4 protracted removals, 16-hour duration each, rates from 0.2 kg of uranium to 0.6 kg of uranium per hour
4	Unannounced diversions (accounting personnel not informed of timing)	- 3 abrupt removals, 0.3 kg of uranium from a storage tank, 0.5 kg of uranium, and 1.2 kg of uranium from 1BP surge tank - 2 protracted removals, 0.5 kg of uranium per hour, ∿12-hour duration
5	DOE contractor demonstration	- 1 abrupt removal, 0.25 kg of uranium from storage tank - 1 protracted removal, 0.85 kg of uranium per hour for 16 hours; - Column inventory experiment

TABLE III

MINIRUNS CONVENTIONAL MATERIALS BALANCE SUMMARY

	With Feed/Product (kg U)		Without Feed/Product (kg U)	
Run No. 1	BI	7.00	BI	7.00
	Feed	1173.58	Input	501.37
	Product	671.03	Waste	126.88
	Waste	126.88	EI	339.08
	EI	339.08		
	ID	43.59	ID	42.41
Run No. 2	BI	339.08	BI	339.08
	Feed	1080.64	Input	169.59
	Product	914.74	Waste	121.69
	Waste	121.69	EI	398.62
	EI	398.62		
	ID	-15.33	ID	-11.64
Run No. 3	BI	398.62	BI	398.62
	Feed	699.07	Input	88.31
	Product	608.81	Waste	196.03
	Waste	196.03	EI	296.13
	EI	296.13		
	ID	-3.28	ID	-5.23
Run No. 4	BI	296.13	BI	296.13
	Feed	924.69	Input	193.30
	Product	726.11	Waste	137.14
	Waste	137.14	EI	368.26
	EI	368.26		
	ID	-10.68	ID	-15.97
Run No. 5	BI	368.26	BI	368.26
	Feed	416.27	Input	--
	Product	421.67	Waste	71.76
	Waste	71.76	EI	292.18
	EI	292.18		
	ID	1.08	ID	4.32
Cumulative ID (Runs 1-5):		13.29		13.89
LEID:		11.7		--

The systems studies of near-real-time accounting[1,2] showed that estimates of the AGNS column inventories to 10% or better should be adequate for sensitive detection of losses. Under the sponsorship of Los Alamos and with participation by the nuclear industry (AGNS and General Atomic) and by universities (Iowa State and Clemson), techniques for estimating the inventory in the pulsed-column contactors were developed.[5,6]

Figure 6 is a schematic diagram of a pulsed column. Flow rates of all inlet streams are monitored to control the columns. For improved control and for NRTA, the concentrations of nuclear material in the feed, product, and waste streams should also be measured. These measurements can then be used to estimate the in-process inventory of nuclear materials in the columns. The form of the estimator is given by

$$H = H_f C_f + H_p C_p + H_w C_w \quad , \qquad (1)$$

where H is the total column inventory and C_f, C_p, and C_w are measured concentrations in feed, product, and waste streams; H_f, H_p, and H_w are constants determined experimentally and through engineering models of specific contactor systems.

IPI DETERMINATION SUMMARY

NUMBER 134
TIME 7229 (= 2 : 0)
DATE 17-Jun-80

FOR TANKS

	PUPROD	PU CTH	1 PU STG	2 PU STG	3 PU STG	PU RWK	1BP	1 SOL FD	3P CONC
MP	2010	2054	2011	2012	2013	2008	2017	2015	2122
LR	84.9618	45.418	21.0229	12.1963	15.3163	55.7624	71.2445	62.7637	118.743
DR	15.0905	14.7108	13.4956	12.9025	13.8784	11.4247	11.531	8.10516	14.1783
T	30.9661	30.9661	31.5538	27.6213	28.0184	25.1027	24.7972	25.7272	0
0	0	0	0	0	0	0	0	0	0
H+	1.936	0	1.655	1.665	1.595	3.161	2.953	.041	0
DN	1.4972	0	1.49455	1.41105	1.49135	1.1441	1.1729	.8325	0
UCONC	.33	.25605	.33416	.27046	.33303	.03753	.02572	.0118	.25605
VOL	172.69	48.6032	49.1117	37.3855	42.5643	587.149	882.531	7531.93	74.0968
0	0	0	0	0	0	0	0	0	0
0	.33	0	0	0	0	.0381	.0559	0	146.008
0	0	0	0	0	0	0	.02898	0	0
KGU	56.9878	12.4449	16.4112	10.1113	14.1752	22.0357	22.6987	88.8767	18.9725

FOR COLUMNS

	2A	3A	2B	3PS	3B
MP	2109	2111	2110	2113	2112
LR	19.4101	18.9444	9.23238	18.1686	6.37534
DR	8.85809	9.08398	8.19916	7.7674	8.45068
WR	445.999	464.588	371.88	146.973	599.149
LI	11.9446	13.0655	0	10.5511	10.6445
SOLV FLOW	217.288	79.1758	0	0	-35.5599
SCRUB FLOW	31.9043	12.9328	78.5815	0	173.656
SCRUB H+	1.29014	1.29014	.155785	0	.155785
FEED FLOW	440.778	58.5903	217.288	0	79.1758
FEED CONC	.04669	.0452	.0531293	0	.0666817
PROD FLOW	0	0	78.5815	0	173.656
PROD CONC	.0531293	.0705637	.0408	-.0054	.041
KGU	9.83537	28.9611	17.6901	4.55025	49.373

TOTAL MEASURED INVENTORY = 373.17 KGS U (EXCLUDING NEGATIVES)
TOTAL SYSTEM INVENTORY = 482.6 KGS U
UNMEASURED INVENTORY = 109.43 KGS U

Fig. 2.
In-process inventory determination summary.

Experiments at AGNS during run numbers 1 and 5 indicate that the column inventory estimates are good to 5 to 25% for individual columns and to about 10% for the total uranium inventory in all four pulsed columns. These column inventory experiments consisted of draining the columns into holding tanks at the end of the minirun. The contents of the holding tanks were sampled and analyzed for uranium, and the measured uranium inventory was compared with the estimated inventory for each of the columns.

During the miniruns, two techniques were used to monitor variations in the column uranium inventories. The first technique was based on Eq. (1) and used available process control data to estimate the uranium concentrations in the column inlet and outlet streams. The second technique used correlations between the column weight recorder (manometer) and the heavy-metal inventory. These techniques appeared to give a reliable picture of the variations in pulsed-column inventory and were shown to be useful for process control as well as materials accounting.

D. Decision Analysis

The minirun data were analyzed using the methods of decision analysis.[7,8] The Los Alamos computer program DECANAL was implemented on the AGNS CNMCAS minicomputer (PDP 11/35), and several unit process accounting areas (UPAAs)

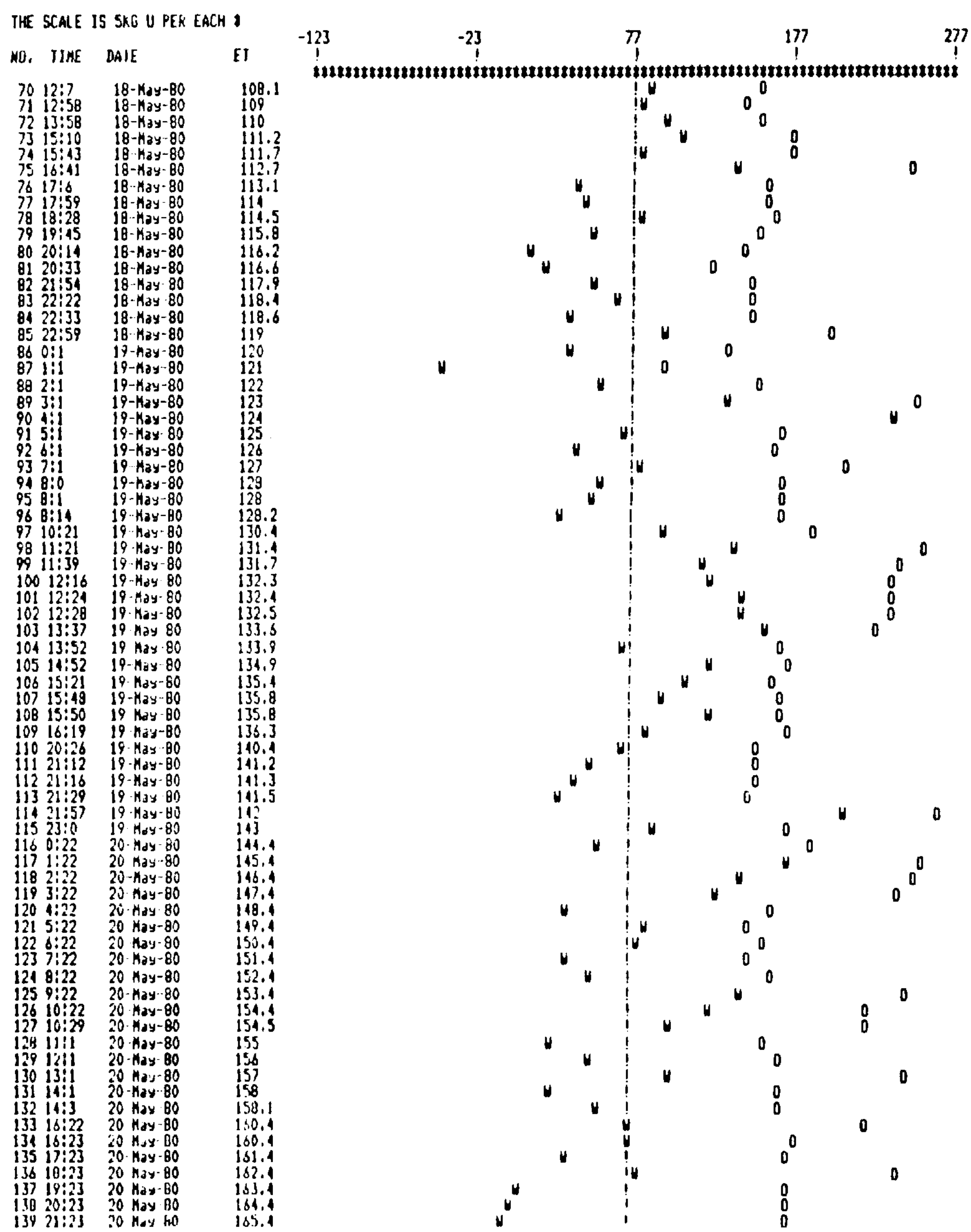

Fig. 3.
Minirun No. 1. Unmeasured inventory plot with (W) and without (O) column inventory estimates.

with overlapping boundaries were defined. This was possible because at certain points in the process there are redundant measurements; for example, the 1BP tank drop-out rate and the 2AF stream head-pot flow meter both measure the 2AF stream flow rate. Likewise product solutions can be measured in the product catch tank, the product sample tank, and the product storage tanks. Materials balance data from overlapping UPAAs and redundant measurements were very useful in detecting and localizing losses and in maintaining continuity when there were measurement problems.

Data from each UPAA were examined using a two-step scan-search procedure. In the scan mode, materials balance and cusum (cumulative materials balance) plots were produced for a selected UPAA over a selected period of time. Tables and plots of the raw measurement data were also produced. These scan data were examined for evidence of statistically significant outliers or trends. If significant losses were indicated, a search of the data was performed in which an alarm chart was generated. In the search mode, the most significant sequence of materials balances was identified, and the

THE SCALE IS 5KG U PER EACH *

NO.	TIME	DATE	ET
1	0:12	16-Jul-80	.2
2	1:2	16-Jul-80	1
3	2:2	16-Jul-80	2
4	3:12	16-Jul-80	3.2
5	4:2	16-Jul-80	4
6	5:2	16-Jul-80	5
7	6:13	16-Jul-80	6.2
8	7:12	16-Jul-80	7.2
9	8:12	16-Jul-80	8.2
10	9:9	16-Jul-80	9.2
11	9:25	16-Jul-80	9.4
12	10:2	16-Jul-80	10
13	11:2	16-Jul-80	11
14	12:2	16-Jul-80	12
15	13:2	16-Jul-80	13
16	14:2	16-Jul-80	14
17	15:2	16-Jul-80	15
18	16:2	16-Jul-80	16
19	17:2	16-Jul-80	17
20	18:2	16-Jul-80	18
21	19:2	16-Jul-80	19
22	20:2	16-Jul-80	20
23	21:2	16-Jul-80	21
24	22:2	16-Jul-80	22
25	23:2	16-Jul-80	23
26	0:2	17-Jul-80	24
27	1:2	17-Jul-80	25
28	2:2	17-Jul-80	26
29	3:2	17-Jul-80	27
30	4:2	17-Jul-80	28
31	5:2	17-Jul-80	29
32	6:2	17-Jul-80	30
33	7:2	17-Jul-80	31
34	8:2	17-Jul-80	32
35	8:35	17-Jul-80	32.6
36	9:2	17-Jul-80	33
37	9:32	17-Jul-80	33.5
38	10:2	17-Jul-80	34
39	10:32	17-Jul-80	34.5
40	11:2	17-Jul-80	35
41	11:32	17-Jul-80	35.5
42	12:2	17-Jul-80	36
43	12:32	17-Jul-80	36.5
44	13:2	17-Jul-80	37
45	13:32	17-Jul-80	37.5
46	14:2	17-Jul-80	38
47	14:32	17-Jul-80	38.5
48	15:2	17-Jul-80	39
49	15:32	17-Jul-80	39.5
50	16:2	17-Jul-80	40
51	17:2	17-Jul-80	41
52	18:2	17-Jul-80	42
53	19:2	17-Jul-80	43
54	20:2	17-Jul-80	44
55	21:14	17-Jul-80	45.2
56	22:14	17-Jul-80	46.2
57	23:14	17-Jul-80	47.2
58	0:14	18-Jul-80	48.2
59	1:14	18-Jul-80	49.2
60	2:14	18-Jul-80	50.2
61	3:14	18-Jul-80	51.2
62	4:14	18-Jul-80	52.2
63	5:14	18-Jul-80	53.2
64	6:14	18-Jul-80	54.2
65	7:14	18-Jul-80	55.2
66	8:14	18-Jul-80	56.2
67	9:14	18-Jul-80	57.2
68	10:14	18-Jul-80	58.2
69	11:14	18-Jul-80	59.2

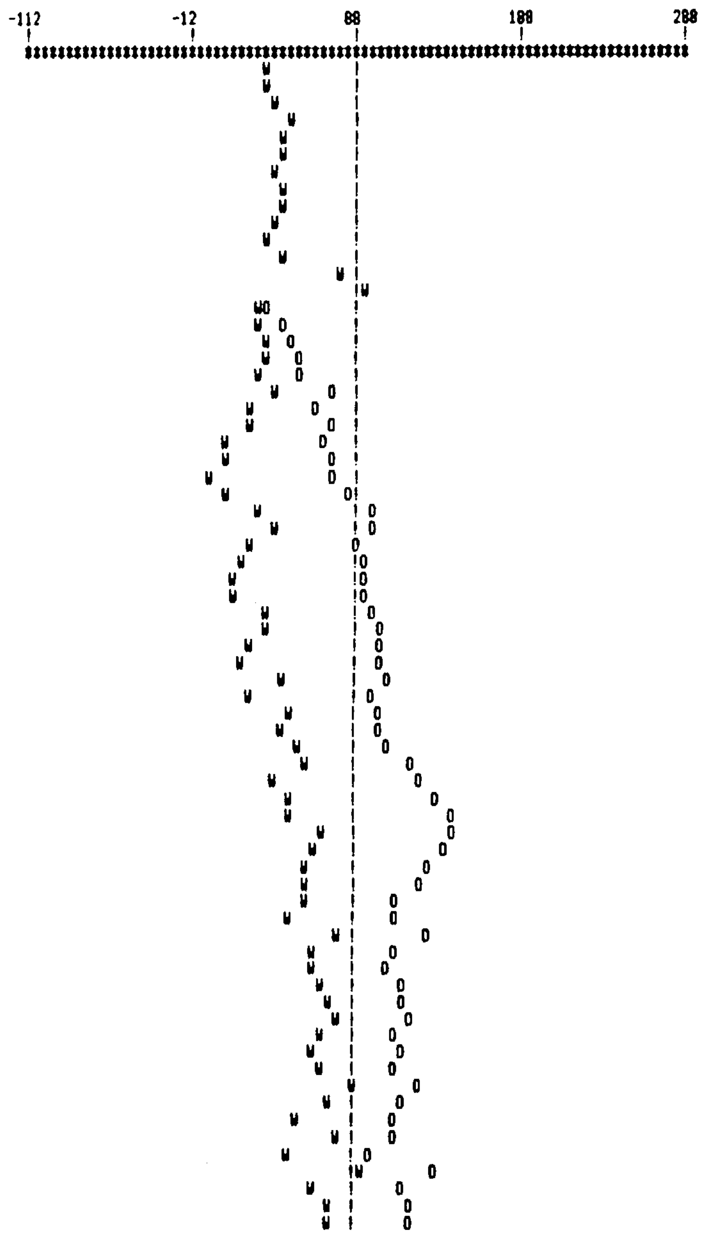

Fig. 4.
Minirun No. 3. Unmeasured inventory plot with (W) and without (O) column inventory estimates.

amount, time, and location of the apparent loss were determined.

Figures 7-11 show one example of analyzing data from steady process operation during minirun 4 (September 4-8, 1980). The accounting data were collected and analyzed every hour.

Figure 7 shows the total inventory of uranium estimated for the pulsed columns. The inventory is slowly varying, except near balance number 50 where there was an abrupt shift, which was caused by an abnormally low uranium analysis.

Figure 8 shows the net-transfer data (inputs minus outputs) across the columns, that is, from the 1BP tank (2AF stream) to the product concentrator (3BP stream). Figures 9 and 10 show materials balance and cusum plots obtained by combining the in-process inventory and net-transfer data. No significant trends are apparent on the

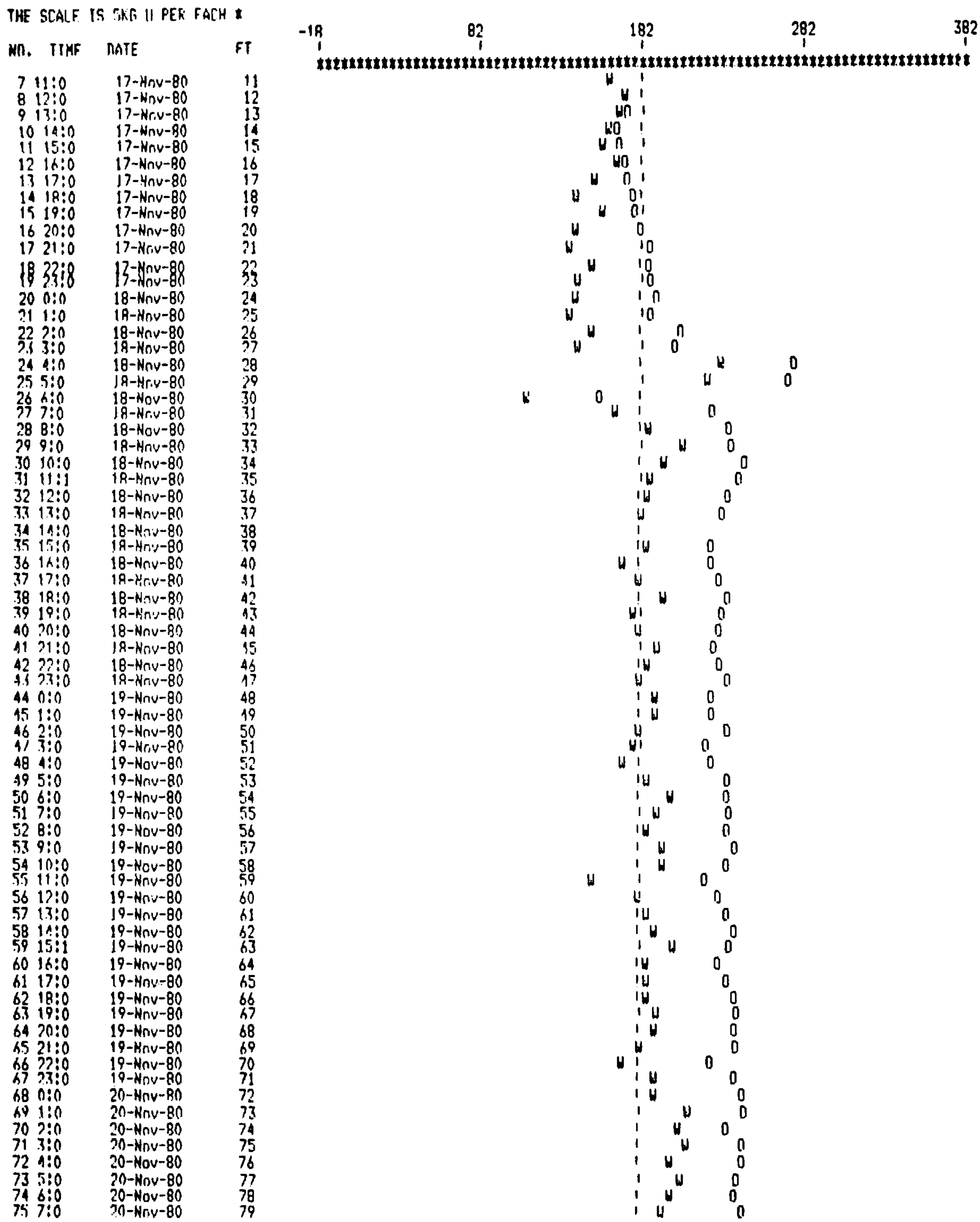

Fig. 5.
Minirun No. 5. Unmeasured inventory plot with (W) and without (O) column inventory estimates.

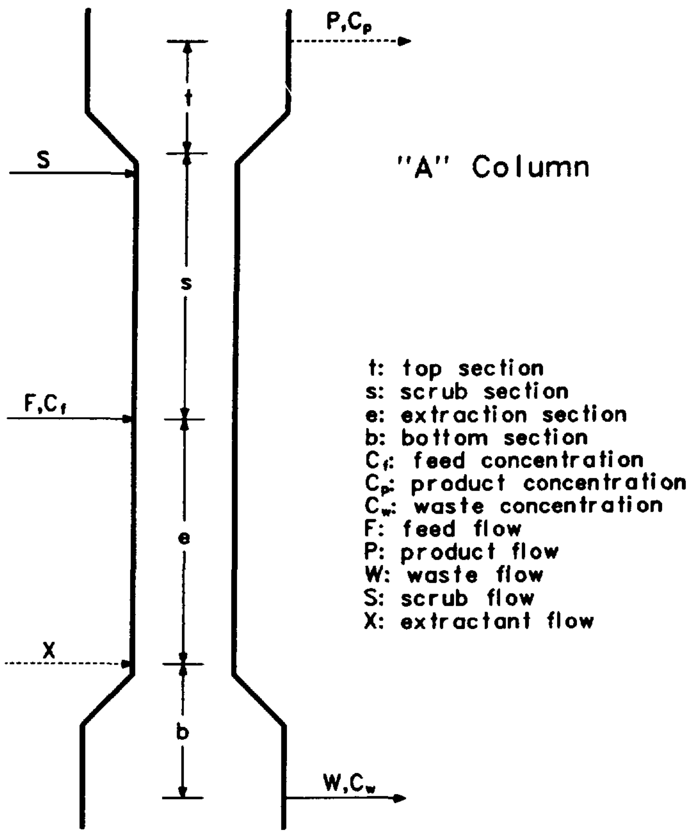

Fig. 6.
Pulsed-column diagram.

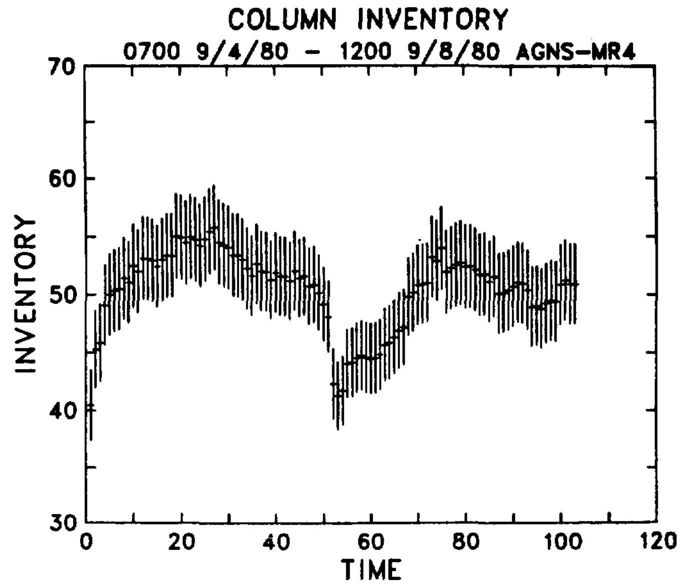

Fig. 7.
Estimated in-process inventory in the pulsed columns.

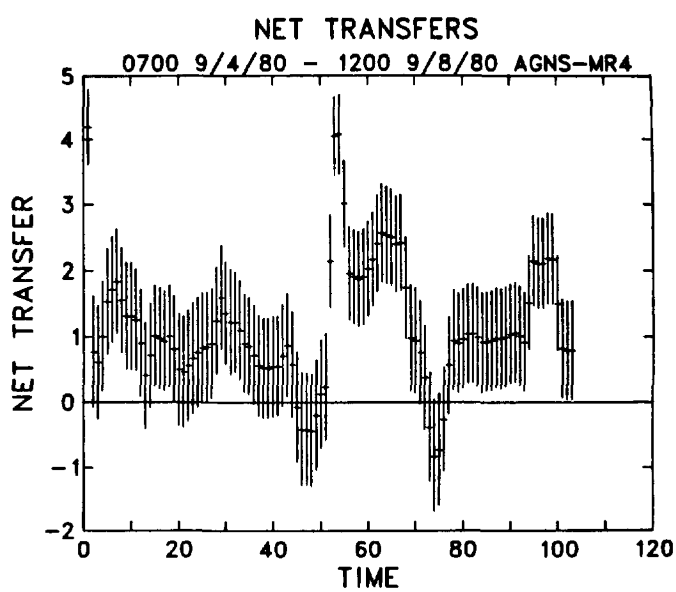

Fig. 8.
Net transfers (inputs minus outputs) across the columns.

materials balance plot; however, three separate positive trends are apparent on the corresponding cusum plot. These trends were caused by two protracted diversion tests from intermediate product streams (balance numbers 20 to 40 and 80 to 100) and an unexpected rapid loss of uranium to waste (balance numbers 50 to 70).

Figure 11 is the alarm chart corresponding to the cusum plot of Fig. 10. Note that all three trends in the data produce highly significant alarms (F and G) and clustering of many alarms. This is clear evidence that unmeasured losses are occurring and that an investigation is required.

IV. CONCLUSIONS

The miniruns are continuing during 1981. Most of the diptube manometers used for on-line process control and accountability have been connected to the autocalibration system. The 1981 runs feature the addition of x-ray fluorescence and possibly x-ray absorption-edge measurements on sample lines from selected waste streams and process streams. Also, a column inventory experiment is planned for each run. The following is a list of conclusions from the 1980 miniruns.

- The results of the miniruns show that the technique of near-real-time accounting for nuclear materials can detect losses (both abrupt and protracted) from the process area of a large nuclear fuels reprocessing plant. The minrun experiments also show that the functions and in-plant systems of NRTA, process monitoring, and control are compatible.

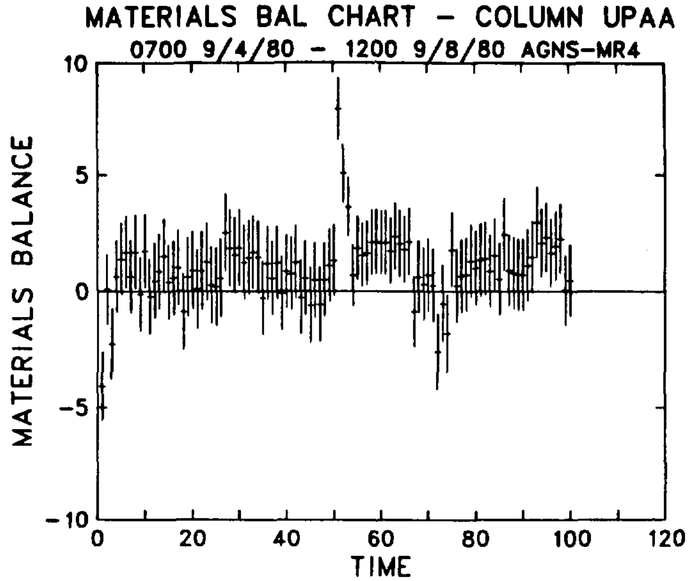

Fig. 9.
Plot of materials balances during minirun 4.

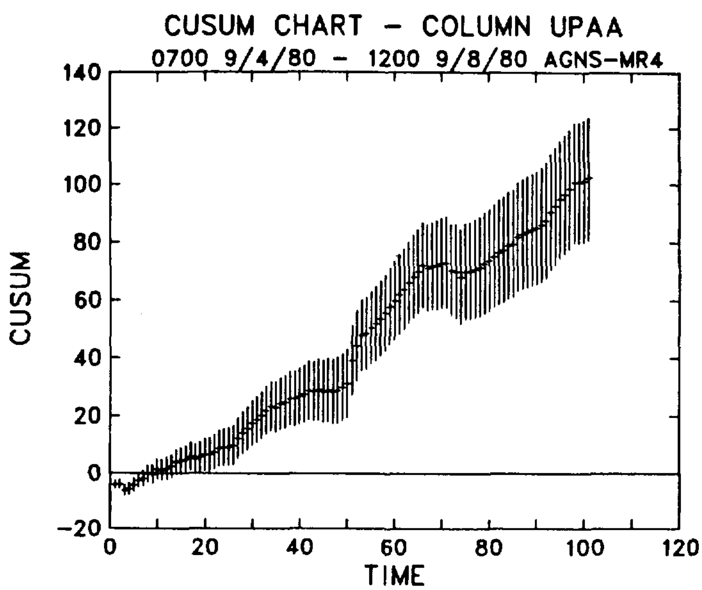

Fig. 10.
Cumulative summation of materials balances during minirun 4.

- Measurements of flow rates and concentrations are needed on process streams, including waste streams, that cross accounting area boundaries. Some of these measurements can be obtained from process flowmeters and instrumentation on adjacent process vessels. A few measurements at flow key measurement points require the placement of nondestructive instrumentation on available sample lines.

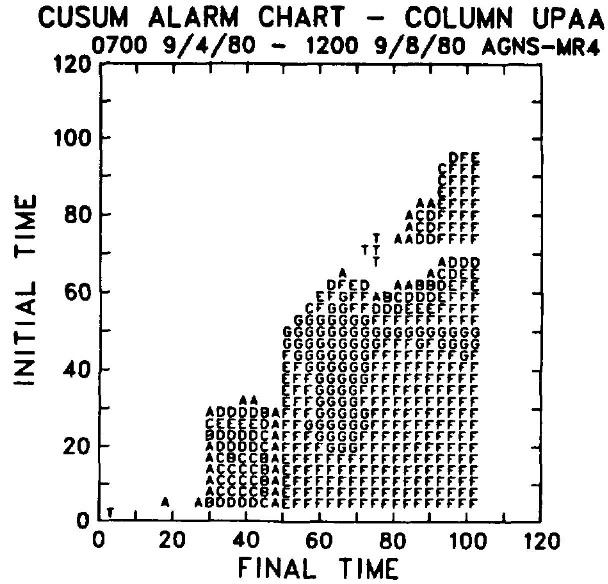

Fig. 11.
Alarm chart corresponding to the materials balance data of minirun 4.

- In-process inventory measurements and estimates for process tanks and vessels usually can be obtained from available process control data. These measurements in general need not be as accurate or precise and may be made less often than the stream measurements. Estimates can be made of the in-process inventory in pulsed columns that are satisfactory for NRTA.
- Overlapping UPAAs and redundant measurements are helpful for system reliability and for localization and detection of losses.
- Computerized analysis and display methods geared to ease of understanding and interpreting the data and the status of the process are necessary components of near-real-time systems.
- The reprocessing facility is an integrated whole, and the safeguards system must address the entire facility. Further in-plant testing of NRTA is required throughout the entire process to refine the technique, particularly the use of data from on-line instrumentation. Process monitoring data generally are sensitive to small changes in process tanks and columns and should be better integrated into the overall system. The final integrated system must be tested in a "hot" facility.

V. REFERENCES

1. E. A. Hakkila, D. D. Cobb, H. A. Dayem, R. J. Dietz, E. A. Kern, E. P. Schelonka, J. P. Shipley, D. B. Smith, R. H. Augustson, and J. W. Barnes, "Coordinated Safeguards for Materials Management in a Fuel Reprocessing Plant," Los Alamos National Laboratory report LA-6881 (September 1977).

2. E. A. Hakkila, D. D. Cobb, H. A. Dayem, R. J. Dietz, E. A. Kern, J. T. Markin, J. P. Shipley, J. W. Barnes, and L. A. Scheinman, "Materials Management in an Internationally Safeguarded Fuels Reprocessing Plant," Los Alamos National Laboratory report LA-8042, Vol. II (April 1980).

3. J. M. Crawford, M. H. Ehinger, C. Joseph, and M. L. Madeen, "Development of a Computerized Nuclear Materials Control and Accounting System for a Fuel Reprocessing Plant," Nucl. Mater. Manage. VIII (Proceedings Issue), 405-415 (1979).

4. J. M. Crawford, "Automated Calibrations and Dynamic Corrections for Differential Pressure Transmitters," Nucl. Mater. Manage. IX (Proceedings Issue), 138-147 (1980).

5. D. D. Cobb and C. A. Ostenak, "Dynamic Materials Accounting for Solvent-Extraction Systems," in Measurement Technology for Safeguards and Materials Control, Proc. Symp., Kiawah Island, SC, November 26-30, 1979, T. R. Canada and B. S. Carpenter, Eds. (American Nuclear Society and National Bureau of Standards NBS Special Publication 582, June 1980).

6. D. D. Cobb, L. E. Burkhart, and A. L. Beyerlein, "In-Process Inventory Estimation for Pulsed Columns and Mixer-Settlers," in Proc. 2nd Annual Symp. on Safeguards and Nucl. Mater. Manage., Edinburgh, Scotland, March 26-28, 1980 (European Safeguards Research and Development Association, 1980), ESARDA 11.

7. J. P. Shipley, "Efficient Analysis of Materials Accounting Data," Nucl. Mater. Manage. VII (Proceedings Issue), 355-366 (1978).

8. J. P. Shipley, "Decision Analysis for Nuclear Safeguards," in Nuclear Safeguards Analysis, Nondestructive and Analytical Chemical Techniques, E. A. Hakkila, Ed. (American Chemical Society, Washington, DC, 1978).