# NUCLEAR MATERIALS MANAGEMENT

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# INMM Editorial

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

Clearly, in designing either national or international safeguards systems, it is necessary to assign available resources, in some rational fashion, to the types of nuclear materials and facilities that need to be protected and/or accounted for. In the national case, less effort would be assigned to materials such as low enriched uranium and more effort would be assigned to high enriched uranium, since it is extremely unlikely that a sub-national adversary would be able to make high enriched uranium from low enriched uranium.

In the international case, however, it is conceivable that a national adversary might construct a clandestine enrichment facility or plutonium production reactor. In order to assign its finite resources in a cost-effective manner, the IAEA has defined goal quantities and timeliness objectives for the different types of nuclear materials. These detection goals are to serve as guidelines for the development of safeguards approaches, not absolute requirements, as has been repeatedly stated. What I want to discuss is the rationale for the timeliness goals, one to three weeks for plutonium and highly enriched uranium compounds, one to three months for plutonium or U-233 in spent fuel, and less than one year for natural and low enriched uranium. The reason for choosing these different times for detection is said by the IAEA to be that they are related to the "approximate range of times required to convert the material to a form suitable for manufacture of nuclear explosive devices".*

A number of thoughtful and sympathetic people have pointed out that plutonium could be extracted from spent fuel or natural uranium could be enriched to 90% in a few days, if a nation had constructed a clandestine reprocessing or enrichment facility. Since this is true, one might conclude that the timeliness goal should be the same for natural uranium as for plutonium oxide, which would impose an enormous burden on the Agency.

The graded safeguards approach which the Agency has chosen makes a lot of sense to me. On the other hand, the Agency may need help in supporting it. The IAEA is not authorized to go looking for clandestine facilities. Consequently, it has based its reasoning on a vague concept - conversion time.

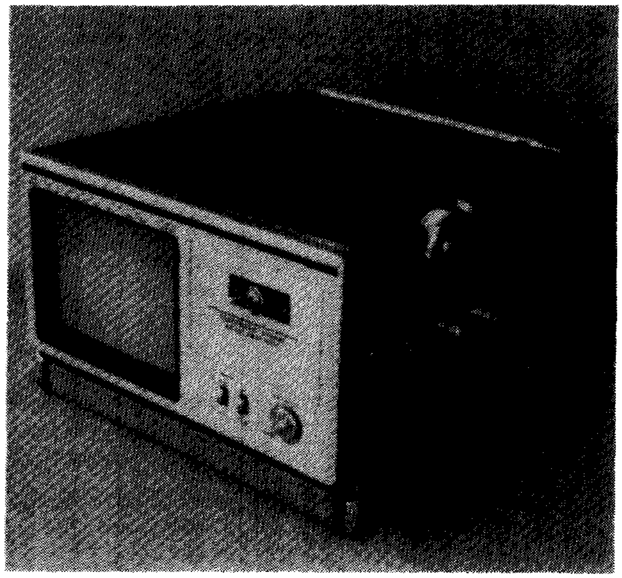
It seems to me that the rationale for the timeliness goals has to do with the decisions a nation would have to make if it were to consider breaking its agreement and to divert nuclear material to fabricate one or more nuclear explosive devices. In any case, it would have to prepare for fabricating a viable device. If it chose to divert spent fuel it would have to construct a plutonium recovery facility. If it chose to divert natural or low-enriched uranium it would have to construct an enrichment facility or a production reactor and plutonium recovery facility. As one goes from plutonium oxide to spent fuel to low-enriched uranium, the cost, the size of the project, the time, and the chances of being detected increase. Consequently, it would seem that the possible incentive for a nation to divert the different types of nuclear material are inversely related to the IAEA's goals for timeliness of detection.

Perhaps the Agency is not in a position to make this argument in support of its timeliness goals. Friendly individuals and nations can, if they so choose.

**IAEA Safeguards Technical Manual, Part A, IAEA-174, 1976*

## NEWS FLASH . . .

# FIVE-INCH BATTERY OPERATED SERVICE MONITOR



The VM 520 battery powered, black and white Service Monitor has a 4.5 inch viewing screen, is 100% solid state, and weighs only 6 pounds. It is ideal for the CCTV and CATV technician on a ladder or a pole, in an elevator or anywhere where power is not easily available. The VM 520 has two 75 ohm video signal input connectors; one BNC and one UHF type and also has a 75 ohm F type connector for VHF signal input. The VM 520 has a quick start feature and can receive broadcast UHF and VHF.

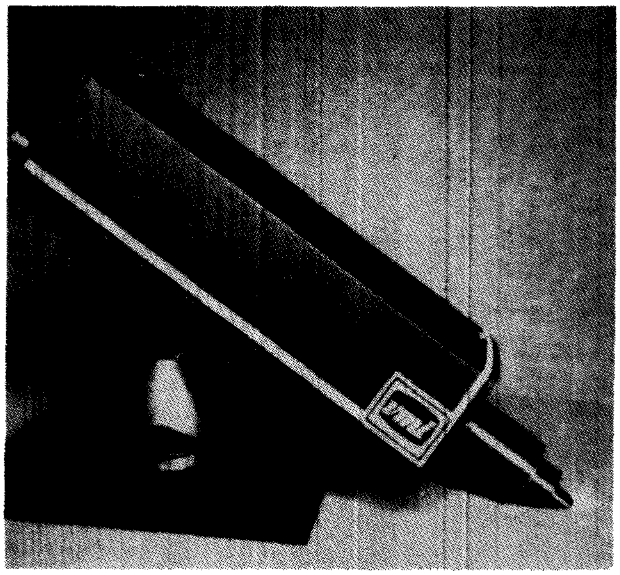
The VM 520 is powered by an integral, rechargeable NiCd battery or by an external source of either 12 VDC or 117 VAC.

An optional carrying case is available to protect the monitor against dropping and rough handling. The case features a neck/shoulder strap, thick padding and tough high impact plastic exterior.

The VM 520 Service Monitor is priced at $339.00 and is available from **Visual Methods, Inc.**, 35 Charles Street, Westwood, New Jersey 07675 (201) 666-3950.

## NEWS FLASH . . .

# ABSCAM PINHOLE CAMERA SYSTEM



The Abscam Pinhole Camera System is specifically designed for concealment of a television camera and lens while providing brilliant television pictures under normal indoor lighting conditions. An exceptionally fast f/1.8 pinhole lens has been integrated with a 550 line, high resolution 2/3 inch television camera to provide 5 times more light sensitivity than any other pinhold lens systems.

The Model 1018 Abscam Camera System has a small 3/8″ front diameter and tapered shape making it simple to install. Interchangeable apertures enable the camera to view through holes as small as 1/16 inch for maximum camera concealment. The lens has an 11mm focal length and 52 degree field of view.

The camera has an automatic 10,000 to 1 light compensation range and a sensitivity of 1 foot candle. The standard system is powered by 117 or 24 VAC, is UL approved, and priced at $599.00. This cost is lower than a pinhole lens and camera purchased separately, while providing dramatically superior performance. Options include a Vidiplex system with camera power supplied up the single coaxial cable, eliminating the need for power source at the camera site. A Nevicon tube is also an option available for low light level applications.

The Abscam Camera System is manufactured by **Visual Methods, Inc.**, 35 Charles Street, Westwood, New Jersey 07675 (201) 666-3950.

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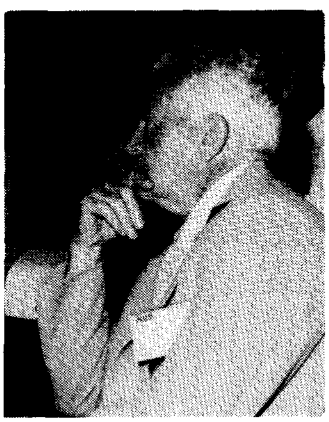
# Chairman's Column

**Gary Molen**
E.I. duPont de Nemours & Co.
Aiken, South Carolina

The new year of 1981 promises to be a very bright one for the Institute. Our scope of activities continues to increase. The Safeguards Committee under the capable leadership of Bob Sorenson (Battelle-PNL) has launched activities in several areas. Through the very fine efforts of Dick Duda (Westinghouse), as a member of this committee, we have just sent a letter to Mr. Louis V. Nosenzo, Deputy Assistant Secretary for Nuclear Energy and Technology Affairs, U.S. Department of State, offering "to act in a liaison role for the U.S. private sector safeguards community to provide broader input to the formulation of U.S. approaches and positions bearing on international nuclear safeguards activities". We are very hopeful that we will receive a positive response to this offer. We will keep you posted as further developments continue.

Our Standards Committee continues to be quite active as you will see when you read Dennis Bishop's column. Tom Sellers' Physical Protection Technical Working Group has held two very successful workshops - one in Gatlinburg, Tennessee on Guard Trianing and the other in Charleston, South Carolina on Physical Plant Security, primarily exterior intrusion detection systems.



*Dr. Sam McDowell listens intently to "Safeguards Today and Tomorrow Session" of 21st Annual Meeting*

Through the diligent efforts of our Secretary, Vince DeVito (Goodyear Atomic), we have finally obtained suitable and adequate liability insurance for the officers and other members of the Executive Committee as well as Standing Committee Chairmen. We owe a big thank you to Vince for all his efforts in this area. As any of the Executive Committee members can tell you, we have spent a lot of time on this issue. We are now able to proceed full speed ahead with our Certification Program under the Chairmanship of Dr. Fred Tingey (University of Idaho). Thank you for being so patient with us, Fred. Also a big thank you to the members of the Certification Examination Board who have been so diligent in the pursuit of the Institute's Certification Program. Many thanks to each of you for your diligence, time, sincerity and patience.

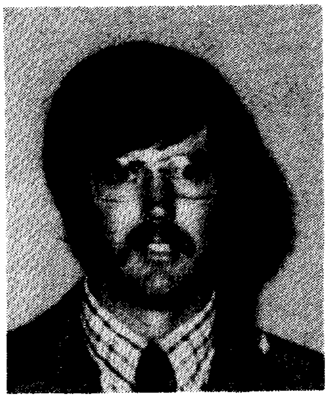
The Annual Meeting Committee Chairman, John Jeach (Exxon Nuclear), has had his hands full in planning this year's meeting. After two very successful years as the Arrangements Chairman for the Annual Meeting Committee, Joe Stiegler (Sandia) has had to resign because his work assignments have taken him out of the safeguards areas. John and I both will miss him very much. It has been a real pleasure working with Joe. Congratulations and best wishes to you, Joe, on your new endeavors. As Joe knows, it is not easy replacing somebody like him.

*Joe Stiegler and wife, Diana, at the 21st Annual Meeting*

I know most of you are aware that E.R. Johnson Associates, Inc. (JAI) of Reston, Virginia has been retained as the INMM Secretariat. As the INMM Secretariat, JAI is supplying the necessary personnel and facilities for the administration and operation of the Institute. As was to be expected there have been some gliches but we are all working toward a smooth and efficient operation. JAI has been most cooperative in working with us as we continue to define the full scope and breadth of what it means to be the INMM Secretariat. So please be patient with all of us as we continue to work through this transition period.

Again let me offer, as I did in the last issue of the Journal, the opportunity to volunteer for service in one or more of the Institute's activities. Much is being done and there is plenty more to do. We need more volunteers who can offer fresh ideas, different perspectives and renewed enthusiasm to our efforts. You really can make a difference! Please offer your services. Contact me or any of the Committee Chairmen if you are interested.

# N15 Standards Committee



**Dennis M. Bishop**
General Electric Co.
San Jose, California

## *Moving Toward New Ground-Transportation*

Based on the consistent performance of the N15 Standards Committee over the past decade, the INMM has recently been asked by the American National Standards Institute (ANSI) to accept Secretariat responsibility for the N14 Standards Committee on Transportation of Fissile and Radioactive Material. This is an honor which should be shared by the entire INMM membership, and a real opportunity for the INMM to move toward new ground in terms of overall technical contribution and industry recognition.

The INMM Executive Committee is currently evaluating the possibility of accepting the N14 Secretariat. No final commitment has been made. Accepting such a responsibility involves significant management, membership and financial support commitments. Clearly, such commitments must be carefully evaluated against available resources and overall objectives. Once it is established that the INMM can maintain the same levels of organizational support and performance currently provided by the N15 Standards Committee, we will move to accept the N14 Secretariat. With luck, this may happen during early 1981. Following such an INMM commitment, ANSI will go out for industry balloting on locating the N14 Secretariat with the INMM. This is a relatively slow process which should be completed by the time of the annual meeting in San Francisco, California.

Some background on the current N14 Standards Committee activities may be useful in stimulating membership interest and will show how this activity fits into INMM goals. The scope for the N14 Standards Committee is summarized as follows:

> *SCOPE: Standards for the transportation of radioactive and fissile nuclear materials in all phases of the nuclear fuel cycle, including shipping container design, licensing, fabrication, and application, including routine use and maintenance; supporting testing and quality assurance procedures; shipment authorization procedures, and insurance procedures.*

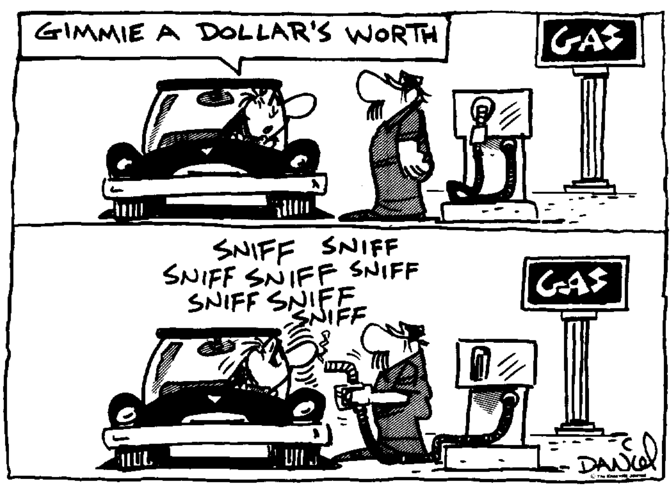
N14 was organized in 1966 with the American Insurance Association (AIA) as the Secretariat. Since that time, eleven (11) standards have been approved. Twelve (12) additional standards are currently proposed. Figure 1 lists titles in both areas.

Clearly the INMM has vital interest and experience in the area of nuclear materials transportation. If this new N14 Standards Committee activity proves feasible, it will represent a major new opportunity for membership participation.

More information will be provided in subsequent issues of the Journal. Interested parties should contact Dennis Bishop or Gary Molen.

**Figure 1 CURRENT N14 STANDARDS ACTIVITIES**

| | Current Standards |
|---|---|
| N14.1-1971 | Packaging of Uranium Hexafluoride for Transport |
| N14.3-1973 | Packaging and Transportation of Radioactively Contaminated Biological Materials |
| N14.5-1977 | Leakage Tests on Packages for Shipment of Radioactive Materials |
| N14.6-1978 | Shipping Cask Lugs and Associated Lifting Devices |
| N14.7-1975 | Guide to Design and Use of Shipping Packages for Type "A" Quantities of Radioactive Liquids |
| N14.9.1-1976 | Packaging Liquid Radioactive Wastes from Nuclear Power Plants |
| N14.10.1-1973 | Administrative Guide for Packaging and Transport of Radioactive Materials |
| N14.10.2-1973 | Administrative Guide for Obtaining Department of Transportation Special Permits for Radioactive Materials for Shipment |
| N14.10.3-1975 | Administrative Guide for Verifying Compliance with Packaging Requirements for Shipments of Radioactive Materials |

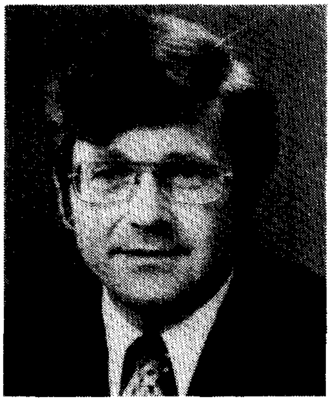


| | Proposed Standards |
|---|---|
| N14 Guide-1974 | Administrative Guide for the Liability Insurance Aspects of Shipping Nuclear Materials |
| P/N14.2 | Tiedowns for Transport of Fissile and Radioactive Material Containers Greater Than One Ton-Truck Transport |
| P/N14.4 | Quality Assurance in the Fabrication, Use and Maintenance of Shipping Containers for Radioactive Materials |
| P/N14.5.1 | Determination of Required Leak Test Sensitivity for Package of Radioactive Material |
| P/N14.8 | Fabricating Testing and Inspection of Shielded Shipping Casks for Irradiated Reactor Fuel Elements |
| P/N14.9.2 | Guide for Packaging of Processed Waste from Nuclear Power Plants for Transport for Ultimate Disposal |
| P/N14.14 | Shipping Containers for Low Specific Activity Materials |
| P/N14.19 | Ancillary Features of Irradiated Fuel Shipping Casks |
| P/N14.20 | Control of Contamination of Transport Vehicles |
| P/N14.21 | Safe Highway Transport of Nuclear Materials |

**Figure 1. INMM - N15 STANDARDS COMMITTEE ORGANIZATION**

| Title / INMM Subcommittee | Chairman / Affiliation | Phone |
|---|---|---|
| -- N15 Chairman | Dennis Bishop, *General Electric Co.* | (408) 925-6614 |
| -- N15 Secretary | Robert Kramer, *Northern Indiana Public Service Company* | (219) 787-8531 |
| -- N15-NSMB Representative | Lou Doher, *Rockwell International* | (303) 497-2575 |
| -- ANSI Staff Representative | Mary Crehan-Vaca, *ANSI* | (212) 354-3360 |
| 1 Accountability | Howard Menke, *Westinghouse* | (412) 373-4511 |
| 2 Material Classification | Whitey Thorpe, *LANL* | (505) 667-5886 |
| 3 Statistics | Frank Wimpey, *Science Applications* | (703) 821-4429 |
| 5 Measurement Controls | Yvonne Ferris, *Rockwell International* | (303) 497-4441 |
| 6 Inventory Techniques | Frank Roberts, *Battelle-PNL* | (509) 375-2606 |
| 7 Audit, Records and Reporting Techniques | Marg Schnaible, *Exxon* | (509) 375-8153 |
| 8 Calibration | Syl Suda, *Brookhaven National Laboratory* | (516) 345-2925 |
| 9 Nondestructive Assay | Darryl Smith, *LANL* | (505) 667-6514 |
| 10 Physical Security | John Darby, *Sandia Labs* | (505) 844-8977 |
| 11 Training and Certification | Fred Tingey, *University of Idaho* | (208) 526-9637 |
| 12 Site Response Planning | Ed Young, *Rockwell International* | (303) 497-2518 |
| 14 International Safeguards | Neil Harms, *Battelle-PNL* | (509) 376-4437 |

# Safeguards Committee



**Robert J. Sorenson**
Battelle Pacific Northwest Laboratory
Richland, Washington

On November 6, 1980 a meeting of the Safeguards Committee was held at the Hyatt Regency in Washington, D.C. Dr. James A. Powers resigned as the chairperson since he accepted a position with the IAEA in Vienna. A number of important activities were initiated and developed during the period he chaired the committee, and we are grateful to Jim for the leadership he provided.

The purpose of the November meeting was to sort through some new ideas for the committee to consider which were generated by the Executive Committee and the membership at large. We developed some short and long term plans and made some assignments. Attending the meeting were:

| | |
|---|---|
| Dick Duda | Syl Suda |
| Ralph Lumb | Charlie Vaughan |
| Howard Menke | Gene Weinstock |
| Roy Nilson | Bob Sorenson |

The committee has good representation from industry and the laboratories/consultants, but no one from the government sector. Attempts to obtain government representation on the committee have not been successful.

The charter or scope of the committee was discussed and it was concluded that we should "provide technical policy input, but leave political policy input to organizations such as the AIF." Reacting to short-term items is difficult to do, and obtaining long-term commitments is equally difficult but more achievable. It was felt that we need to walk the narrow line between technical and political issues. Our charter should include reacting to and providing input to new government regulations (thus influencing), and developing technical positions as a resource on certain issues. Responding to news articles was determined to be outside our charter. We are exploring interface/coordination activities between the Safeguards Committee and the AIF and ANEC. A plan to impact and influence new Congressional Oversight Committee and provide input to the GAO is being formulated.

It was decided to recommend that the Executive Committee adopt the skills directory as reported by Joe Steigler at the Palm Beach Annual Meeting. The committee believes that it should be integrated with the membership listing that Ed Johnson will prepare this year. Having more than one data base within the INMM would weaken all the Institute's data bases. Also, some of the key information in the skills directory could be included in the membership directory. Incidentally, the committee felt that phone numbers should be included in any membership directory.

It was concluded that the emergency response activities should be consolidated with the skills directory. The committee could not conceive of a situation where an immediate response would be needed for safeguards purposes. Rather, any emergency response by the INMM would be a delayed response for evaluating and analyzing a problem using a variety of technical experts. Also, it was believed that the frequency would be very low. It was felt that some licensees would seek outside help from their own consultants rather than from the INMM. Thus, the skills directory and response planning functions should be combined by the INMM, using such resources as the Secretariat.

The committee reaffirmed its belief that informal and periodic meetings between members of the NRC and INMM are very desirable. It was suggested that this be achieved through a small subcommittee of the Safeguards Committee and chaired by a member of the committee. We believe that the NRC supports this idea, and we are in the process of requesting that such a series of meetings be formally established.

The Safeguards Committee formally commented to the NRC on a proposed rule change regarding enforcement actions. We also plan to comment on the NRC's proposed rule change on the Protection of Unclassified Safeguards Information.

In addition we have another half dozen activities under development, thanks to a very active committe. It is a real pleasure for me to be associated with such a dedicated and hard working group of professionals.

## INMM ANNUAL DISTINGUISHED SERVICE AWARD

*To be presented July 1981 at the 22nd Annual Meeting in San Francisco, California*

It is the intent of the Institute to present its Annual Distinguished Service Award to a deserving individual during its 22nd Annual Meeting. Nominations will be accepted until March 1, 1981.

Selection will be based upon dedication and contributions to the field of safeguards and nuclear material management. Nominees need not be members of the INMM.

Nominations should include a biographical sketch and supporting information. Submit nominations to:

**Ralph F. Lumb,** *Chairman,* Awards Committee
c/o NUSAC, Incorporated
7926 Jones Branch Drive
McLean, Virginia 22102

# Report of The Awards Committee

**Ralph F. Lumb**
NUSAC, Inc.
McLean, Virginia

The INMM Awards Committee has actively pursued its two major awards programs: the annual Student Paper Award and the Distinguished Service Award.

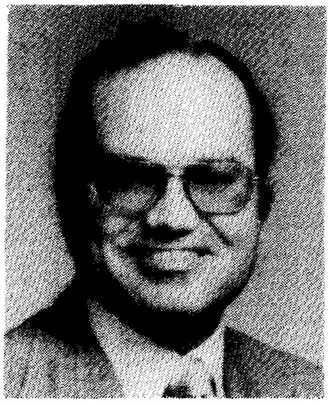
There has been a broader distribution of the announcement of the Student Award this year. Copies have gone to most U.S. colleges and universities with nuclear programs. In addition, INMM chapters in Japan and Europe have been helpful in distributions in their areas. It is hoped that, in spite of the reported decrease in enrollment in nuclear degree programs, we will continue to receive high quality papers.

There has been a mailing to all INMM members calling to their attention the Distinguished Service Award. The Committee needs the suggestions and recommendations of the membership. This is an area in which all members can participate. It is gratifying to report that there has been some response to that mailing.

The Committee also wishes to remind the membership that there may be other awards - recognition of exceptional effort by members in organizing a meeting or workshop, or just consistent performance in support of INMM activities. The Committee is open to all suggestions from the Institute membership. Nominations and suggestions should be sent to:

> **Ralph F. Lumb,** *Chairman*
> INMM Awards Committee
> c/o NUSAC, Incorporated
> 7926 Jones Branch Drive
> McLean, Virginia 22102

# Membership Committee Report



**J.E. Barry**
Gulf States Utilities
Beaumont, Texas

## *Welcoming Frank O'Hara and "A New Beginning"*

I wish to welcome Frank O'Hara of the Vienna Chapter to the Membership Committee. Frank recently completed service on the INMM Executive Committee and has graciously consented to work on this committee representing, for practical purposes, the European area. As you will note from the list below, he has apparently already stimulated memberhsip growth in his locale. His address is IAEA, P.O. Box 200, A-1400, Vienna, Austria. By the next report I hope to announce new committee persons from other regional areas of the U.S. and abroad.

With the new year and a new administration in Washington, D.C., that of President Ronald Reagan, we all optimistically look forward to the possibility of a coordinated era of international renewal of emphasis on nuclear power based on concrete actions. By the time this report reaches you the IAEA will have announced the first group of U.S. nuclear facilities to come under inspection through implementation of the U.S.-IAEA Safeguards Treaty. With this announcement and the subsequent U.S.N.R.C. notifications and DIQ requests, the INMM should experience additional U.S. membership growth and interest in its activities. For all the above reasons the Annual Meeting in San Francisco July 13-15, 1981 promises to be a very exciting one!

### New Members

The following forty-two individuals have been accepted during the period October 1, 1980 through January 16, 1981 including twelve in the Vienna and twenty-four in the Japan Chapter areas. To each, the INMM Executive Committee extends its welcome and congratulations. New members not mentioned in this issue will be listed in the Spring 1981 (Volume X, No. 1) issue.

**Reza Abendin-zadeh,** *Safeguards Inspector,* International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria 2360/2057

**W. Ted Aichele,** 1500 Cottonwood, Richland, WA 99351 (509) 373-1210

**Rokaya A. Al-Ayat,** *Project Leader,* Lawrence Livermore Laboratory, P.O. Box 808, Livermore, CA 94550 (415) 422-8467

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**Ernest W. Brach,** *Safeguards Analyst,* International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria 2360/1832

**Richard Frank Duda,** *Manager Fuel Cycle Planning and Evaluation,* Westinghouse Electric Corporation, P.O. Box 158, Madison, PA 15663

**Haruo Fujii,** *Section Head,* Department of Nuclear Fuel, Shikoku Electric Power, 2-5 Marunouchi, Takamatsu City, Kagawa Pref. Japan 0878-21-5061

**Akira Hayashi,** *Deputy General Manager,* Mitsubishi Heavy Industries, Ltd., 2-5-1 Marunouchi Chiyoda-Ku, Tokyo, Japan 03-212-3111

**Ralph J. Hemmer,** *First Officer,* International Atomic Energy Agency, P.O. Box 200, A-1400, Vienna, Austria (222) 2360/1885

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**Masami Itoh,** *Section Manager of Nuclear Engineering,* The Hokkaido Electric Power Co., Inc. 2, Higashi 1-chome, Ohdori, Chuo-Ku, Sapporo, Hokkaido, Japan 011-251-1111

**Masaaki Iwabuchi,** *Chief Engineer,* Nippon Electronics Co., Ltd., 500 Soya Hatano City, Kanagawa Pref., Japan

**Toshio Kasamatsu,** *Director General Manager,* Nuclear Fuel Industries, Ltd., 23-5 Nishi-Shinbashi 3-chome, Minatoku, Tokyo, Japan 03-433-3111

**Eric E. Kehl,** *Cost Free Expert,* International Atomic Energy Agency, P.O. Box 200 A-1400, Vienna, Austria 2360/2235/2238

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3. *Examination Location* – The examinations will be given in conjunction with the Annual Meeting and regionally if appropriate. Sufficient notificiation will be given in advance so that interested applicants can respond.
4. *Examination Content* – The written examination will encompass six categories of application: 1) general, 2) accounting, 3) materials control, 4) physical protection, 5) measurements, and 6) statistics.

   The Safeguards Intern examination will consist of a total of 100 questions from all categories with at least 15 from each category. The Safeguards Specialist examination will consist of 150 questions with at least 65 questions from the applciant's specified field and at least 15 questions from each of the remaining five categories.
5. *Type of Questions* – The questions will be multiple choice or true and false, each worth one point on the exam.
6. *Type of Exam* – Closed Book
   a. Reference Material – No looseleaf notes, old exams from any source or other study material will be allowed. There will be no sharing of tables, charts or graphs during the exam.
   b. Calculators – Acceptable.
7. *Length of the Exam* – Three hours will be allowed with brief breaks as needed. Time and place of examination will be furnished to the qualified candidates prior to the exam date.
8. *Absences – "No Shows"* – If a candidate fails to take the examination and fails to give cancellation notice, 50% of the examination fee will be retained by the INMM Certification Board to cover the cost of verificiation, review of applications, and test preparation.
9. *Changes and Revisions* – The examinations will be changed periodically. Several versions may be used at one time. Retake versions may be different from previous versions. A person who fails to pass the examination may be admitted on application to a second examination after six months without payment of fee. A candidate who fails to apply for re-examination within two years must then submit a new application with payment of the regular fee.
10. *The Proctors* – The examinations will be proctored by members of the Certification Board as designated by its Chairman. Proctors are responsible for following instructions in administration and for maintaining security. They may neither divulge information concerning any details or exact nature of the exam proctored. All examination blanks will be identified with the name of each candidate and must be opened from specially sealed envelopes.
11. *Passing Criterion and Awarding of Certificates* – A satisfactory (passing) grade for certification as a Safeguards Intern shall be 60% or better. A satisfactory grade for certification as a Safeguards Specialist shall be 60% or better in each category, and 70% or better in the applicant's specified field, with an overall grade of 65% or better. In addition, the Safeguards Specialist must successfully pass an oral examination to follow shortly after the written examination and to be administered by designated members of the Certification Board. Exam results will be announced to participants within two weeks after the exam date and for Safeguards Specialists, in most instances, within a day so that the oral examination will not necessitate additional travel on the part of the applicant and the oral review board. Numerical scores are not reported; only whether the candidate has passed or failed the exam. All successful candidates will receive a personal letter of commendation together with the Certification Board code of ethics and re-certification materials. All names will be published in the INMM quarterly journal. Certificates will be mailed to the individual candidate's organization where appropriate for formal presentation at a suitable ceremony. Successful candidates will also be recognized at the annual business meeting of INMM. In order to preserve the integrity of the test questions, examinations will not be returned to the applicant.
12. *Submit Proper Application and Registration Fee* – Only those whose applications have been approved by the Certification Board are eligible to take the written examination. Applications for a scheduled examination will not be processed if received after the deadline date. Applications received later will be returned.

    The registration fee must accompany the application form, or arrangements made for payment at time of meeting registration. Fee schedules are subject to change.

# Pacific Northwest Chapter

**Robert J. Sorenson**
Battelle Pacific Northwest Laboratory
Richland, Washington

The Pacific Northwest Chapter of the INMM concluded a very successful first year under the leadership of its first chairman, Dr. Roy Nilson. Besides the inaugural meeting held on March 27, 1980, the Chapter held four other dinner meetings:

- October 24, 1979 - Mr. George Bailey, "WPPSS And Who Are Those Guys" - An Overview of the WPPSS projects
- February 28, 1980 - Dr. Harold Forsen, "The Laser Enrichment Process and Its Non-proliferation Aspects"
- May 29, 1980 - Mr. Neil L. Harms, "A Funny Thing Happened on the Way to the Polish Border, and Other IAEA Inspection Considerations"
- July 10, 1980 - Dr. A.S. Adamson of Harwell, England, "The Status of the Nuclear Industry in England, Safeguards for the Back-End of the Nuclear Fuel Cycle, and ESARDA"

New officers for FY-1981 include:

**Bob Sorenson** (PNL) ........................ *Chairman*
Battelle Pacific Northwest Laboratory
**Bob Carlson** (HEDL) .................... *Vice-Chairman*
Westinghouse Hanford Company
**Clint Doriss** (UNI) .................... *Secretary-Treasurer*
United Nuclear Industries
**Etoy Alford** (WPPSS) .............. *Executive Committee*
Washington Public Power Supply System
**Curt Colvin** (RHO)
Rockwell Hanford Operations
**Dean Engle** (HEDL)
HEDL - Westinghouse Hanford Company
**Roy Nilson** (ENC) ....................... *Past Chairman*
*Exxon Nuclear Company*

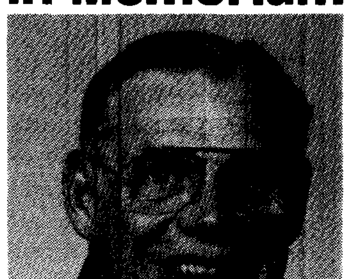
In November the Chapter hosted a short course, "Accounting and Auditing of Nuclear Materials", in Richland. The three and a half day course was designed for people associated with nuclear material control who do not have an accounting background. The instructors were Sheldon Kops, former Chief of the Materials Management and Safeguards Branch, DOE Chicago Operations Office; Lewis (Cal) Solem, formerly of NRC's Office of Standards Development who is now with the International Safeguards Project Office at Brookhaven, and Paul Korstad of Battelle's Accounting Department. The course was held in Battelle's facilities on November 18-21. Shown in the enclosed photograph are the participants and three instructors. Thanks to Shelly, Cal, and Paul the workshop was well designed and presented. The participants indicated that it was a very useful short course.

*Front row: Cal Solem, Marlis Perry, Joyce Taylert, Carol Smallwood, Shelly Kops, Louis Perez, Joe Roemer, Dennis Brandt; Second row: Mahavir Jain, Rosann Logsdon, Elizabeth Collins, Marilynn Halliday, Nicholas Roberts, David Frederickson, Greg Lyckman; Back row: Obie Amacker, Dave Bouse, Ray Stein, Leo Wadle, Paul Korstad, Blair Lewis, Brian Harper, Gary Getterolf.*

The first dinner meeting for FY-81 was held at the Holiday Inn in Richland on Wednesday, October 22. Pat O'Callaghan and Diane Graham of HEDL's Safeguards Application Section discussed personnel identification systems application to materials safeguards and gave a demonstration of the Sandia-developed Ident-O-Mat system. The presentation and demonstration held everyone's interest. The large crowd enjoyed what Pat and Diane had to say and spent a lot of time with the two demonstration units.

Going into the second year, the chapter seems to be providing what the members want, or so we hope. Our attendance continues to be very good and the discussion topics appear to be of interest to the members and their spouses.

# In Memoriam



## Munson M. (Whitey) Thorpe

We note with sorrow the death of "Whitey" Thorpe on February 22, 1981. Whitey was an employee of the Los Alamos National Laboratory for more than 18 years. He was Group Leader of Group OS-2, Nuclear Materials Management, the organization responsible for accountability and control of the special nuclear materials at LANL. Within the INMM, he has long been a well known and highly respected leader in this field. He has authored and co-authored many technical papers published in the INMM Journal and has actively participated on the N15 Standards Committee and its working subcommittees.

# Guest Editorial

**J.W. Carr**
Atomic Energy of Canada, Ltd.
Chalk River, Ontario

## *Physical Security of Nuclear Plants and Nuclear Material*

### *The SAHARA Principle*

It has been suggested elsewhere that the security of nuclear installations and materials should be dealt with in the same way as the safety of operation of these facilities. This seems to be a reasonable approach as long as we recognize that neither the safety nor the security of any undertaking can be guaranteed to a level of zero risk by practical or acceptable means. Nevertheless, in dealing with security, some authorities appear to be attempting to attain unreasonable goals. Scenarios are dreamed up to describe every conceivable security threat; these are analysed using the most sophisticated techniques; standards are then prepared detailing procedures and equipment for meeting the perceived threats and finally published regulations give detailed requirements for coping with the original imaginary scenarios.

Additional fear and paranoia appear to be generated and reinforced by each new scenario and analysis, resulting in the further escalation in security requirements to visionary and impractical levels. In some cases we have reached a level that approaches *security for security's sake,* adding a punishing penalty to customers and taxpayers who must absorb the increased cost of nuclear research and nuclear power and losing sight of the need to carry out the operations concerned in an orderly and efficient manner.

Having condemned the extreme and excessive levels to which nuclear plant security and the security of transported material has progressed, it is time to acknowledge that a certain level of security is necessary and acceptable. This should be arrived at, however, on a *reasonable* basis and without an attempt to cover every possible threat to the ultimate degree. Accepting that a parallel exists between physical protection and nuclear safety in respect to the protection of the public, reference can be made to the ALARA principle for the release of radioactivity from nuclear establishments in which it is expected that these omissions will be kept to a level which is **A**s **L**ow **A**s **R**easonably **A**chievable while taking account of the social and economic factors which prevail. A similar concept can be applied to physical security and the proposed designation is *SAHARA* which stands for **S**ecurity **A**s **H**igh **A**s **R**easonably **A**chievable.

To put these concepts into perspective and to get a feel for the amount of effort and resources that should be expended in these areas, it is necessary to examine the definition of the descriptive word *reasonable* which appears in both of them.

The following definition is found in the Concise Oxford Dictionary:

*REASONABLE*

1. Endowed with reason, reasoning;
2. Sound of judgement, sensible, moderate, not expecting too much, reach to listen to reason;
3. Agreeable to reason, not absurd, within the limits of reason, not greatly less or more than might be expected, inexpensive, not extortionate, tolerable, fair. Hence reasonableness, reasonably.

To foster a return to reason and reasonableness where physical security is concerned, I propose that the *SAHARA* principle be adopted and that due emphasis be put on adhering to the spirit of the definition of *reasonable.*

# News Release

## *U.S. Ecology*

Nuclear Engineering Company, Inc., announced today that it has changed its name to US Ecology, Inc. effective January 1, 1981.

According to Admiral Vincent P. de Poix, company President, the change has been made to more accurately reflect the company's service - operation of waste management sites for the disposal of low-level radioactive and potentially hazardous chemical wastes.

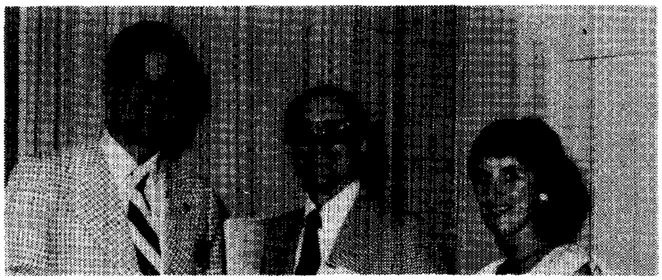
The Louisville based company was founded in California in 1952 and was acquired by Teledyne, Inc., Los Angeles, in 1974.

US Ecology operates low-level radioactive waste disposal sites in Beatty, Nevada and Richland, Washington. The company's chemical disposal sites are at Beatty, Nevada; Sheffield, Illinois; and a company subsidiary, Texas Ecologists, Inc., at Robstown, Texas.

"The safe disposal of low-level radioactive and chemical materials has become a crucial issue throughout this country and around the world. Because of our commitment to helping preserve the public health, safety, and the environment, we feel the name US Ecology more precisely reflects our company's aim," de Poix commented.

Mr. Tom Gerdis, formerly the editor of the INMM Journal is now employed by U.S. Ecology.

*Members of the 1980 Program Committee, L to R, Dennis Wilson, Dick Chanda and John Glancy*



*Past Chairman of INMM, Bob Keepin, talks with Chairman Gary Molen and his wife, Sara*

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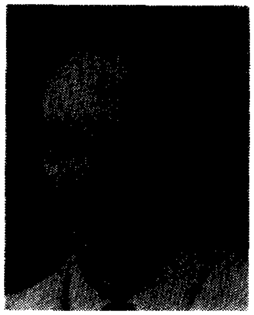
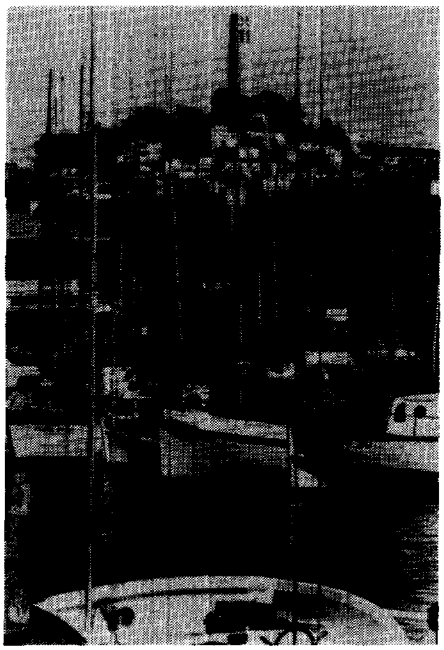
# Meet Me in San Francisco

## 1981 Annual INMM Meeting
## July 13, 14, 15, 1981

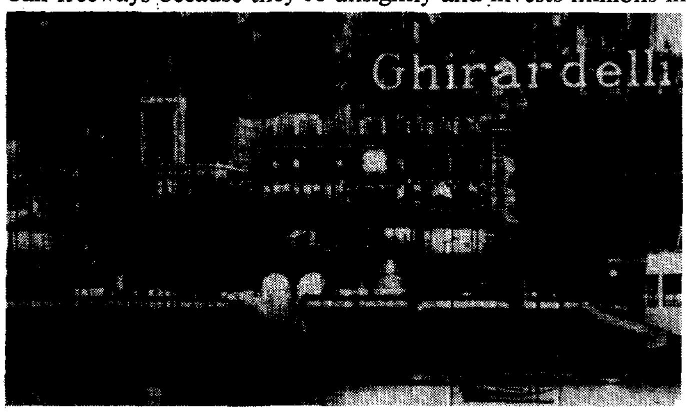


**Herman Miller**
Chairman, 1981
Local Arrangements Committee



Don't stop me if you've heard it before. The 1981 Annual INMM-Meeting is being held in one of the world's favorite cities, San Francisco. Whatever you're looking for, you can find it here . . . except hot weather. The following information comes from the San Francisco Convention Bureau, but even they can't do justice to the City.

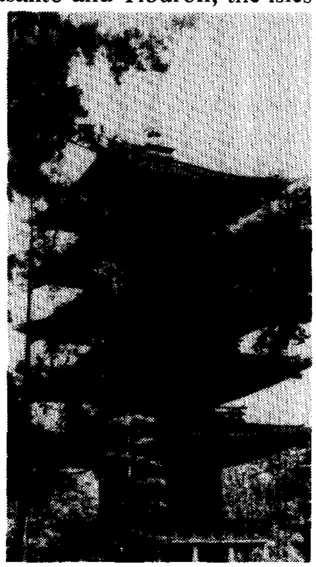
San Francisco refuses to fit a mold. It climbed hills while other cities spread out. It encouraged immigrants to guard their ethnic distinctions while other cities assimilated them. It delights in a cable car system as obsolete as a Dodo, rejects urban freeways because they're unsightly and invests millions in campy keepsakes (an abandoned factory, an antiquated cannery, a plaster of Paris palace) with felicitous results.




Born as the Barbary Coast, San Francisco is congenitally worldly, inherently irrepressible. Its verve is contagious.

Many things contribute to this charisma. San Francisco rises like a siren out of the sea. The surrounding water casts a whitish aura over the city. Wisps of fog fly like pennants from its spires. Buildings of every description cling to its pinnacles. Clanging museum-pieces swoop over them. Tiers of windows turn gold in the sunset. The air is almost always crisp.

The City's a cinch to explore. Confined to 47 square miles, it's America's Leading Compact. You can stroll from its shopping center, Union Square, to its Neapolitan-flavored nightlife belt, North Beach, taking in Chinatown and Wall Street West enroute. Or catch a cloud-hopper over the hills to Fisherman's Wharf and the northern waterfront's red brick rialtos. Public transport will whisk you from Golden Gate Park to the Embarcadero, from Ocean Beach to the East Bay. Ferries will carry you to the resort-like ports of Sausalito and Tiburon, the isles of Angel and Alcatraz and the terminal at Larkspur near Pt. San Quentin for bus link-ups to Muir Woods National Monument and Point Reyes National Seashore.



"Chinoiserie, chiaroscuro, chili sauce" is the way one writer describes San Francisco's ethnic mix, omitting the teriyaki. The most oriental city in the occident now has not one but two Chinatowns as well as a Little Italy, a Spanish-accented Mission District and a Japanese quarter known as Nihonmachi.

*Photos Courtesy of San Francisco Convention & Visitors Bureau*

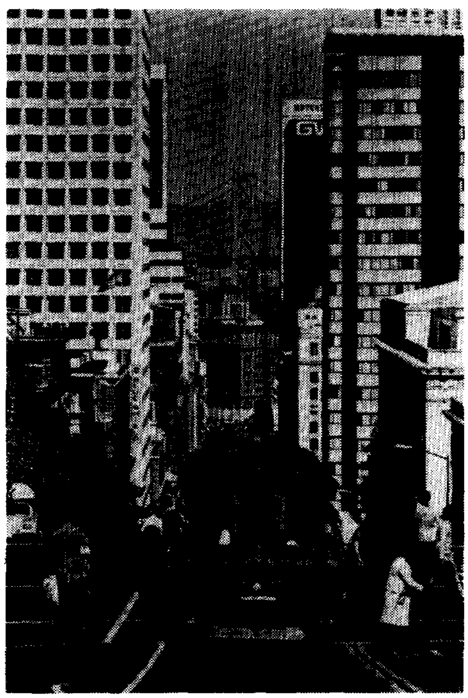
The landscape yields all manner of picturesque momentos - Gold Rush nuggets like Jackson Square, gingerbread mews like outer Union Street, Victorian whatnots all over Pacific Heights.

Any compendium of local attractions should list *Restaurants* in large type. There are over 2,600 of every nationality. This is one of the great eating towns of the world, famed for its cuisine since the days of the railway barons and bonanza kings.

San Francisco has a glittering tradition in the performing arts. Generally acknowledged to be the cultural capital of the Northwest, it has its own opera, ballet, symphony and drama (American Conservatory Theatre) companies, all of exceptional caliber. The country's oldest international film festival is held here annually. Top shows are imported from New York and London, and long run hits are launched by innovative local companies. Movie houses proliferate. The city supports four public art museums - the Asian, de Young, Palace of the Legion of Honor and Modern Art. There are at least 30 other repositories of culture and local lore, ranging from vintage ships to a 200 year-old mission, from a car barn (cable) to an island (Alcatraz) of unusual interest.

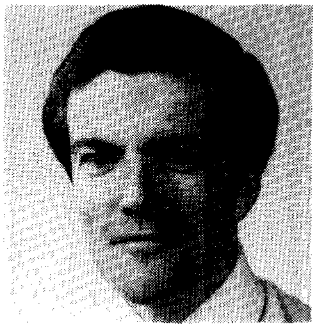
Sports fans can find it all in the Bay Area - pro baseball (S.F. Giants, Oakland A's), football (S.F. 49er's, Oakland Raiders), basketball (San Francisco Pioneers and Golden State Warriors), many special sporting events, soccer, horse racing and collegiate contests.

Amazingly, the fourth largest metropolitan complex in the United States now embraces what might be described as an urban Yellowstone, a backpacker's paradise within sight of the skyscrapers. Congress in 1972 set aside 39,000 undeveloped San Francisco and Marin County acres as the Golden Gate National Recreation Area. Administered by the National Park Service, this magnificent preserve takes in the city's shoreline greenbelt, its offshore islands and miles of rugged headlands, beaches, coastal fortifications, lagoons, wildlife sanctuaries, redwoods and ranchlands just across the Gate. What's more, the Golden Gate National Recreation Area's northern reaches adjoin the 65,000-acre Point Reyes National Seashore.

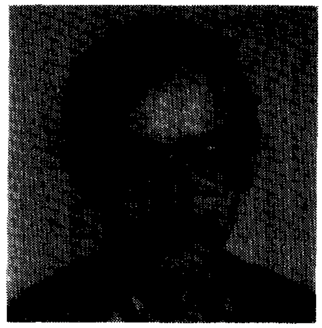


Headquarters for a vast vacationland, San Francisco is within easy driving distance of the high Sierra resorts of Lake Tahoe and Yosemite, the scenic Monterey-Carmel Peninsula, San Simeon, California's great wine bin, the Redwood Empire and the spectacular Mendocino Coast.

# Biographies of Authors



**ROBERT C. BEARSE** received his Ph.D. in Nuclear Physics from Rice University. He spent two years in the Army at the Nuclear Defense Laboratory in Maryland followed by a three year post-doctoral stint at Argonne National Laboratory. In 1969, he joined the Physics and Astronomy faculty at the University of Kansas. He has been a visiting staff member in the Safeguards Program at Los Alamos since 1972.

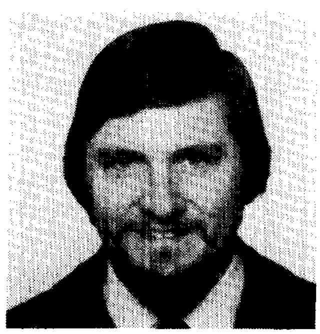


**M.J. CANTY** (Ph.D., University of Manitoba, 1969) is a member of the program group "Nuclear Energy and the Environment" at the Kernforschungsanlage in Julich, Germany. He is currently involved in the German support program for IAEA safeguards; designing and assessing safeguards approaches for high temperature reactor fuel cycle installations and bulk processing facilities.

**ELDON L. CHRISTENSEN** (B.S., Chemistry, North Dakota State, 1951, M.S., Physical Chemistry, North Dakota State, 1951) joined LANL in January 1952. He is presently Deputy Group Leader, Plutonium Chemistry and Metallurgy Group (CMB-11) Supervisor, Plutonium Recycling and Purification Plant at LANL. He has developed programs for safeguards and accountability including the basic format for computer record of SNM at Los Alamos. He has participated in the design of the LANL New Plutonium Facility. He has also served on numerous AEC, ERDA, and DOE committees and task forces.

**STEIN DERON** (Ph.D. 1964, Analytical Chemistry, University of Illinois) is Head of the Safeguards Analytical Laboratory, International Atomic Energy Agency. A native of France, he worked at the Centre d'Etudes Nucleaires de Grenoble prior to joining IAEA in 1970.

**JOHN J. MALANIFY** (Ph.D., Nuclear Physics, Renssalaer Polytechnic Institute, 1964) has been associated with the Nuclear Safeguards Program at Los Alamos National Laboratory since 1969. He has contributed to the development of nondestructive assay (NDA) instruments and techniques. For the past two years he has been responsible for the DYMAC system which is a state-of-the-art near-real-time accountability system employing in-line NDA instrumentation.



**JAMES D. NAVRATIL** (Ph.D. 1975, Analytical Chemistry, University of Colorado) is a staff member of the International Atomic Energy Agency, Vienna, on leave of absence from Rockwell International, Rocky Flats Plant. His research interests are in actinide chemistry and processing and chemical separations.

# The Credibility of Technical Safeguards

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Federal Republic of Germany

**ABSTRACT**

The implications of the inspector-operator adversary situation in international safeguards are discussed within the context of the basic technical control measures of material accountancy and containment and surveillance. It is concluded that the credibility of any safeguards approach depends primarily on the effectiveness of the inspector's measurement procedures.

## 1. Introduction

Technical safeguards procedures, as currently applied by the IAEA to monitor the sensitive material in the world's nuclear fuel cycles, are one of the mainstays of non-proliferation. If safeguards are to continue to enjoy the general acceptance of the international community as providing a reliable index of commitment to the peaceful use of atomic energy, it is essential that every effort be made to ensure their credibility and effectiveness.

In existing international agreements the IAEA is required to rely heavily on states' systems of material accountancy and control, even though the only potential diversions of nuclear material that could lead to proliferation would be instigated by the states themselves. If this rather paradoxical construction is to have any validity whatsoever, it must be built up and assessed as an adversary situation. Put bluntly, it must be assumed that the facility operator, acting on behalf of his government, will try to divert as much material as he "can get away with". This assumption of dishonesty is of course purely formal, but essential for the development and implementation of adequate safeguards measures. Its implications and the resulting criteria that should be applied for credible safeguards form the subject of this paper.

It is well known that the fundamental tool of safeguards is material accountancy. This is a logical and, indeed, the only possible consequence of the goal that has been set: the unambiguous establishment that at any given time a significant amount of sensitive material has <u>not</u> disappeared from the peaceful fuel cycle. Such a conclusion can only be made objectively on the basis of the principle of conservation of matter, the principle upon which material accountancy is founded.

Another important safeguards technique is the containment and surveillance (c/s) of nuclear material. (These terms, just like the term material accountancy, are self-explanatory.) Although c/s methods are relegated to a supplementary or supportive role in international agreements on safeguards, they are coming more and more into discussion as an attractive means of controlling large inventories in situations where classical material accountancy is thought to be either too inaccurate or too cost-intensive.

We shall consider, in the following, first the role of c/s in safeguards and then the problem of material accountability, trying to emphasize some important consequences of the adversary situation just mentioned.

## 2. Containment and Surveillance in Safeguards

Two real benefits can result from the application of containment and surveillance techniques:

- The measurement of material inventory and flow, necessary for material accountancy, may be aided and simplified. For example, a verification of the integrity of a tamper-proof seal on a container eliminates the necessity of measuring its contents, provided, and this is essential, those contents were measured by the inspecting authority immediately prior to sealing. Carried to the ultimate, an entire inventory of a material balance area may be so well controlled by c/s methods that physical inventory taking can be postponed indefinitely.

- The timeliness for detection of a diversion, a fundamental consideration in IAEA safeguards, may be improved substantially beyond that offered by the periodic closing of material balances. For instance the inspection of video records from strategically located cameras can be done on a regular basis without in any way disturbing normal facility operations.

Any concept relying heavily on c/s methods or other indirect methods of controlling nuclear material flow and inventory (e.g. monitoring a fuel handling machine rather than the fuel itself) should not neglect the following basic requirements:

- The measures must be so reliable and the physical situation to which they are applied so transparent that it is clear at all times that every possible diversion path has been accounted for. The more complicated the facility, the less credible the measures become.

- The contained or observed material must remain measurable. Otherwise the reaction of the inspectorate to a false alarm, device failure or an actual diversion attempt cannot be anything but arbitrary. Objectivity, a prerequisite for the international acceptance of IAEA controls, would be lost. If an inspector is confronted with a broken seal on an enclosure containing a large amount of irradiated fuel, it is of no use to start a crash research and development program to find a method of re-establishing the inventory. A proven method must exist and be available at all times. A c/s system without backup inventory verification procedures is worthless, since it is premised either on the assumption that all alarms will be false alarms and all device failures unintentional, or that false alarms and device failures are impossible. The first assumption is unacceptable as it completely ignores the adversary principle, and the second is utopian.

- If, for technical or economic reasons, measurement is simply not feasible, c/s techniques must be applied in such a way that, in the event of an alarm or device failure, an upper limit can be placed on a possible diversion which is considerably less than a significant quantity. This would allow the "writing-off" of the material over which control had been lost, at least temporarily, and still exclude the possibility of a significant diversion. Unique identification seals on some types of reactor fuel elements fall into this category.

Nuclear installations with relatively static inventories (reactors, storage facilities, etc.) can rely heavily on c/s methods for safeguards provided inventory verification is available as backup. Processing facilities and research laboratories experimenting with reactor fuel pose a very different problem, however. The material may be in such a high state of flux or spread over such a large area that the covering of all possible diversion scenarios by means of c/s techniques alone (or even conceiving of them all in the first place!) is unthinkable. Material balancing based upon direct, repeated measurement is now essential to meet safeguards goals. Fortunately it is in precisely these situations that the facility operator is often forced to make extensive measurements for process control reasons so that his obligations under safeguards to report regular material balances are in part fulfilled automatically. It is in the *interpretation of the operator's data* where pitfalls arise. In order to make this clear we shall now look at the procedure of material balancing in some detail.

## 3. Material Accountancy and Verification

According to procedures set out in INFCIRC 153 /1/, material accountancy under IAEA-safeguards is realized in the following way: At the end of each and every inventory period the facility operator produces the results of an exhaustive determination of all terms in the material balance equation...previous physical inventory, inflow, outflow and final physical inventory. If the operator's data are accepted as correct, they are used to establish MUF (material unaccounted for), defined as the difference between book inventory and current physical inventory, and a statistical test is applied to interpret its significance.

The fundamental equation for material accountancy is

$$I_n + F_n - I_{n+1} = MUF$$

where $I_n$ and $I_{n+1}$ are, respectively, the physical inventories for a material balance area (MBA) at the beginning and at the end of the $n^{th}$ inventory period, and $F_n$ is the net material flow into the MBA between inventory takings. The book inventory is defined as

$$B_n = I_n + F_n .$$

If the operator measures all three quantities $I_n$, $I_{n+1}$ and $F_n$, there are only two diversion strategies available to him should he wish to avoid detection:

- diversion into MUF
- data falsification.

We will treat these two strategies separately in the following sections.

### 3.1 Diversion Into MUF

In this scenario it is assumed that the operator diverts an amount of material, say $M_1$ kg, and reports <u>true</u> measurement data to the safeguarding authorities, i.e., the results of an honest measurement of inventory and flow <u>after</u> the diversion has taken place. He would hope to conceal this diversion in his own measurement uncertainties, perhaps as part of an overall strategy of protracted diversion. If we assume the random variable MUF to be normally distributed with variance $\sigma_{MUF}{}^2$ then the inspection authorities' detection probability can easily be shown to be /2/

$$1 - \beta_{MUF} = \Phi(M_1/\sigma_{MUF} - U_{1-\alpha_{MUF}}) \qquad (1)$$

where $\Phi$ is the cumulative normal distribution functions, U is its inverse, and $\alpha_{MUF}$ is the desired false alarm probability. The diversion hypothesis is accepted if

$$MUF > S = U_{1-\alpha_{MUF}} \cdot \sigma_{MUF}.$$

Two preconditions must be met before this test can be used to make a statement about the material balance within the material balance area:

1) The operator's data must be honest, even if he has behaved illegally. Otherwise the test statistic, MUF, is simply not available and no test can be performed.

2) The operator's inventory and flow measurements forming the components of MUF must have been exhaustive.

The first condition is self-evident. The second condition is, in practical situations, often ignored. For instance, if the operator does not require for his own purposes a continual redetermination of his entire inventory, he may be unwilling to make the necessary measurements and prefer to rely on the carrying forward of book data. At inventory taking he could claim that, since he had measured a certain number of items at some previous physical inventory and had "done nothing to them" in the meantime, a re-measurement is superfluous. He might point to tags or labels on containers for the material involved which indicate the results of the last measurement. Such a procedure, although it may be defended strongly on practical and economic grounds, should be recognized as being entirely incompatible with the use of MUF for safeguards purposes. There are two very obvious reasons for this. First, the operator can only conclude that the items in question have not been altered on the basis of his own operating records, i.e., his books. If book inventory is used to deduce current physical inventory, MUF, per definition, is not being determined. Second, as has been emphasized already, the use of the operator's MUF as a safeguards index is only possible if the operator's data are honest. Therefore the operator cannot divert material from those items which he does not remeasure otherwise he will necessarily be reporting data which have been falsified intentionally. This, in turn, would imply an arbitrary division of inventory into items or batches from which the operator may divert material, and those from which he may not. Of course the operator will divert wherever he likes. A logically consistent application of the MUF statistic test as a means of detecting diversions thus requires complete redetermination of physical inventory, whether the data are needed operationally or not.

If the supposedly unaltered material is sealed or under surveillance by the control authority, then, and only then, is a remeasurement unnecessary. The material in question would contribute neither to MUF nor to its variance.

It will now be argued that the inspector has an additional weapon in his arsenal, namely the right to verify the data of the operator by independent measurement before accepting them. Material actually remeasured by the operator as well as inventory batches the characteristics of which have simply been carried over from previous inventories could be verified in this way. The necessity of data verification leads us, however, to consideration of the other diversion strategy, deliberate falsification of data by the operator.

### 3.2 Data Falsification

We will not attempt to show that in many realistic situations as soon as the possibility of deliberate falsifying is admitted (as of course it must be), the establishment of MUF on the basis of operational data reduces to a formal exercise enabling, in itself, no quantitative statement about non-diversion. Any requirements on the operator to make additional measurements for safeguards, over and above those that he would normally make anyway, can then be relaxed. The price to be paid is the recognition that the real assurance of non-diversion is provided primarily by the verification data alone.

By data falsification is meant the following: The operator diverts an amount of material, $M_2$ kg say, and reports false data to the authorities, for example physical inventory measurement results that were correct before the diversion but which are no longer so. If the operator behaves rationally, the data will always be falsified in such a way as to make the material balance appear to be correct. The deficit in material (resulting from the diversion) is passed on either to the next inventory period or to a neighbouring MBA, depending upon whether inventory data or flow data have been falsified, respectively. The inspector's counter measure /3/ is normally to apply the D-statistic test to samples taken from inventory strata and similar tests to incoming and outgoing material for flow verification.

The D-statistic is the inspector's estimator for the discrepancy between the actual physical inventory and that claimed by the operator. It may be written

$$D = \sum_{i=1}^{K} \left\{ \sum_{j=1}^{n_i} \frac{N_i}{n_i} (X_{ij} - Y_{ij}) \right\}$$

where $X_{ij}(Y_{ij})$ is the result of the operator's (inspector's) measurement for the $j^{th}$ item in the $i^{th}$ inventory stratum, K is the number of strata, $N_i$ is the number of batches in the $i^{th}$ stratum and $n_i$ is the corresponding verification sample.

Assuming for simplicity that the random variable D is normally distributed /2/, the inspector's detection probability for the diversion $M_2$ is, in analogy to (1),

$$1 - \beta_D = \Phi \left( \frac{M_2 - U_{1-\alpha_D} \, \sigma D/H_o}{\sigma D/H_1} \right) \quad (2)$$

Here $\sigma D^2/H_o$ is the variance of D under the hypothesis $H_o$ (no diversion) while $\sigma D^2/H_1$ is its variance under the alternative hypothesis $H_1$ (diversion of $M_2$ kg). $H_1$ is accepted if D exceeds a decision threshold

$$D > U_{1-\alpha_D} \, \sigma D/H_o.$$

### 3.3 Assurance for Non-Diversion, A Numerical Example

The point that we wish to make is the following: if the threshold quantities and detection probabilities for both diversion strategies are to be comparable, i.e. $M_1 \sim M_2$ and $1 - \beta_{MUF} \sim 1 - \beta_D$, then the inspecting team must always invest approximately the same measurement effort as the operator, given similar measurement accuracies. Requiring the operator to determine his MUF to such an accuracy that $M_1 \ll M_2$ serves no real purpose, since the operator will then simply resort to data falsification. The detection probability remains the same.

A simple numerical example serves to illustrate this point. Consider an (idealized) inventory of N = 2000 items, each containing Q = 0.100 kg of nuclear material (determined, let us say, from an accurate destructive assay sampling measurement). Assume that both operator and inspector have statistical measurement accuracies of $\sigma/Q$ = 5% for inventory taking (eg. using non-destructive assay techniques). For simplicity we ignore systematic errors and require that no material flow occur between two successive inventories, so that

$$MUF = I_n - I_{n+1}.$$

If this were a real situation, then of course the material would be stored in a sealed area or kept under surveillance, since no material flows are involved. It should be understood merely as an illustration.

In this very simple case the operator would not measure all items, since he knows that the variance of the true item contents in the ensemble is negligible compared to his measurement variance. He would define two strata, one for beginning and one for ending inventory, and choose representative samples of n items from each stratum. (This does not necessarily exclude the pure strategy of diversion into MUF (see section 3.1). If the operator has diverted and still wishes to present honest data, he must only ensure that his sample is indeed representative. He could, for example, divert a similar amount from all items, so that the small ensemble variance assumption is still valid.) The operator's variance of MUF is given by

$$\sigma^2_{MUF} = 2\,\frac{N^2\,\sigma^2}{n}$$

Choosing n = 200 and detection and false alarm probabilities 95% and 5%, respectively, the largest amount that may be diverted into MUF is, from (1)

$$M_1 = \sigma_{MUF} \cdot (U_{0.95} + U_{0.95}) = 3.29 \text{ kg.}$$

That is, the MUF-statistic test would catch this diversion with 95% probability, the decision threshold being

$$S = U_{0.95}\,\sigma_{MUF} = 1.64 \text{ kg.}$$

Alternatively, the operator can divert the 3.29 kg and falsify his final inventory data so that MUF < S. In the present example he could do this by (a) choosing a non-representative sample - eg. items from which he had diverted no material, or by (b) manipulating his measurement data appropriately. An application of equation (2) with a reasonable assumption regarding the number of falsified items shows that, in order to achieve the same detection probability for this diversion strategy, the inspector would have to verify a statistical sample of no less than 300 items of the final inventory. The verification effort needed is thus comparable to the operator's original effort of physical inventory taking.

In many situations the inspectorate will simply not have sufficient resources and manpower to match the operator's measurement effort. When this is so, the final quantitative conclusion made at the closing of the material balance should be determined by the verification procedure, giving full credit to the possibility of data falsification, and the operator's MUF given little or no significance. The number of measurements that the inspector has to make will be determined by what he himself defines to be a significant diversion. If, in the preceding example, we assume the detection limit of say 20 kg, the required verification sample is 32 items. If the opertor has confidence in his book data, he need make no measurement at all for safeguards reasons, but simply claim MUF to be zero and leave it to the inspecting team to satisfy itself that this is so. It has been demonstrated in /4/ that optimal use is made of operational and verification data if a mixed diversion strategy is assumed (ie, diversion into MUF and data falsification) and if all data are tested simultaneously (the MUF-D test). However, whenever the available verification effort is only a small fraction of the effort necessary for a true determination of MUF, the overall detection probability tends to that of the D-statistic test alone. The variance in the random variable MUF-D is dominated by the variance in D.

The practice of dispensing with a true material balance (in the sense of the strict definition of MUF as a book-physical inventory difference) is certainly not new, and is tolerated in many installations where regular remeasurements are either not feasible or not necessary to meet safeguards goals. However, as very large bulk processing facilities come into operation in non-nuclear weapons states there is little doubt that the IAEA will exert considerable pressure on facility operators to install extensive measurement equipment exclusively for safeguards purposes. The questions of the associated verification effort that the inspectorate will have to invest if such safeguards systems are to be believable will then become crucial.

### 4. Conclusions

The discussion that has been presented here is admittedly oversimplified. There may be a great deal of additional, indirect information available which increases the inspector's subjective confidence in the effectiveness of his c/s measures and in the validity of operational data, and this should most certainly be taken into account in his overall assessment. We have tried to emphasize in a general way some consequences of the adversary nature of international safeguards. Our conclusion is that verification by direct measurement by the inspectorate of the material to be safeguarded is the final guarantee of effectiveness of safeguards systems, whether they are based on containment and surveillance methods or on material accountancy. The greatest emphasis therefore should be placed in future on the development of improved and efficient verification measurement techniques.

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# An Operational Advanced Materials Control and Accountability System

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**ABSTRACT**

An accountancy system based on the Dynamic Materials Accountability (DYMAC) System has been in operation at the Plutonium Processing Facility at the Los Alamos Scientific Laboratory (LASL) since January 1978. This system, now designated the Plutonium Facility/Los Alamos Safeguards System (PF/LASS), has enhanced nuclear material accountability and process control at the LASL facility. The nondestructive assay instruments and the central computer system are operating accurately and reliably. As anticipated, several uses of the system have developed in addition to safeguards, notably scrap control and quality control. The successes of this experiment strongly suggest that implementation of DYMAC-based systems should be attempted at other facilities.

**INTRODUCTION**

An accountancy system based on the Dynamic Materials Accountability (DYMAC) System[1-4] began operation concurrently with processing at the new plutonium facility at the Los Alamos Scientific Laboratory (LASL) in January 1978. Its designer, LASL Group Q-3, began transferring responsibility for operation of the system to the LASL Operational Safeguards (OS) Division in late 1979. In early 1980 the system was redesignated the Plutonium Facility/Los Alamos Safeguards System (PF/LASS), and on March 3, 1980, day-to-day operation was placed under the control of Group OS-3. Group Q-3 continues to upgrade the system's nondestructive assay (NDA) instruments and provide maintenance support.

PF/LASS is providing near-real-time knowledge of inventory status and has demonstrated that improved safeguards can be realized by NDA instruments, a central computer, and careful process-control techniques. Two-and-one-half years of operating experience indicate that significant benefits have accrued to the plant management beyond those associated with safeguards. This report outlines the benefits of the DYMAC system to both safeguards and process control interests at the LASL Plutonium Processing Facility.

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**BACKGROUND**

**Safeguards**

The safeguarding of special nuclear material (SNM) at domestic facilities is the responsibility of two complementary systems: the physical protection system and the materials control and accountability (MC&A) system. The physical protection system is responsible for limiting facility access to authorized personnel and for allowing only authorized transfer of SNM across a facility boundary; these responsibilities are exercised primarily at the facility perimeter. The MC&A system is responsible for the material while it is within the facility. This system (1) defines procedures for controlling the movement of material, (2) monitors the adherence to these procedures, and (3) provides data for detecting diversion of SNM. In case of an actual or claimed breach of the safeguards system, the MC&A system has a number of responsibilities that include (1) assessing the validity of a claim, (2) providing a description of the missing material, (3) determining the time period during which material was diverted, and (4) identifying material custodians.

Accounting of SNM at LASL has a long history dating back to the middle 1940s. In 1952, Christensen et al.[5] developed an automated processing system to improve SNM accounting at LASL and at the same time to provide process data. They presumed that good accounting data are also good process control data. Punched cards of 80 columns were coded with information detailing each transfer of SNM between unit processes. The cards were sorted on an IBM 083 sorter and then further processed on an IBM 1401 computer. This system was used at the fromer LASL plutonium facility. Because of the 80-column limit, certain operating procedures were developed, such as round-off rules; these are still in effect. The high state of development of SNM accounting at the former plutonium facility contributed significantly to the success of the DYMAC application at the new facility, although some aspects of this accounting approach are more encumbering than might now be necessary.

**Principles of DYMAC**

The concepts of a DYMAC system have been espoused on many occasions (see Refs. 1-4), but have never been reported in any one document. Briefly, these concepts require adoption of the following principles:

1. The processing plant is divided geographically into non-overlapping, contiguous material balance areas (MBAs), each of which is divided into unit processes. No area of the plant where SNM may reside is excluded. Each unit process is completely contained within one MBA.

2. Each item of SNM is assigned a unique name. A central computer keeps track of each item by its name.

3. No material crosses a unit-process boundary or changes chemical character without a transaction being performed to update the book inventory that resides in the central computer.

4. Measurements are made in near-real-time on each item as it enters and as it leaves a unit process. All items, even waste and scrap, are measured.

5. All measurements are made nondestructively with instruments that are certified daily by comparison to standards traceable to the National Bureau of Standards.

6. All NDA instruments transmit measurements directly to the central computer without process-technician intervention.

7. Two persons are always involved in the transfer of an item from one unit process to another: one person to measure and send it, the other to receive and measure it. The sender and receiver may together perform a measurement on a single instrument to satisfy this requirement.

8. The person who makes a measurement is responsible for making the related transaction. Transactions must be made immediately upon transfer of an item or a change in its chemical character.

9. A Nuclear Materials Officer (NMO) is responsible for accountability of all the SNM in the plant. The NMO reports to an organization that does not have immediate re-

sponsibility for plant production. The effectiveness of a DYMAC System depends on the effectiveness of the NMO. However, the NMO cannot be effective without timely and reliable data concerning the SNM content and location of every item in the plant. A DYMAC system can and must supply this information.

10. The accounting system and associated records must be auditable in the usual sense; for example, it must be possible to develop a detailed history of the passage of an item through the facility.

**Principles of PF/LASS**

The system installed at the LASL plutonium facility does not embody all of the DYMAC principles. Several compromises were necessary. Some were made in the interest of process efficiency; others were made because it was not technologically possible to fulfill all of the DYMAC precepts. Thus it is appropriate to differentiate the conceptual system (DYMAC) from its application at the plutonium facility (PF/LASS).

The main features of PF/LASS as documented in a DYMAC Phase II report[4] are listed here. PF/LASS is a system for near-real-time accountancy of SNM. The system incorporates on-line NDA instrumentation, for analyzing and verifying SNM content, with a set of procedures for handling and measuring SNM as it passes through the facility. Thirty-six digital electronic balances,[6,7] other NDA instruments,[8-15] and 23 terminals are located throughout the plant at key points. Additional instruments and terminals are located in the vault and in the adjacent cold support building where the computer is located. Operating procedures require that measurements be made and communicated to the central computer[16,17] whenever a change occurs in an item, such as a change in its location or physical state, or whenever an item is split or combined with another item. These measurements are either typed on a terminal or transmitted directly to the computer over communication lines that connect some of the electronic balances to the central computer. For each transaction, the computer uses the measurement data and the information supplied by the process technician to update its inventory. The inventory data base may then be queried by process technicians and supervisors to obtain up-to-date information on the location and status of any item in the plant.

PF/LASS departs from DYMAC in the following ways:

1. Not all measurements are made on certified instruments. For example, when a PF/LASS balance is out of service, a technician sometimes uses a process balance to obtain the measurement data but reports to the central computer that a PF/LASS balance was used. While this practice is undesirable in principle, it is justifiable in terms of processing efficiency. Because process balances are calibrated and a check weight is performed before a measurement is made, no problems have resulted.

2. Most material transfers involve only one individual who often carries the material across a unit-process boundary to continue processing. In addition, only one measurement is made as material crosses a boundary, rather than the two required in principle. Since DOE regulations do not now require double measurement, and since process efficiency would suffer if such a rule were adopted, the single measurement approach is used. No associated problems have resulted.

3. Some determinations of SNM content must be inferred rather than measured, primarily because

not all residues are amenable to measurement on current instrumentation. For example, at present there are no NDA instruments in the PF/LASS system for assaying $PuF_4$, although experimental models of such an instrument[12] are now undergoing trials.

4. Not all of the NDA instruments are tied directly to the computer. At present, only 17 balances are directly connected. Thus, most measurements are reported to the PF/LASS computer by process technicians. This is a violation of the tenets of DYMAC, but is allowed by DOE regulations.

5. The NMO is responsible to the plant manager. This is a violation of DYMAC precepts, but is acceptable under DOE regulations.

6. Many features of the present software system are not transportable. The record structure of the PF/LASS system is unique, the packets containing the interactive dialogue are unique, and the method of keying records is unique. Thus the software developed for the LASL plutonium facility cannot be directly useful at other installations unless exactly the same computer (a Data General Eclipse C330), the same operating system--the Advanced Operating System (AOS), and the same file structure are used.

### Successes of PF/LASS

Many anticipated benefits of PF/LASS have been realized. Some impact primarily on safeguards, others on process control. These benefits, and features of the system that bring them about, are outlined below. They include quick inventory, decreased error rate, timely accountability, online instrumentation, instrument reliability, instrument measurement accuracy, system reliability, system flexibility, improved reporting, improved process control, and process-technician satisfaction.

### Quick Inventory

The most conspicuous success of PF/LASS has been the decrease in the amount of time required for inventory. Preparing inventory reports with PF/LASS is so quick and easy that an inventory report is routinely prepared on the last working day of each week for each glovebox in the reprocessing wing; the report is then confirmed by the individual responsible for the area.

According to facility staff, the annual and semiannual inventories are significantly facilitated by PF/LASS. Under the old paper accounting system used at the former facility, the last afternoon and evening before the start of the inspection were always hectic because of the need to balance the books and to eliminate inventory items of negative mass. With PF/LASS, facility personnel claim they are prepared for these inventories and do not experience the previous last-minute confusion. They also state that PF/LASS saves them a day at each inventory.

In addition, because the inspectors now have available the means for a more reliable inventory verification, safeguards are improved. Before PF/LASS, the inspectors had to rely on weight measurements and simple survey-instrument measurements for verification. Now, NDA instruments are used to verify the presence and amount of SNM in items.

At present, facility personnel must perform a complete shutdown and cleanout before each physical inventory. This halts production for three to four weeks. After the inventory is complete, the scrap generated during the cleanout process must itself be reprocessed before regular production can begin again. This costs another several weeks. The plant loses between 1/6 and 1/4 of its production capacity because of inventory procedures. With 145 process technicians employed at the facility, the price paid for cleanout is significant.

Facility staff are currently analyzing PF/LASS data to provide justification for a request to forego shutdown and cleanout before each physical inventory; the detailed knowledge of plant holdup made possible with a DYMAC system obviates that need. DOE regulations give encouragement to this possibility. If facility management can demonstrate that holdup in certain processes and gloveboxes is minimal and that gloveboxes having large holdup are cleaned several times a year, then shutdown could be eliminated, at a financial savings of about $1 million per year.

**Decreased Error Rate**

Except for the plutonium facility, LASL uses a standard paper-entered accounting system. Although mistakes in entering and transcribing data on forms are infrequent, much time and effort is expended in detecting and rectifying these errors. Before PF/LASS, the production control office at the plutonium facility made about 80 corrections per month to 15,000 transactions in the data base just to correct item names. With PF/LASS, although few of the computer's potential verification capabilities have been incorporated, the error rate has decreased dramatically. (At present, little is done beyond checking whether the item identification number actually exists in the data base before allowing the transaction; even this simple check catches many errors.) The production control office estimates that four additional employees would be needed to detect and rectify errors if the error rate equaled that existing before PF/LASS was initiated.

Studies indicate that the goal of achieving an auditable accounting system has been realized. The low error rate and the timeliness of the information contained in the transaction file make it possible to develop detailed histories of each item's movement through the plant and each item's interaction with other items. These histories, called audit trails, are beginning to prove useful in quality control and accountability studies.[18]

In spite of the decreased error rate, a small part of the information in the data base is erroneous. These errors are introduced in several ways. The most common is the typographical error made during data entry. Another is the incorrect designation of the measurement instrument used during an assay. Some of these errors are caught by the present system. Many others could be recognized prior to acceptance of a transaction if the computer were programmed to flag impossible variables (for example, instruments that are out of service or not in the same unit process as the material being assayed) and potentially erroneous or unexpected variables (for example, unlikely changes in material weight, composition, or unit process). Any approach will require that process supervisors have the authority to establish procedures for circumventing malfunctioning instruments with minimum disruption to processing efficiency. As supervisors recognize that the benefits of such approaches outweight the difficulties, these approaches will undoubtedly be adopted. The basic structure of the computer programming makes such adoption possible.

Access to the system is tightly controlled by the use of passwords. The process technician is asked for his/her LASL identification number and a password. If both are answered correctly, the technician is given access to the system at a specified level of privilege. The computer determines this level by comparing the password to a table of privileges for that password. Different individuals have different privileges on the system (for example, only supervisors can write correction transactions).

At present, transactions do not record the identity of the persons making the transactions. This information would be essential should a processing anomaly or a material diversion occur. OS Division has proposed that the computer automatically add that data to the transaction record.

### Time Accountability

Because of reduced errors and a more up-to-date book inventory, the accountability of the plant is greatly improved over that of the previous facility. Although not all aspects of certain inventory differences are fully understood, and although not all of the NDA instruments are connected directly to the computer, the timely nature of the data base is a clear improvement over the old paper system.

Little on-line accountability is implemented and the only alarm system available to the NMO is an "overdue in transit" alarm. Because the processes in operation at the facility are varied and complex, due to the research-and-development nature of the plant, accountability programs need to be developed and implemented unit process by unit process. Past emphasis has been to obtain an accounting system. That has now been largely achieved so that accountability can be given higher priority.

When the processing of an item in a unit process is complete, the product is transferred out of the unit process. Material associated with sidestreams, such as waste and scrap, is also transferred out either at that time or at some later time. The computer is notified of each of these transferred items by means of transactions. The difference between the SNM content of the item(s) entering the unit process before processing and the SNM content of the items leaving the unit process after processing is designated as material in process (MIP). When a unit process has been cleared, the central computer determines the MIP (Designated as MIPXX where XX uniquely identifies a unit process) and adds that amount of SNM to the account that records the MIPs produced in a particular unit process. Process technicians determine when the MIP will be calculated; if they mistakenly claim that a unit process is empty, an improper value is reported.

Facility management has a need for on-line graphs of MIP for each unit process. Although the PF/LASS data base contains all the information necessary for plotting these graphs, they are not produced on the PF/LASS computer. Instead a tape is generated and sent to the LASL Central Computer Facility (CCF) where the necessary graphs are produced off-line on a scheduled basis. The graphs would be more timely if produced directly by the PF/LASS computer. Because they display clearly the accountability aspects of each unit process they are a key to an effective safeguards program. The present inability to produce these graphs on-line is a serious deficiency that must be corrected.

The system does not now readily handle items containing more than one material type. Since the item "name" is made up of ACCOUNT/MATERIAL TYPE/ITEM IDENTIFICATION, items containing more than one material type have more than one name that PF/LASS will recognize, one for each material type. The process technician can report that one name has left the unit process and forget that additional names must also have left the unit process. The computer then believes that there are several items in several places when in fact all these names are associated with one physical item. If process technicians are not careful to recognize that they have a mixed item, they can mistakenly clear their account of one material but not the other. The system should be reworked so that a physical item can have one and only one "name." For items of mixed material types, the computer should alert the process technician to make additional transactions to clear the unit process.

In spite of these minor handicaps, PF/LASS has improved safeguards at the facility. A particularly illuminating example of improved safeguards was evidenced in the lean-residue ion-exchange process. In this process, four streams feed the ion-exchange columns from which there are several outgoing streams, including effluent, eluant, and scrap. This process evidences large gains and losses in the MIP with a generally upward trend. On several occasions the process has had to be cleaned out to reduce the MIP to acceptable levels. Although the detailed data from PF/LASS for each input and output stream have not yet made it possible to pinpoint the source of this MIP, comparisons of the recent data to older data show that this MIP is due to holdup, not diversion.

**On-Line Instrumentation**

While it has been determined that all of the NDA instruments are capable of transmitting their measurement results directly to the computer, only 17 balances have been coupled directly to the computer. For all the other NDA instruments, the process technician must note the reading and then enter it as part of a transaction on a PF/LASS terminal. This not only slows processing but increases the opportunity for error.

Another difficulty arises from failure to have the instruments on-line. Rather than take the time to certify an instrument before making a measurement, some process technicians make measurements with one instrument and report that they were made with another. To reduce the tendency of process technicians to avoid using the proper instrument, the responsibility for certifying each NDA instrument each working day has been assigned to a single individual.

This approach is not a panacea, however. A few process technicians avoid using the PF/LASS instruments because of the inconvenience of moving materials back and forth from their processing area to the instruments and because they have to walk back and forth several times between the terminal and the balance to effect a weighing.

One possible solution is to require that all measurements be authenticated by the computer as outlined in a previous paragraph. To avoid disruptions caused by out-of-service NDA instruments, supervisors could be given the authority to modify the information used by the computer for authentication. Then, if an instrument is out-of-service, the process technician could be assigned an alternative instrument that the computer will recognize as acceptable. When the original instrument is returned to service, permission to use the alternative instrument could be withdrawn. Some reprogramming would be necessary to effect these improvements.

Consideration of the problems just discussed makes it clear that from a safeguards perspective all the measurement instruments should be on-line. There are now more than a hundred instruments and terminals that need access to the main computer. As it is now configured, only 80 units may be directly interfaced to the computer; the computer is now so busy that it cannot adequately service even this number.

This computer-access problem could be overcome by multiplexing the instruments to the main computer via minicomputers. Discussions indicate that such an approach is feasible. Care must be taken, however, to ensure that the communication protocol between instrument and central computer is error-free.

If all instruments are brought on-line, it will also be necessary to find a way for process technicians to perform all the weighing steps during one trip to a balance. Presumably this could be accomplished with a microprocessor-based hand-held terminal such as that employed with the thermal neutron coincidence counting system (THENCS) units.[4]. The process technician could use this terminal to control the taring and weighing operations so that the PF/LASS computer could obtain both measurements at one time.

### Instrument Reliability

The past year of PF/LASS operation has seen much improvement in NDA instrument reliability. Because initial failure rates with the first version of the solution assay instrument (SAI)[11] were unacceptable, that instrument was removed from the process line and reworked. The second and third instruments are refined versions of the original and are interchangeable. Reliability has improved to the point where there have been no hardware failures during the last six months. Software failures are fewer that one per month per instrument.

In late May of 1980, an SAI was contaminated with plutonium, and the decontamination procedures apparently ruined the instrument's electronics. Because of its modular design, the instrument was repaired within seven working days after obtaining access to the decontaminated equipment.

The thermal neutron coincidence counters (TNCs)[8] have proved to be very reliable in operation. Although there are 18 TNCs in the plutonium facility, only 7 are used because of a lack of calibration standards. Additional standards are now being prepared for bringing more TNC units into regular use. Group Q-3 personnel are called on to repair an average of about 1-1/2 units per month. Thus, the mean-time-to-failure is approximately five months, a remarkable statistic for a device that must work in a difficult and experimental environment.

There are 40 electronic balances[4] associated with the PF/LASS installation. Other types of balances are also used for processing. The balances associated with PF/LASS are checked daily and adjusted where necessary to bring them into tolerance. In addition to routine calibration checks, a technician provides maintenance beyond the routine adjustments. During a recent 3-month period, 11 balances needed repair. Most of these repairs were minor; for example, replacement of a light bulb or a malfunctioning switch. Two balances, however, gave continuing trouble until they were finally replaced. Both malfunctioning units were operating in a glovebox whose temperature variations exceeded specification.

One of the two segmented gamma scanners (SGSs)[10] has operated for five years and has needed repair on an average of three times per year. Considering the complexity of the mechanical and electronic systems of the SGS, this is a very acceptable performance. The second SGS has been in operation for only 18 months and has given considerably more trouble.

### Instrument Measurement Accuracy

Measurements made with the NDA instruments are accurate. For example, the SAI measurements are considered so trustworthy by facility personnel that many samples, particularly more concentrated ones, are no longer routinely sent for chemical analysis. The availability of the SAI mesurement data not only speeds the processing at decision points, but obviates the need for making a second entry to the accounting system when the results of the chemical analysis are known. Before the availability of the SAI, average values were determined for each step and were carried by the accounting system until the results of chemical analysis were obtained about two weeks later. Then the deviations from the average for 5 or 10 samples were credited (or debited) to the appropriate MIP account. The present method is a clear improvement.

An apparent difficulty with the SAI arose at the peroxide precipitation and dissolution step of the Fast Flux Test Facility (FFTF) process. Here the SAI measures the feed stock and the output solutions as well as minor side streams. A consistent material loss of approximately 5% of throughput was observed. Because the SAI was a relatively untried instrument, its accuracy was suspect. A set of experiments was undertaken that traced the discrepancy to the fact that two different bottles of solution that were assumed to be equivalent were not. One of these bottles contained the dilute wash from rinsing the filter, thus changing the average concentration of plutonium. Chemical measurements were being made on the solution contained in only one of the bottles, leading to an assay error of about 100g per month. The process procedures have now been modified to avoid these inhomogeneities; the average differences in the plutonium content of the two bottles are now within the expected measurement error of the SAI.

Particularly disconcerting was the discovery that the balances sometimes gave incorrect readings with no other indication of failure. A digit in the readout display would sometimes read zero instead of the actual value measured, due to malfunction of the digital readout circuit. A circuit was designed and installed[6] in each balance that allows the operation of the digital readout to be checked before each use. No further problems have occurred. Had this problem gone undetected, it could have had serious repercussions.

On the whole, most of the measurement instruments work very well. Further development is necessary to make the instruments more capable of assaying solutions with low plutonium concentrations. This might be accomplished through further refinement of the SAI, through installation of a K-edge densitometer,[19] or through installation of a transmission-corrected x-ray fluorescence unit.[20] This would provide additional places in the process stream where samples need not be taken for delayed chemical analysis.

The biggest measurement problems are associated with the ion-exchange columns in the lean-residue process where the MIPs rise very quickly and fluctuate significantly. Better methods are needed for measuring the contents of the horizontal receiving tanks and for making measurements on the various streams as they flow into the tanks. A procedure is needed for accurately determining the flow rate and plutonium concentration as a function of time so that integration of the data can give a better estimate of the tank contents. At present, the solutions are being routed to a calibrated vertical tank for volume measurement. The solutions are also stirred and sampled for plutonium analysis.

One small problem concerning measurement accuracy has resulted from the natural tendency of an instrument user to expect more from the instrument or system than was designed into it. The instruments are usually designed to work with one class of materials or range of concentration. The specifications for these instruments are usually determined and agreed to in consultation with the plant management before the instruments are developed and installed. After having experience with them, and gaining confidence in them, the natural tendency is to want to use the instruments for purposes other than those intended. The reaction of the average process technician is usually one of disappointment when an instrument is not able to perform adequately under unplanned-for circumstances. This is clearly another area where careful and continuing attention to communication as well as to continued system development and upgrade is called for.

### System Reliability

The computer itself has been quite reliable in the four months since it has been turned over from development by Group Q-3 to control by Group OS-3. During the three-month period of April through June 1980, there were no software failures, although some minor problems continued to be identified and corrected in the transaction packets. This followed a period of frequent failures during the conversion to a new operation system. Hardware availability has averaged between 90 and 95%.

There are now about 23,000 records in the on-line data base.

Between 8,000 and 10,000 transactions are handled each month. In addition, the computer keeps track of the details of more than 300 separate sets of steps to be followed in developing a transaction. These sets contain the material that forms the dialogue between process technician and computer.

About 80% of the transactions handled by the computer each month involve in-transit transactions--transactions that place items in-transit or take them out. This contributes to the overload of the system, perhaps unnecessarily, and could raise questions about the reliability of the system. The possibility of handling in-transit activity in a manner that minimizes impact on the computer should be considered. Many items are placed in-transit when they are being moved within a unit process or between adjacent unit processes. Since the computer must interact with a process technician once to place the item in-transit and a second time to take it out, the number of transactions would be halved if a single transaction could be used to effect the transfer. Not all in-transit transactions can be replaced, but system performance would benefit by redesigning the transactions used within a particular unit process.

### System Flexibility

A serendipitous feature of PF/LASS is the manner in which it assumes the responsibility of accounting for silver, gold, platinum, and other precious metals in the facility. The system coding was designed to keep track of SNM using a two-digit code for material type. The 9X series of material type (user designated) has been assigned to accountable precious metals. The process technicians simply transfer and account for precious metals in the same manner that they account for SNM--by using PF/LASS transactions. This same approach is also used to account for nonfissile radioactive sources and to keep track of subaccountable amounts of SNM.

The system can also handle shipments that have peculiarities outside the range of those normally anticipated. For example, a recent shipment contained recoverable amounts of plutonium and uranium as well as significant amounts of iron and titanium. The 80-column format of the old paper system had no provision for additional information. With PF/LASS, the information was partially encoded through appropriate entries. To alert process technicians to the peculiarities of the item, the other constituents were listed in the remarks section of the transaction that created the inventory listing.

### Improved Reporting

PF/LASS assists in the determination and reporting of shipper/receiver differences. Scrap lots are usually shipped with a receipt showing the net SNM content. When they arrive at the facility, the contents are sorted into sublots of similar scrap type. Each sublot is assayed using the best method available for that sublot, and the total SNM content for the sublots is compared to the shipper's claim. The timely and convenient reports generated from PF/LASS data greatly simplify this complex process.

Because the material in many scrap lots is small, several items from different shipments are combined for processing. PF/LASS data allow credit to be given for each shipper's share of the material being produced. These data are also used to assist in the production of the monthly scrap report for the Central Scrap Management Office (CSMO) and to help prepare a weekly FFTF oxide production report. The production control office estimates that PF/LASS saves about 1-1/2 man days/month over the old paper system in preparing the CSMO report.

Plant management meets weekly to plan processing for the remainder of the week. Data from PF/LASS that have been analyzed at the LASL CCF are heavily used during these sessions; such data would be useless if two weeks behind, as can easily happen with a paper system. Processing priorities are determined at this meeting by a number of factors, including the amount and kind of material in the vault and what material is available or causing overcrowding. This key information is readily available from PF/LASS. Although a paper system could supply data that are reasonably up-to-date, extraordinary efforts would be called for, at a prohibitive cost.

On July 1, 1980, a flexible new system of inventory report generation was made available. A requestor can now specify the kinds of records to be included in the report (for example, records on $^{239}Pu$ in the button-oxidation, oxide-dissolution, and peroxide-precipitation unit processes only). The computer assembles a subfile of all inventory items that meet specified requirements; the report is then generated from that subfile. Reports can be generated by unit process, material type, account number, etc. With this technique, more useful reports with less extraneous information can easily be generated. These reports are used by the plant NMO, by process personnel, and by groups within the LASL safeguards R&D program for accountability studies.

**Improved Process Control**

PF/LASS also provides more timely, more effective, and easier process control. Nondestructive assay allows timely determination of solution concentrations or fissile content so that decisions may be made at branch points in a batch process. Before the installation of PF/LASS, these decisions could not be made until the results of wet-chemical analysis were known, causing a delay of almost two weeks. Materials had to be returned to the vault and processing had to be halted on that item. Now, because of the NDA instruments, production need not be halted.

The following example illustrates another way that NDA instrumentation benefits process control. Much of the work at the facility involves acid leaching of plutonium from indissoluble scrap. After a leaching is complete, the processor must decide whether another leaching should be done or whether the material should be sent to retrievable waste storage. Before installation of the 18 TNCs, the material had to be bagged out and transferred to a central measurement point. This not only took significant time and posed health hazards, but it created even more waste and scrap. With the ready availability of an in-line TNC, the processor is able to determine, without bagging out, whether further leaching is necessary.

Much waste and scrap are accumulated by the process technicians, who determine the plutonium content of their collection by using the TNC. The process technicians send this scrap to reprocessing only after they have accumulated enough material to make such a transfer cost-effective. By transferring relatively large amounts, the percentage uncertainty in the amount transferred is improved.

The facilities of the PF/LASS computer are being used for quality control of enrichment. In the FFTF oxide production process, the final product must meet tight specifications of isotopic enrichment, typically to within 0.5%. Since the PF/LASS transaction process automatically calculates the enrichment of a mixture from the original amounts, the process technicians have a powerful tool to assist them in obtaining the proper mixture. Process technicians sign on to the terminals, enter the data for a transaction, then wait for the net isotopic enrichment to be fed back to them. If the enrichment is within acceptable limits, they complete the transaction. If the enrichment is not within acceptable limits, they abort the transaction and select different items to be combined. In other words, they use PF/LASS to perform the mixing calculation for them so that they do not have to do it themselves.

Another advantage of PF/LASS is

that personnel in the production control office can monitor activities in the processing rooms from their terminals. Because the data base is always timely, the personnel who monitor transactions occurring in various parts of the plant are able to pinpoint trouble spots so that corrections can be applied quickly, before errors compound.

Process managers now assess the inventory for each item of material in their area of responsibility. Because this inventory is as up-to-date as the last transaction made, managers can determine whether bottlenecks are developing in their areas. They can then move immediately to eliminate these bottlenecks, thus realizing improvement in process efficiency and, hence, cost-effectiveness.

The results of the NDA measurements are also useful in criticality control. Although the design of the facility has been carefully planned to avoid criticality problems, and although conservative limits have been placed on the size of items that can be moved into each area, criticality control is still an area of great concern. Use of the quick inventory feature of PF/LASS allows a process supervisor to spot potential areas of concern and to act accordingly. The management of the facility plans to implement a revision of the PF/LASS computer program that will automatically check for criticality concerns and produce a signal to indicate when limits might be exceeded if a proposed transfer of material was permitted.

Another area where nondestructive assay is of significant use is in the monitoring of effluent streams from ion-exchange columns. In the lean-residue ion-exchange process, effluent planned for transfer to the evaporator system is kept in a large number of holding tanks to accumulate the desired batch size. Intermediate tanks are used to collect the effluent from individual ion-exchange runs until verification is made that the plutonium concentrate is below the evaporator process limits. Inadvertantly adding an item of relatively high SNM content to these tanks could require that the entire tank be reprocessed, at significant expense in terms of delay in the plant. To ensure that each item is below the evaporator process limits, the effluent is monitored with the SAI and the decision to reprocess or concentrate in the evaporator system is made from that information. Thus, even though the concentrations are below those that the SAI can actually measure, its ability to determine an upper limit on SMN content saves a few days relative to radiochemical analysis. The final accountability determination must still await the results of radiochemical analysis.

**Process-Technician Satisfaction**

The majority of persons at LASL who have worked on both a process line with PF/LASS and on one with the standard paper system much prefer the computer-based system. This view is doubly gratifying because, as in any undertaking of this type, problems can develop because processing goals differ from safeguards goals. As indicated, compromises were sometimes necessary between the demands of efficient processing and the stringencies of a good safeguards program. That an effective system with process technician acceptance is now in place suggests that this experiment has been successful.

Management at the facility believes that PF/LASS is easier to learn to use than the old paper system was. While the dialogue style employed in PF/LASS may slow experienced process technicians, the neophyte is carefully coached by a series of prompts specific to each process. Thus, the process technician need not become an expert in PF/LASS procedures before making process transactions.

Consideration is being given to the development of a series of generic transactions that would have almost universal application. Operations such as splitting or combining batches are common to most processes. If all such transactions were handled identically, the training in PF/LASS procedures that a process technician would receive for working in one unit process would apply equally to any other unit process.

It has become clear that the question-and-answer procedure for data entry is slower than the better process technicians would like. The process technicians quickly learn what will be asked and when. Since the input and output of the terminals are independent, a technician can enter several pieces of data while the terminal is still displaying questions. Unfortunately there are limits to this approach and the technicians are sometimes forced to wait. One solution would be to replace the present terminals with cursor-positioning terminals. Then the technician would need only to fill in the blanks in the displayed array. This would greatly speed data entry and improve Technician satisfaction even more. Also, since this approach would look more like the paper-entry system, training time might be reduced for individuals who are familiar with the paper system.

Process-technician satisfaction would probably be enhanced by increasing the number of terminals in the plant and by changing their type. Currently, in many areas of the plant, the technicians must walk back and forth between the terminals and gloveboxes where measurements are performed to effect automatic weighings. Some technicians avoid this by recording the various measurements on a piece of paper and then reporting the final results at one sitting. This clearly increases the opportunity for error. For measurements to be made properly, all the NDA instruments should be interfaced to the computer and each should have an associated hand-held terminal. These instruments should be capable of making measurements that need not be reported to PF/LASS.

## SUMMARY

This first DYMAC experiment has been a success, but not necessarily in the way expected. The benefits to the processor were perhaps underestimated by Group Q-3 and thus not necessarily optimized. More discussion with the management of target processes could enhance this outcome and perhaps lead to concomitant increases in system safeguards.

Not enough attention appears to have been given initially to the "people" problems that, in retrospect, we know were bound to occur. Much was known and allowed for in instrument design; similarly, steps were taken to make the dialogue between the computer and the process technician transparent and simple. Little was anticipated and allowed for, however, in the sociology of the interaction between the two organizations involved--processing and safeguards, organizations that have different missions, backgrounds, types of employees, and personalities. The next DYMAC experiment must pay more attention to this concern and recognize that a tight safeguards system is usually perceived as inimical to efficient processing, even if the safeguards system is optimally designed. Since this conflict is inevitable, care must be taken to minimize it and to provide benefits to the processor that outweigh the detriments. More effort must be spent by Group Q-3, not only in understanding the needs and concerns of the customer and the peculiarities of the particular operation, but in providing a safeguards system that takes these needs, concerns, and peculiarities into account. PF/LASS has clearly shown that benefits to the processor are significant. These benefits need to be communicated effectively to other facilities.

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# Needs and Availability of Chemical and Isotopic Reference Materials in the Nuclear Fuel Cycle

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**ABSTRACT**

A summary is presented of the availability of and requirements for reference materials by which to calibrate and/or verify measurements in the nuclear fuel cycle.

## I. Introduction

An International Atomic Energy Agency (IAEA) Advisory Group meeting titled "Chemical and Isotopic Reference Materials in the Nuclear Fuel Cycle" was held at the United Kingdom Research Establishment, Harwell, April 15-18, 1980. Nineteen participants from the European Community, France, the Federal Republic of Germany, Japan, the Netherlands, Poland, the United Kingdom, the Union of Soviet Socialist Republics, and the United States were in attendance, as well as representatives of the International Organization for Standardization (ISO) and IAEA. This was the third meeting of its kind; the observations and recommendations of the first Group (1972) were not widely publicized and circulated, as was the case with the 1977 meeting (1,2).

One of the major topics of discussion of the present meeting was the review of the activities of standardization organizations and Member States concerning their needs and availability of reference materials. The results of the discussions on the other topics (certification procedures, transfer and transport problems, and international cooperation in analytical measurement technology) and recommendations to the IAEA are presented elsewhere (3). The results of this meeting as well as an IAEA inquiry on the needs and availability of reference materials for chemicals and isotopic analyses in the nuclear fuel cycle are summarized herein.

## II. Current and Anticipated Activities of Some Standardization Organizations

Most of the information presented at the meeting will be reviewed in the next section. Only points of special interest are reported here.

The Pu-244 tracer certified by the U. S. National Bureau of Standards (NBS) will be available in 1981 for use as a primary reference material. Some Pu-242 certified tracer is available from the EURATOM Central Bureau of Nuclear Measurements (CBNM). NBS also plans to offer similar material by 1983, after the completion of the fabrication and characterization of the new plutonium isotopic reference materials on an "absolute" basis. New batches of the existing low enriched uranium isotopic reference materials NBS are being recertified in U-235 isotopic abundance with an accuracy of 0.02% compared to 0.1% previously. The accuracy statement on their uranium chemical reference material U-960 will also be improved by NBS.

NBS has postponed the certification of a thorium oxide reference material until a higher purity source material can be found. Requests for new reference materials like Pu-239/Pu-244 or Th-230 tracer will not be funded at NBS unless the demand justifies a priority change.

The New Brunswick Laboratory (NBL) is the only producer of a certified mixture of U-233/U-235/U-238 isotopes. Its reference materials of depleted and high enriched uranium, certified for both element and isotopic composition, are also particularly useful for the calibration of isotopic dilution analyses. Its uranium ore reference materials cover a range of uranium concentration between 0.00004% and 70%. Besides producing reference materials, NBL continues to conduct the General Analytical Evaluation (GAE) and the Safeguards Analytical Laboratory Evaluation (SALE) programmes of measurement comparison. The latter programme has recently resumed the distribution of plutonium samples to European laboratories.

CBNM is coordinating an ongoing programme for the certification of EEC uranium and plutonium elemental reference materials to cover the needs within EURATOM. New isotopic reference materials have also been prepared in support of the IDA-80 interlaboratory experiment on isotopic dilution analysis, and may subsequently become generally available. These include mixed U-233/Pu-242 tracers in solution or metal form, a synthetic mixture of low enriched uranyl nitrate and product plutonium nitrate to simulate a diluted spent fuel solution. A certified mixture of Pu-239/Pu-242/Pu-244 isotopes is also planned, but no U-233/U-235/U-238 mixture will be produced for the time being.

Like NBL, the National Bureau of Standards and CBNM have become involved in the fabrication and characterization of working reference materials for non-destructive techniques. These are essentially developed for Safeguards purposes. CBNM and NBS are conducting a programme for joint certification of LEU isotopic RM's for NDA, upon recommendation and advice from the European Research and Development Association (ESARDA) and with the support of IAEA and DCS.

The Commissariat a l'Energie Atomique (CEA), contrary to the statement at the previous Advisory Group meeting in 1977 (1), has produced several new reference materials, besides the $(U,Pu)O_2$ mixed oxide material now in fabrication. A primary reference material of uranium metal, containing less than 100 ppm of total impurities, was prepared by electrorefining and electron beam melting. 0.5 to 1 g solid chunks are packed under vacuum in sealed ampoules, and certified for element concentration. The composition is certified to an accuracy of 0.005% on the basis of a complete impurity analysis. The installations for its fabrication, however, have now been dismantled. Sintered $UO_2$ pellets have also been fabricated in special 400 mg size for use as a convenient secondary reference material. The office of "Coordination de l'Analyse" and the "Commission d'Establissement des Methodes d'Analyse" which organize these projects, conduct the evaluation of analytical methods and manages several interlaboratory experiments concerned with analytical techniques in reprocessing and enrichment technology.

There is no coordinated programme for the certification of primary reference materials within the U.K. However, uranium isotopic reference materials available from British Nuclear Fuel Limited (BNFL) have been compared with NBS materials an intercomparison with Pierrelatte and CBNM is currently in progress. Primary standards consist of 99.418% mass U-235 and 99.99243% mass U-238, prepared originally by magnetic separation at Harwell. Secondary standards calibrated with the above primary standards are as follows:

99.23% mass U-235, 0.7113% mass U-235 and 0.3139% mass U-235. A series of eighty reference standards certified to 0.1% relative are available normally as $U_3O_8$, but can be converted to uranium hexafluoride on request. These standards will be re-certified to 0.05% relative in late 1980. Technical inquiries regarding these uranium isotopic reference materials should be addressed to the Chief Chemist, British Nuclear Fuel Limited, Capenhurst.

Elemental primary reference standards for $UO_2$ and $PuO_2$ are being intercompared within the EEC, and will be available from CBNM. The $UO_2$ pellets supplied by BNFL have an O/M ratio of about 2.0005. The $PuO_2$ supplied by BNFL is at least 99.95% pure, in which the plutonium content is certified to 0.1%. Ignition in air at 1250°C is carried out to produce stoichiometric $PuO_2$ (see BNFL Report 205W for details).

BNFL has working reference materials of high purity sintered uranium dioxide and plutonium dioxide. The following base materials could also be supplied by BNFL - uranium trioxide, uranium tetra-fluoride and uranium metal, all at depleted U-235 concentration. In addition, uranium ore concentrates could be made available.

Harwell is known for the fabrication of reference radioactive sources and calibrated spike solutions for alpha-spectrometry. Sources and solutions can be prepared and characterized on request.

The Japan Atomic Energy Research Institute (JAERI) has prepared several reference materials essentially for national needs. A primary reference material of uranium metal (99.99%) containing less than 40 μg/g of total impurities was prepared by electro-refining and electron-beam melting. Other uranium reference materials provided are oxides for isotopic measurements and for impurity determination. An analyzed uranium carbide powder for determination of carbon and nitrogen is available. Zircaloy and five types of nickel- and iron-based high temperature alloys for constituents are also available. JAERI coordinates these activities of certification and a programme of evaluations of analytical methods.

The Khlopin Radium Institute in Leningrad (USSR) has prepared basic reference materials for accountability and safeguards measurements. A synthetic mixture of U-235 and U-238 isotopes, in a 0.02 ratio, is used to calibrate mass spectrometers, and a natural uranium reference material to calibrate chemical assays. U-233 and Pu-242 tracers are characterized by potentiometric and coulometric titrations as reference materials for mass spectrometric isotopic dilution analysis. A Pu-238 tracer has also been prepared for alpha spectrometric isotopic dilution analysis. Numerous working reference materials are prepared and used by nuclear facilities and research institutes throughout the USSR. But these materials are the property of these organizations and are normally not available for distribution.

The Federal Republic of Germany (FRG) does not produce reference materials, but relies on CBNM for a consistent RM programme. Its industrial facilities can supply high purity source materials, like sintered $UO_2$ pellets, for the preparation of reference materials. The Analytical Laboratories of the Kernforschungs-zentrum Karlsruhe (KFK) and of the Bundesanstalt fur Materialprufung (BAM) in Berlin collaborate in the characterization of reference materials, in particular within EURATOM or for the IAEA.

Similar services are provided by the Netherlands Energy Research Foundation (ECN) in Petten.

Poland cooperates with the USSR, CSSR and the German Democratic Republic (GDR) in the international

SROK programme. The Institute of Nuclear Research produces calibrated radioactive sources of fission products and actinide isotopes, in particular U-233, Np-237, and Pu-238.

The Analytical Quality Control Services (AQCS) of the IAEA supply pitchblende ore reference materials containing between 0.014 and 0.527% $U_3O_8$; in addition, a soil and a lake sediment material analyzed for a large number of elements including uranium at concentrations of 3.0 and 4.0 μg/g, as well as thorium at 11.3 and 14 μg/g, respectively, and a potassium feldspar material containing 2.5 μg/g and 1.4 μg/g thorium are available. But the services distribute mostly control samples for periodic laboratory intercomparison, in particular on $UO_2$ powders and environmental and biological samples.

## III. Needs and Availability of Reference Materials

Tables 1 to 5 present the most significant changes in the needs and availability of reference materials since the previous review made in 1977 (1,2). They are based on the information provided by the participants or known to them, and include a preliminary evaluation of the results of an inquiry conducted by the IAEA between July 1979 and April 1980 (3).

In 1977, 24 materials were reported to be lacking and needed. Thirteen of these requests are or will be fulfilled in 1980 (Table 1). Six other requests have only been partially addressed: the recertification of the NBS isotopic reference materials for plutonium will soon be completed with improved accuracy, but the basic demand for a set of reference materials certified on an absolute basis will not be met before 1982-1983 (Table 3); enriched and certified U-235 and U-238 isotopes can be supplied by NBL, but materials of isotopic purity above 99.95%, if still needed, are not available, a supply of natural Nd and Sm oxides exists at NBS, but the materials are not certified; finally, JAERI has prepared a uranium carbide, certified for C and N, but this item is in low supply for research purposes only.

Also, according to present plans, only two reference materials requested in 1977 should become available in the next three years (Table 3): the Pu isotopic reference materials on an absolute basis and the equal mixture of 239-Pu, 242-Pu, and 244-Pu isotopes.

Five of the 1977 requests still cannot be contemplated unless priorities are changed (Table 4). These are Th metal for element content, 230-Th spike for isotopic dilution analysis, substoichiometric uranium dioxide, uranium dioxide with gadolinium oxide, Pu and mixed (U,Pu) carbides.

On the other hand, the participants examined the demand and availability of some seventeen other items which are not or could not be considered in 1977. Ten of these items, needed for the analysis of ores, impurities or cladding materials or for tracer analyses, are actually already available (Table 2). But there is as yet no funded programme to certify and supply the reference materials to meet the remaining seven new requests (Table 4). They deal with materials necessary in burn-up measurements, in the analysis of boron, spent Th fuels, and Np, Am, and Cm, isotopes and/or elements. In the absence of appropriate programmes at the standardization laboratories, cooperative actions may help to meet these requests at least partially. Possible suppliers of source materials or custom-made reference sources have been identified and should be contacted by interested laboratories.

Finally, Table 5 lists three reference materials developed for the calibration of non-destructive techniques, especially in safeguards applications.

Tables 1 to 5 provide a selected listing of the prominent needs but it is by no means an exhaustive one. Actually, some 90 different reference materials are defined under the needs expressed in an inquiry conducted by the IAEA in 1979-80. More detailed information, obtained by CBNM in a similar inquiry with the European Community in 1977, is to be included to provide the most representative survey to date. Two publications will effectively summarize this work. The new edition of the CBNM catalogue (September 1980) lists all reference materials available at present, with the additions and corrections resulting from the Agency inquiry and the comments of the participants. The Agency will present the needs expressed at this date in a separate report, to describe the nature of the reference materials requested and their intended use, but also estimates of the annual quantities needed. It is hoped that this information will serve to encourage activities to meet the most important requests which have not yet been addressed.

## IV. Summary

The major points of present trends may be summarized as follows:

a) Reference materials used in isotopic and isotopic dilution analysis of spent fuels remain in priority demand. The needs and availability are in fact now more diversified and reflect the implementation of national and international safeguards of reprocessing plants.

b) The new demand for ore reference materials is in line with the increased efforts in ore exploration. Low grade ores are now of economic interest, thus a need exists for reference materials containing 100 μg/g of uranium or less.

c) Several reference materials in wide use are now in low supply. New batches or new materials are being prepared and certified with improved accuracy. Other commonly used materials are intercompared or recertified, also with greater accuracy.

These activities, if properly publicized, should strengthen common bases of measurements and reduce duplication of activities. Despite this fact, several basic needs could not as yet be met, in particular the request for Pu isotopic reference materials on an absolute basis including a certified mixture of 239-Pu, 242-Pu, and 244-Pu isotopes. Coordinated international cooperation should be encouraged to cover confirmed needs which cannot be addressed by current plans.

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**Table 1**

**NEEDS AND AVAILABILITY OF REFERENCE MATERIALS REQUESTED IN 1977 AND CURRENTLY AVAILABLE**

| Material | Form | Characterized for | Supplier |
|---|---|---|---|
| $^{242}Pu$ | solution | $^{242}Pu$ atoms | CBNM |
| $^{244}Pu$ | solution | $^{244}Pu$ atoms | CBNM |
| $^{233}U$ | solution | $^{233}U$ atoms | NBS<br>CBNM |
| $^{233}U/^{235}U/^{238}U$ (1:1:1) | solution | isotope ratios | NBL |
| Pu isotopic RMs | sulfate | isotopic compos. recertified | NBS |
| $UF_6/U_3O_8$ (0.2-93% $^{235}U$) (depl. nat. LEU) | | isotopic composition | BNFL<br>CEA<br>EC |
| $UF_6$ | | element, isotopic composition | NBL |
| $^{235}U$ (enriched 93%) | metal | element, isotopic composition | NBL |
| $^{238}U$ (enriched 99.5%) | metal | element, isotopic composition | NBL |
| nat. $Nd_2O_3$ | powder | (source material only) | NBS |
| nat. $Sm_2O_3$ | powder | (source material only) | NBS |
| $D_2O$ | | isotopic compos. | CBNM<br>AECL Can.<br>CEA |
| $(U,Pu)O_2$ U/Pu=3/1 | pellets | element, isotopic composition | NBL |
| $PuO_2$ | powder | element, isotopic composition | BNFL<br>NBL |
| TRISO, BISO $(U,Th)O_2$ | coated particles | element, isotopic composition | NBL |
| UC | powder | C, N, for research | JAERI |
| $UO_2$ low enriched | powder | element, isotopic composition | NBL |
| natural $UO_2$ | sintered pellet | element | BNFL<br>CEA |
| natural $UO_2$ | powder | element | EC |
| UAl (20-25%) (93% $^{235}U$) | alloy | element, isotopic composition | CBNM* |
| Pu,U alloys | alloy | element, isotopic composition | CBNM* |

*On request only

**Table 2**

**NEEDS AND AVAILABILITY OF REFERENCE MATERIALS
NEW REQUESTS COVERED BY 1980 PROGRAMMES**

| Material | Form | Characterized for | Supplier |
|---|---|---|---|
| U | metal, turnings | uranium | CEA<br>NBL<br>NBS<br>JAERI<br>UKAERE |
| $U_3O_8$ | powder | impurities | CEA<br>NBL<br>JAERI |
| zircaloy | disks | component and impurities | JAERI<br>NBS |
| uranium ores | powder | uranium<br>Ra/U | IAEA<br>NBL<br>South Africa<br>BNFL |
| rock | powder | uranium | NBL<br>NBS<br>South Africa |
| soils | | uranium | South Africa |
| Pu | metal | element | NBS<br>EC<br>CEA |
| natural Li | metal | element | CBNM |
| $PuO_2$ | powder | impurities | CEA |
| U | metal | C* | CEA |

*C in metal U is dissolved in water as hydrocarbon compounds.

Table 3

**NEEDS AND AVAILABILITY OF REFERENCE MATERIALS**
**REQUESTS TO BE COVERED UNDER EXISTING FABRICATION PLANS**

| Material | Form | Use | Supplier | Available from |
|---|---|---|---|---|
| Pu sulfate | powder | M.S. calibration | CBNM | 1981 |
| | | "absolute" | NBS | 1983 |
| LEU, $UF_6$ | | isotopic U-235 0.02% | NBS | 1983 |
| | | isotopic increased accuracy | CBNM | 1981 |
| $UF_6$ | | isotopic (new set) | CEA | 1984 |
| LEU, $U_3O_8$ | powder | isotopic updated certif. U-235 0.02% | NBS | 1981 |
| $PuO_2$ | powder | element | CBNM | 1981 |
| $(U,Pu)O_2$ | pellets | elements, Pu isotopic, impurities | CEA | 1981 |
| Pu-239/242/244 (1:1:1) | solution | M.S. calibration | CBNM | |
| U | metal | C,N | CEA | 1982 |
| $UO_2$ | pellets | element | CBNM | 1981 |
| U ores | powder | uranium, Ra/U | CEA | 1982 |
| | | | NBL | new set |
| Pu-242 | solution | spike (IDA)* | CBNM | 1981 |
| U-233 | solution | spike (IDA)* | CBNM | 1981 |
| U-233/Pu-242 | solution | mixed spike (IDA)* | CBNM | 1981 |
| U-233/Pu-242 | alloy | mixed spike (IDA)* | CBNM | 1981 |
| U-233/Pu-242 | nitrate | dried mixed spike (IDA) | IAEA | 1982 on request |

*(IDA) for isotope dilution analysis.

**Table 4**

**NEEDS AND AVAILABILITY OF REFERENCE MATERIALS REQUESTS NOT COVERED UNDER CURRENTLY FUNDED PROGRAMMES**

| Material | Form | Use | Possible Supplier |
|---|---|---|---|
| Th | metal | element content | UKAEA, Harwell<br>NBL<br>NBS |
| 230-Th | solution | isotopic dilution analysis | UKAEA, Harwell<br>NBS<br>CBNM |
| 230-Th/232-Th (1:1) | solution | mass spectrometer calibration | NBS<br>CBNM |
| 150-Nd | solution | isotopic dilution analysis | NBS<br>CBNM |
| 150-Nd/143-Nd | solution | mass spectrometer calibration | NBS<br>CBNM |
| 10-B(99%) | | isotopic dilution analysis | NBS |
| Np | oxide, metal | element content | CBNM<br>UKAEA, Harwell |
| $^{243}Am$ | solution | calibrated source | UKAEA, Harwell<br>NBS |
| $^{243}Cm$ | | radiometry | ORNL<br>CEA |
| $^{244}Cm$ | | radiometry | ORNL<br>CEA |
| $^{244}Cm$ | solution | calibrated source | UKAEA, Harwell |
| $UO_2$ (O/M 2) | sintered pellet | element, O/M | BNFL |
| $UO_2(Gd_2O_3)$ (1,3,5,7,0% $GD_2O$)<br>($^{235}U$ = 1-4%) | powder sintered pellet | elements | RBU |
| PuC<br>(nat. U, Pu)C | powder sintered pellets | elements isotopics, C | CBNM<br>UKAEA, Harwell<br>TU |

**Table 5**

**AVAILABILITY OF REFERENCE MATERIALS FOR NON-DESTRUCTIVE TECHNIQUES**

| Nature | Form | Use | Supplier | Available from |
|---|---|---|---|---|
| LEU, $U_3O_8$ | powder | isotopic | NBS<br>CBNM | |
| $PuO_2$ | powder<br>large sample | isotopic | NBS | in planning |
| $PuO_2$ | powder<br>small sample | element<br>calorimetry | NBS | in planning |

# Computer-Assisted Audit Trails on the Los Alamos Dymac System

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**ABSTRACT**

Computer-assisted generation of audit trails has been demonstrated at the Los Alamos National Labotarory Plutonium Processing Facility, using data stored by the Dynamic Materials Accountability (DYMAC) System. Examples are given.

**Introduction**

Several automated safeguards accounting systems have been reported in the literature.[1-3] These all derive from paper systems and provide many of the same advantages and disadvantages of paper systems, but at higher speed. All systems must meet the requirements of a good accounting system, one of which is to provide an "audit trail" -- a detailed history of the material as it passes through the processing plant.

Shortly after processing began in the Los Alamos Plutonium Processing Facility, the DYMAC System was reviewed by a NUSAC consulting team at the request of its designers. The team analyzed the strengths and weaknesses of DYMAC. One of the weaknesses was that an audit trail capability had not been demonstrated. Los Alamos considered this a serious shortcoming, especially since the systems at Mound Laboratory and at Oak Ridge were reported to have audit trail capability. It was not obvious, moreover, that such a capability could be demonstrated, since a feature of DYMAC not common to the other systems is that it must deal with a processing environment that generates many side streams that take on different identities (names) in the accounting system. Furthermore, DYMAC utilizes the unit process area accountability technique.

One of the purposes of this paper, then, is to demonstrate that an audit trail capability does indeed exist for the DYMAC System. Our procedure provides more than a simple audit of a single item. It provides a detailed history of the material in a single item and its associated sidestreams as it travels through the plant. One simply indicates to the computer the ID number of an item at any one time. Its detailed history (or future) is then printed out in a single run of the computer program. Moreover, the program may be run "forward" or "backward" so that if the fate of an item is wanted rather than its history, it can also be obtained. Thus, one can select an item name at any point in a process, make two passes by the computer-- one forward and one backward-- and obtain details on where the material in that item came from and where it went to. We present examples of audit trails prepared using a six-month data base (October 1978 through March 1979) to indicate the complexity of the data with which we are dealing.

Our second purpose is to document the methods of this audit trail technique so that future projects

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using the technique will have a basis for proceeding. One such project using the entire DYMAC data base for two and one-half years has already been reported.[4]

While the root concepts used in the development of our audit trail program are simple and easily transportable, the actual methods are heavily dependent on the details of the DYMAC System itself and the methods and formats used for recording data. Thus, before the audit trail system can be discussed, an extensive digression into the details of DYMAC are necessary.

**Background**

DYMAC is a real-time safeguards accounting system,[3] installed at the Los Alamos Plutonium Processing Facility. The hub of the system is an Eclipse computer that receives information on activities and transactions within the facility, and that can provide at any time the location, quantity, and composition of all special nuclear material (SNM) processed and stored in the facility. Nondestructive assay instruments are placed strategically throughout the process areas. Measurements made with the instruments are sent to the computer either directly or by operator intervention at computer terminals. Currently 38 balances[5] are installed, of which 15 are connected directly to the computer. Other instruments in use include 3 solution assay instruments[6] for measuring plutonium and americium in liquid samples, 2 segmented gamma scanners[7] for measuring plutonium content of scrap, and 18 thermal neutron counters[8] for the assay of plutonium in bulk.

The Los Alamos Plutonium Processing Facility is divided into four wings, plus a vault area. Each wing is subdivided into material balance areas (MBAs), which are further subdivided into receipt areas (unit processes). Some receipt areas are as small as a single glovebox, others include several gloveboxes. No glovebox is in more than one receipt area, and no receipt area is in more than one material balance area.

A fundamental requirement of DYMAC is that whenever a significant change is made in an item, or when an item moves from one receipt area to another, the computer is notified of the change and certain information is sent to the computer to characterize this change. The computer uses the information to generate a computer record that is referred to as a "transaction." Table I displays the information contained in a transaction. It may be seen that a transaction consists of 157 16-bit words of information. In principle, no movement of an item, nor change in its character, should take place without the computer being notified or without the computer generating a transaction indicating that change. It is possible to take various parts of an item and create new items by dividing old ones or combining several others. The creation of each new item involves a transaction indicating the amount of material transferred. Thus, because items may be divided, combined, and renamed, the same plutonium atoms may, at different places and times, be identified with very different item numbers.

**Principles**

An analysis of the details of the transactions is used to produce an audit trail. The approach is a simple one. Consider a time-ordered file of all the transactions--the earliest transaction is first and the latest transaction is last. Table II provides a concrete example of such an ordered file. To follow a certain item through the plant, we need to focus only on the item identification (ID) numbers. For the sake of simplicity, we will refer to the ID numbers as the FROM-ID and the TO-ID, which are the ID numbers on the FROM side of the transaction and on the TO side of the transaction, respectively. The computer is informed of the ID of the material that is to be tracked through the facility. Returning to the list of Table II, let us assume that the ID of this material is TOM-1. The computer starts at the beginning of the list of transactions and looks for one involving a FROM-ID that is the same as the ID it has been asked to track, TOM-1. When it finds such an ID number (in our example transaction number 3), it knows it has found a transaction involving material taken from item TOM-1. It then examines the other side of the transaction, the TO-ID, to determine where the material from TOM-1 was placed. If it has not yet found that TO-ID, to determine where the material from TOM-1 was placed. If it has not yet found that TO-ID, it adds this item-ID to the list of IDs which it is searching for. According to our example in Table II, the computer would then examine the FROM-IDs, looking for TOM-1 and DICK-2. It compares each transaction to both transactions on its list. When it finds a transaction that involves either of these ID numbers, e.g., transaction number 8 in our example, it again examines the TO-ID and determines whether this ID is one that has been found; if not, it adds the ID to its list. In this way, all the ID numbers identified with a particular original item are determined. It is a simple matter to search through the data base a second time to print out all transactions involving these IDs.

Several difficulties with this simple approach can and do occur. The first difficulty involves material-in-process (MIP) transactions, external transactions, and transfers to waste. When a particular item is involved in a MIP transaction, the TO-ID will be of the form MIPXX, where XX designates the particular receipt area involved. If this type of ID is added to the search list then, because items with different ID numbers contribute to that MIP, the search process will blow up and all ID numbers passing through the receipt area will be found. (Note transaction 12 and 13 of Table II.) To avoid this difficulty, and the similar difficulty involving external transactions and transfers to waste, the search process checks all of the ID numbers found and requires that at least one numeral be contained in the identification. In cases where a numeral is not included, that ID is not added to the search list. The transactions involving MIPs and external transactions are not completely ignored. When the transactions in an audit trail are printed, all the transactions to and from IDs of interest are indeed printed out, including those to and from MIPs.

At the plutonium facility, a number of residue batches have other ID numbers such as MSRPOT, ROT, GLOVES, and RAGS. If we searched for these designators, the effect on the search would be the same as if the MIPs or external transactions were searched for. Because these have no numerals, they are not searched for and thus material is not tracked through them, although material is tracked to and from them if the transactions involve an ID of interest.

**Procedures**

As explained, the principle of operation of our audit trail programs is to search on a time-ordered list of transactions. Unfortunately, the DYMAC computer does not maintain its list of transactions in a time-ordered manner. It keeps, on disk, four to six weeks of information arranged by MBA and receipt area. Each month the most recent four-week record is dumped to tape for preservation. Because the data is not placed on tape in time order, we ordered the data we analyzed according to the time the transactions occurred.

We used a six-month period between October 1, 1978 and April 1, 1979. This six-month period involved 26,000 transactions, which provided a substantial data base since each transaction consists of 157 words. It was impossible, using our computer, to place all the transactions on one disk. Therefore, the following strategy was employed to allow us to check the applicability of the technique described.

We extracted from each original transaction the information shown in Table III. That information is sufficient to completely characterize most transactions. Each extracted transaction consisted of only 23 words so that the information for the entire six-month period could be contained on one disk. Since transactions are available on a month-by-month basis, individual files of extracted information were prepared from each month of transactions, a total of six files. The date and time of each transaction were encoded into a floating point word that is proportional to the date and time--the smallest number corresponds to the earliest transaction and the largest number to the latest. By searching on this list of time pointers, each month was ordered on the disk. The monthly files were then concatenated and placed in a single file, called EXTRACT. The first record of this file contains the number of transactions in the file. This data base was used in our subsequent studies.

A program was written following the search principles outlined above and diagrammed in Fig. 1. That is, the program examines the file EXTRACT seeking particular FROM-IDs. Upon finding such a FROM-ID it checks to see if the TO-ID is contained in the array of words it was searching for. If not, the TO-ID is added to the array for subsequent searches. (A comparable program searches backwards in time. It searches on the TO-IDs and adds FROM-IDs to the array of searched-for IDs). After all the IDs are found, the data base is searched a second time to print out all transactions involving those IDs. In both the forward- and backward-searching cases, the printout starts with the earliest transaction and continues in time order. The transactions are also sent to a file, called TRANLIST, for subsequent manipulation. A separate program prints out the contents of the TRANLIST file grouped by ID, in time order within each group. This facilitates interpreting the trail since all transactions into and out of each item ID are grouped together.

**Results**

Shown in Figures 2 and 3 are examples of audit trails developed with the assistance of the computer. The tree developed in Fig. 2 was provided by asking the computer to search on the ID LA0108C0. The computer identified 23 ID numbers and 109 transactions leading from the original ID. There are several streams feeding LA0108C0 and one of these was explored by performing a backward search on the designation LA0108IC. This result is shown in Fig. 3. Note the odd behavior on the left chain involving DB1061 and NX102. The dotted line is an inferred transaction to avoid showing transactions to and from NX102. Note also that 660 g of SNM flows to ROT, but that this flow has not been followed further for the reasons discussed above. There are 19 IDs and 44 transactions involved in this pattern. Since the data base includes only a six-month period, the origins and final destinations of every item shown in the two figures are not external to the facility.

Only the transactions that change receipt area have been indicated in Figs. 2 and 3. (There is one exception, in Fig. 3.) There are often several transactions within a given receipt area, and including them would overcomplicate the figure. There were 153 transactions involved in these two searches.

As an example of how complicated the search process can become, the computer was asked to do a backward trace on PE0672S. The computer found 545 ID numbers linked to the original ID number and printed out approximately 2300 transactions. This is an extraordinary number of transactions, too difficult to diagram, but it should be remembered that this richness of data is a reflection on the complexity of the chemical processes, not an indictment of the computer program. In this process many residue side streams are involved. Because many streams in turn entered these streams, the search process found too many item IDs to diagram. To comprehend the process would require ignoring certain minor sidestreams and, thus, many transactions. It would be possible to eliminate some of these sidestreams by refusing to trace through ID numbers involving arbitrarily small amounts of material. For example, if we were following 2000 g of plutonium, and did not include a 2 g (0.1%) sidestream in the search, we would reduce the number of transactions, but at the expense of a detailed understanding of the process.

### Conclusions

Our work shows that audit trails can, indeed, be developed off-line using the DYMAC data base. Further developments and a computer with more disk space could provide on-line trails. We intend to use the audit-trail capability for extensive studies of the accountability aspects of the various processes. Before accountability of DYMAC is ensured, detailed studies of each of the processes must be made to identify how the MIPs are generated in each case and how the uncertainties in these MIPs are affected by the measurements made on the streams that are coupled to the MIPs.

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**Table I**

**DYMAC TRANSACTION STRUCTURE**

| Word No. | | Content | Format | |
|---|---|---|---|---|
| 1 | | Transaction type | Integer | |
| 2, 3 | | MBA | Alpha | |
| 4 | | Material type | Alpha | |
| 5-9 | | LOT ID number | Alpha | |
| 10 | | Receipt area | Alpha | |
| 11, 12 | TO | Project | Alpha | |
| 13-17 | | Person | Alpha | |
| 18, 19 | | Location | Alpha | |
| 20, 21 | | Shelf | Alpha | |
| 22 | | Special designator | Alpha | |
| 23, 24 | | Item description | Alpha | |
| 25-49 | | Remarks | Alpha | |
| 50-99 | | FROM INFORMATION | Same as TO format | |
| 100, 101 | | Destination | Alpha | |
| 102-104 | | Transaction ID | Alpha | |
| 105-107 | | Date | Alpha | |
| 108-110 | | Time | Alpha | |
| 111, 112 | | SNM amount | Real | |
| 113, 114 | | Uncertainty SNM amount | Real | |
| 115, 116 | | Enrichment | Real | |
| 117, 118 | | Uncertainty enrichment | Real | |
| 119-142 | | Isotope breakdown | Real | |
| 143, 144 | | COEI number | Integer | |
| 145-148 | | Seal number | Alpha | |
| 149, 150 | | Measurement code | Alpha | |
| 151, 152 | | Bulk amount | Real | |
| 153 | | Verification amount | Real | |
| 154, 155 | | Verification amount | Real | Used for external |
| 156 | | Verification instrument | Alpha | transactions only |

**Table II**

**HYPOTHETICAL LIST OF TRANSACTION IDs PLACED IN TIME ORDER**

| Transaction Number | FROM-ID | TO-ID |
|---|---|---|
| 1 | LGO-796 | LGO-796A |
| 2 | FS-1057 | FOX-1057 |
| 3 | TOM-1 | DICK-2 |
| 4 | NX-3 | NX-3 |
| 5 | LAI-1087 | MIPBL |
| 6 | CAN-734 | DRUM 5876 |
| 7 | WAS 111900 | IRA 309 |
| 8 | DICK-2 | HARRY-3 |
| 9 | DICK-2 | DICK-2 |
| 10 | INC 90401 | RAG790102 |
| 11 | H001097R1 | IRA 309 |
| 12 | TOM-1 | MIPRR |
| 13 | MIPRR | WAS 111900 |

## Table III

### SPECIFICATIONS OF THE DATA IN EXTRACT

| Word Number | Contents | Format | Remarks |
|---|---|---|---|
| 1 | DATE | Integer | Stored as $(YR-1978)*10^4 + MO*10^2 + DAY$ |
| 2 | TIME | Integer | Stored as $HR*10^3 + MIN*10 + SEC/10$ |
| 3–5 | TO material type | Alpha | Two alphanumeric characters per word |
| 6–8 | TO-ID | Alpha | |
| 9 | TO receipt area | Alpha | |
| 10–12 | FROM material type | Alpha | |
| 13–15 | FROM-ID | Alpha | |
| 16 | FROM receipt area | Alpha | |
| 17–18 | SNM amount | Single-precision Real | |
| 19–20 | Measurement code | Alpha | Indicates which instrument provided the measurement |
| 21–22 | Bulk amount | Single-precision Real | |
| 23 | Bulk units | Alpha | Unit of measurement for bulk amount |

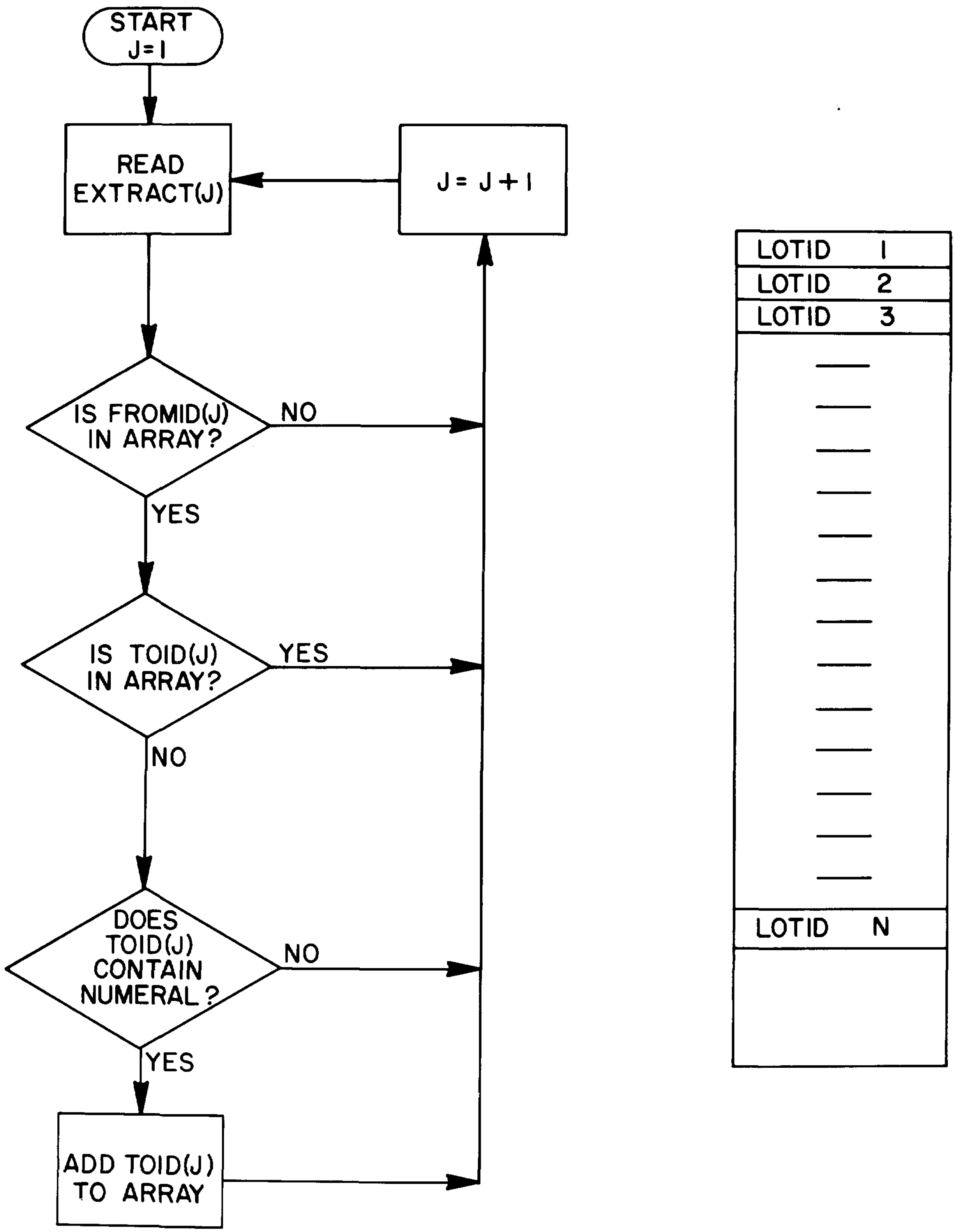


Figure 1 - A flow diagram for the audit trail program. ARRAY contains the list of item IDs (called LOTID) being searched for. EXTRACT contains the transaction. All transactions are ready from EXTRACT in turn.

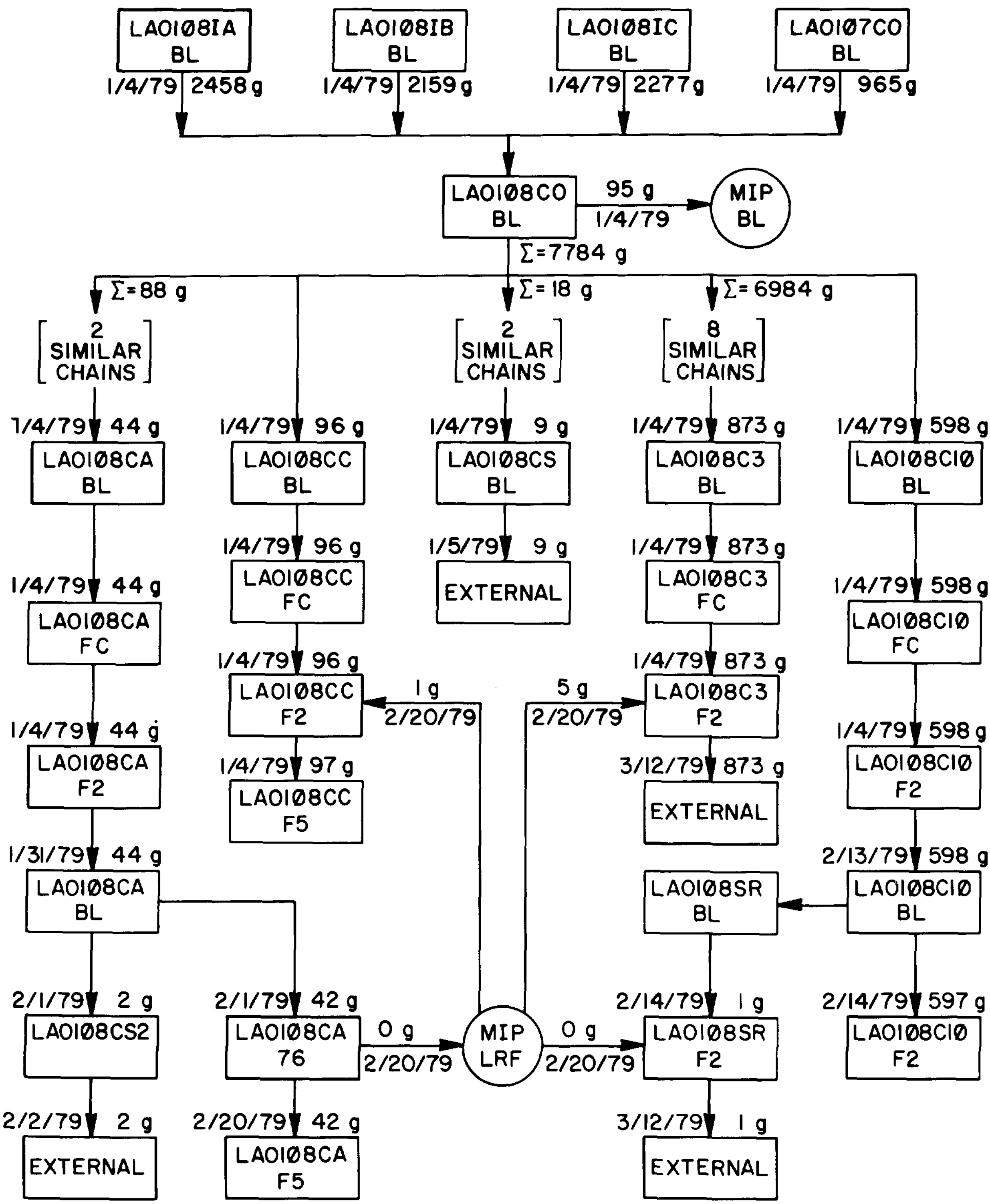


Figure 2 - Shown are part of the transactions during the six-month data base period deriving from the item ID LA0108C0. Since many of the descending streams are similar, only one has been shown for each case. Also, transactions that do not change receipt area are not indicated. The data were extracted from the six month data base in a single run of the computer program. Data are printed out on a single report.

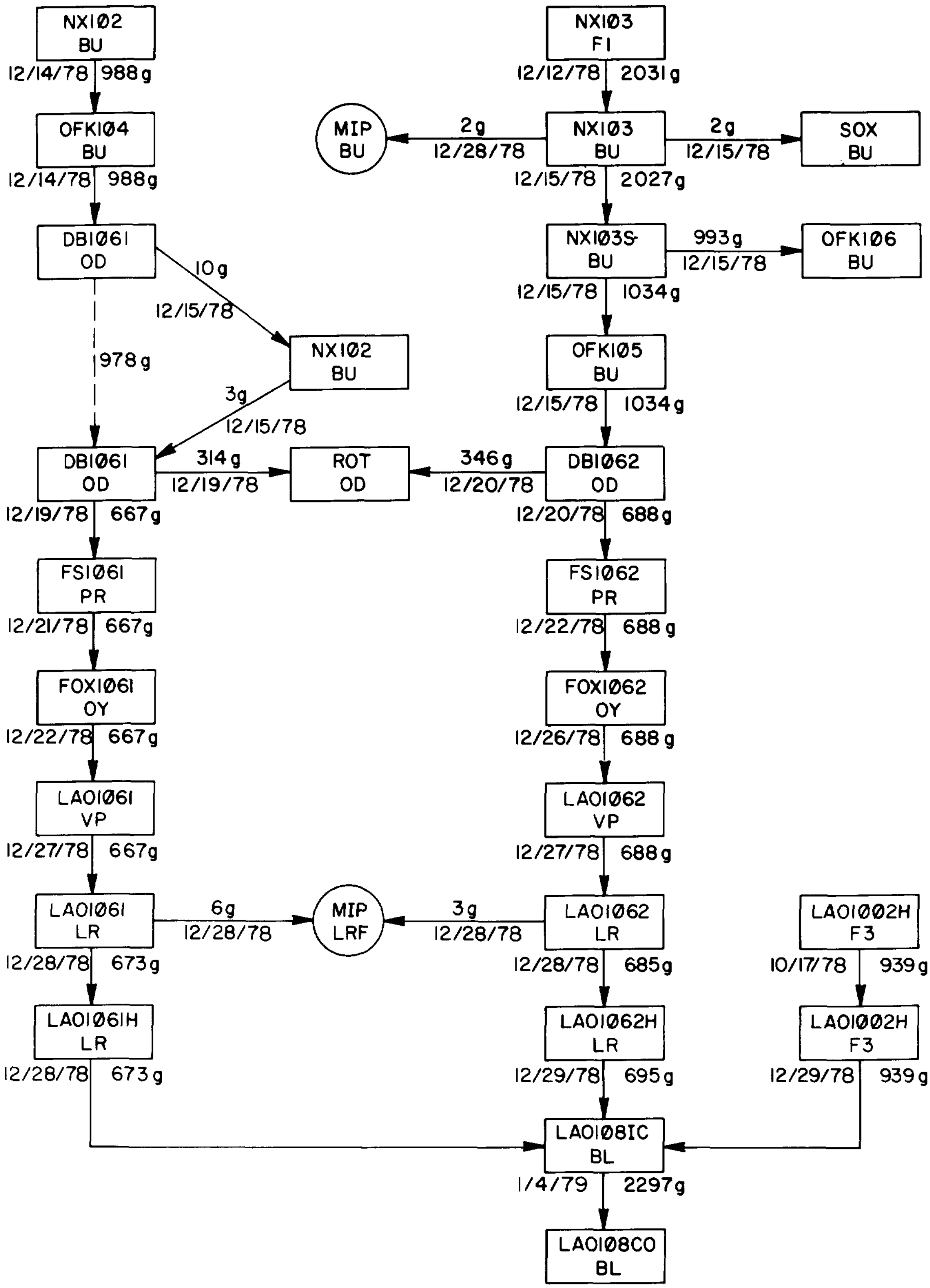


Figure 3 - Shown are the transactions that lead to LA0108C0
which in turn couples to Figure 2.