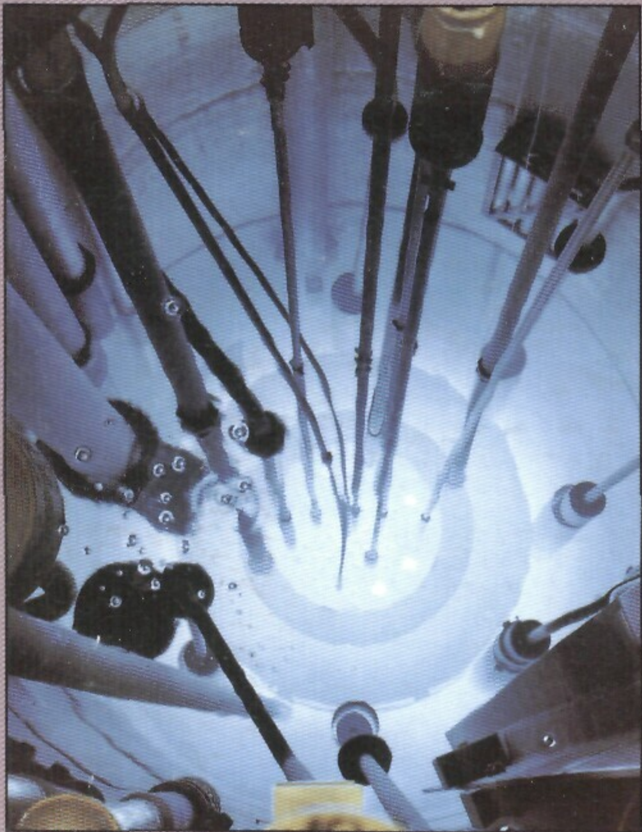
JNMM
JOURNAL OF
THE INSTITUTE OF
NUCLEAR MATERIALS MANAGEMENT



Volume XVIII, Number 2 • February 1990

CONTENTS

Volume XVIII, Number 2 ▪ February 1990

PAPERS

EDITORIALS

INMM NEWS

ANNOUNCEMENTS AND NEWS

On the Cover:
Looking into the TRIGA Mark I research reactor operated by General Atomics, San Diego, California U.S.A. The Mark I, still in operation, was the first of more than 60 TRIGA reactors built. The American Nuclear Society designated it a national nuclear landmark.

JNMM is published four times a year by the Institute of Nuclear Materials Management, Inc., a not-for-profit membership organization with the purpose of advancing and promoting efficient management and safeguards of nuclear materials.

SUBSCRIPTION RATES: Annual (U.S., Canada and Mexico) $100.00, annual (other countries) $135.00; (shipped via air mail printed matter); single copy regular issues (U.S. and other countries) $25.00; single copy of the proceedings of the annual meeting (U.S. and other countries) $65.00. Mail subscription requests to *JNMM*, 60 Revere Drive, Suite 500, Northbrook, Illinois 60062 U.S.A. Make checks payable to INMM.

ADVERTISING, distribution and delivery inquiries should be directed to *JNMM*, 60 Revere Drive, Suite 500, Northbrook, Illinois 60062 U.S.A. or contact Thalia Keeys at (708) 480-9573, telecopy (708) 480-9282. Allow eight weeks for a change of address to be implemented.

ISSN 0893-6188

TECHNICAL EDITOR'S NOTE

In 1986, forty years after the nuclear arms race began, the United States and the Soviet Union finally began to seriously discuss reducing their nuclear weapons systems. This became possible when it was agreed to include credible verification measures in the Intermediate-range Nuclear Force (INF) Treaty. The INF Treaty was signed Dec. 8, 1987.

Immediately, both governments initiated studies of verification measures which might be needed for further and more significant nuclear reduction agreements. Some of the techniques developed for domestic and international safeguards were employed for the INF Treaty and a number of people previously engaged in developing safeguards verification measures were invited to assist in developing verification techniques which might be useful for possible future arms control agreements.

In the editorial of a recent issue of the *Journal*, Chairman John Lemming suggested that the Institute might expand its scope to include verification of arms control agreements. At its meeting last July, the INMM Executive Committee established an ad hoc committee to recommend whether the Institute should do so. The ad hoc committee has decided to recommend that verification of arms control agreements be added to our areas of interest. As a starter, it plans to have a number of papers on this subject presented at the INMM Annual Meeting in Los Angeles, July 15-18.

Obviously, such a move will need the support of the members. This editorial is an appeal to the membership for comments as to the desirability of such a move and to what the INMM program should consist of.

The present nuclear arms control discussions involve primarily the United States and the Soviet Union. In the future these must include other nuclear and non-nuclear weapon countries. The proposed agreements on conventional armed forces and chemical weapons will require the participation of many countries. The assistance of those anywhere, interested in and knowledgeable of verification techniques, will be needed.

The Institute is *the* international professional organization for those interested in domestic and international nuclear safeguards. The membership is made up of government, industry and R&D personnel engaged in safeguards activities. Our expertise is in the systems studies, the techniques, and the evaluations needed to implement the policies. We have meetings, seminars, and publications to exchange information.

A number of other institutions are interested in the policies, and a few others have been studying arms control verification approaches since before it became a major government program. We should make sure that what we do is coordinated with, and complementary to, these other programs.

It may be useful to mention some of these other institutions and some of the sources of information on arms control verification with which I am familiar. I invite others to complete this list. The United States established the On-site Inspection Agency to implement the verification provisions of the INF Treaty on Jan. 15, 1988. The INF Treaty contains detailed descriptions of the nuclear weapon systems to be destroyed and the verification measures. The new agency has published a number of articles explaining how this has worked in practice. Descriptions of the nuclear weapons systems and other military systems are published in the Stockholm International Peace
12 Research Institute (SIPRI) year book. The National Resources Defense Council has participated in verification exercises for a nuclear test ban and other possible agreements jointly with the Committee of Soviet Scientists for Peace and Against the Nuclear Threat. In 1987 The Soviet Committee and the Federation of American Scientists initiated a joint research project on analysis of potential nuclear arms control agreements and on relevant verification techniques. One result of this is a new journal, "Science and Global Security," co-chaired by Roald Sagdeev, Space Research Institute, Moscow and Frank von Hippel, Princeton, New Jersey. The first issue, published by Gordon and Breach, became available in January.

Please send your comments to the INMM office or discuss this with the officers and others at the Annual Meeting.

To return to an older theme: As you can see, a number of members have contributed the technical articles in this issue. We need more such volunteers to fulfill our responsibility to our members.

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

Now Is the Time To Get Involved

Fellow members and friends of the INMM, the 31st Annual Meeting of the Institute will be held July 15-18, 1990 at The Biltmore Hotel in Los Angeles, California. I apologize that meeting notices were not mailed to you sooner. This year, for the first time in my memory, negotiations for the hotel took longer than expected.

There will be some changes in the Annual Meeting this year. The number of papers is being limited to 200; there were approximately 235 in Orlando last year. In addition there will be a session on arms control. A number of our fellow members are interested in this subject and promise to educate us in this very important part of nuclear material control. The new session does not indicate less attention to traditional subjects such as physical protection, material control and accountability, international safeguards and others. The Technical Program Committee is working hard to assure that those sessions will be even better than last year.

A year ago in this column I expressed the opinion that the Institute's membership should grow from 800 to 1000. Unfortunately that has not happened. During the past year the membership brochure and application have been revised. I am hoping that before I become the immediate past-chairman in October we can attain the goal of 1000 members. Each of you will receive a copy of the new membership brochure and an application form. Please pass it along to a colleague. If you have specific ideas about a membership drive please give me a call. My time is running out.

The Communications Committee is working to reestablish a public relations program for the Institute. If you are interested in working on this project or have a sure-fire idea, we need your help.

Remember, the INMM is a volunteer organization and exists only in and through its members. It is time now for you to become involved. If you cannot be on a committee, standards writing group, or come to the meetings or workshops, please give us feedback on what the INMM means to you. Let me know. My address is: EG&G Mound Applied Technologies, P.O. Box 3000, Miamisburg, Ohio 45343 U.S.A.

John F. Lenning
EG&G Mound Applied Technologies
Miamisburg, Ohio

Physical Protection Report

The scheduled activities of the Technical Working Group on Physical Protection are listed below:

- Workshop, "Security Personnel Training," is scheduled to be held April 9-11, 1990 at the Clarion Four Seasons Hotel, Albuquerque, New Mexico. Harry Leith, ERCE, (803) 642-8787 is the Workshop Chairman.
- Workshop, "Package Search Techniques," is currently being considered, but has not been tentatively scheduled. Such a workshop would concentrate on better and more effective methods of searching packages which enter restricted areas. If you have an interest in such a workshop please contact Donald Kasum, Nuclear Regulatory Commission, (301) 492-3379.

Workshops on other subjects of interest to physical protection personnel will be considered if enough interest is expressed. Additional details about the group activities are given below.

General

Security Personnel Training

The next workshop on this topic is scheduled to be held April 9-11, 1990 at the Clarion Four Seasons Hotel, Albuquerque, New Mexico. This has been a very popular workshop in the past has included a visit to the Department of Energy's Central Training Academy. If you have questions about the workshop or suggestions for topics to be covered please contact Harry Leith, ERCE, (803) 642-8787, Workshop Chairman.

Detecting Outsiders and Insiders by Integrating the Elements of Delay, Intrusion Detection, and Entry Control into Physical Security Systems

A Workshop on this topic was held Nov. 6-9, 1989, Cavalier Hotel, Virginia Beach, Virginia. This was a very successful and informative workshop.

James C. Hamilton, (614) 897-2204, Martin Marietta Energy Systems, was the Workshop Chairman.

Annual Meeting

The 31st Annual Meeting of the INMM will be held July 15-18, 1990 at the Biltmore Hotel, Los Angeles, California. There were approximately 60 Safeguards and Security/Physical Protection papers presented at last year's meeting which was held in Orlando, Florida and we expect that this year's meeting will be equally as good.

James D. Williams
Chairman
INMM Technical Working Group on Physical Protection
Albuquerque, New Mexico, U.S.A.

Corrections

The first line of the abstract of "Mass Spectrometry of Nuclear Materials—Attention to Detail" by William Shields (JNMM, November 1989) should read "Measurements of the $^{235}U/^{238}U$ ratio in product-quality material have improved from uncertainties of 0.1 percent (rel) to 0.02 percent since the Manhattan Project." *JNMM* regrets the error.

The top cover photograph of the November 1989 issue of the *Journal* is the original New Brunswick Laboratory in New Brunswick, New Jersey.

Pacific Northwest

The winter meeting of the Pacific Northwest Chapter of INMM was held Nov. 17, 1989. Harold Ransom spoke of his safeguards consulting activities with BRI, Inc. since his retirement from DOE Safeguards. During the business portion of the meeting, the 1990 officers were introduced and the gavel was passed to Don Six. The following officers were elected for 1990:

Chairman
Don E. Six

Vice-Chairman
Brian W. Smith

Secretary/Treasurer
Debbie A. Dickman

Executive Committee
Wayne L. Delvin
Jim B. Edgar
Bonnie J. Johnson
Obie Amacker, Jr. (Past Chairman)

Debbie Dickman, Secretary Treasurer
INMM Pacific Northwest Chapter
Pacific Northwest Laboratory
Richland, Washington, U.S.A.

Japan 10th Anniversary

The Japan Chapter of the Institute of Nuclear Materials Management celebrated its 10th anniversary in 1989. The INMM Board of Directors offers the Chapter its warmest wishes in celebrating 10 years of growth and progress and recognizes the Chapter's significant contributions to the Institute as an international organization.

1989-1991 Japan Chapter Officers

The following officers were elected for the 1989-1991 term and approved at the 29th Executive Committee Meeting held Oct. 3, 1989 in Tokyo.

Chairman
Dr. Mitsuho Hirata
Nuclear Safety Technology Center

Vice Chairman
Mr. Tohru Haginoya
Nuclear Material Control Center

Secretary
Mr. Takeshi Osabe
Japan Nuclear Fuel Co., Ltd.

Treasurer
Dr. Yoshinobu Seki
Mitsubishi Metal Corp.

Members at Large
Mr. Kazuhisa Mori
Japan Atomic Industrial Forum
Dr. Reinosike Hara
Seiko Instrument Inc.
Mr. Harumitsu Iwamoto
Nuclear Fuel Transport Co., Ltd.

Executive Committee Meetings

The 30th, 31st, 32nd, 33rd, and 34th Executive Committee meetings were held at Nuclear Material Control Center headquarters, Tokyo, on Nov. 7, 1988, Dec. 23, 1988, March 10, 1989, June 2, 1989 and June 8, 1989, respectively.

Mr. Kouzo Iida, The Federation of Electric Power Companies.

10th Annual Meeting

The 10th Annual Meeting was held in Tokyo on June 9, 1989. Mr. Hiroyoshi Kurihara, Power Reactor Nuclear Fuel Development Corp., served as program chairman for the meeting. The meeting program was as follows:

Opening Address: H. Kurihara Program Chairman

Chairman's Address: M. Hirata Chapter Chairman

Invited Lectures: M. Hirata, Chairman. "Significance of Atomic Energy Reconsidered In This Changing World," Y. Nakae, Atomic Energy Commission of Japan. "Current Topics On Physical Protection In Japan," K. Murakami, Nuclear Safety Bureau/Science & Technology Agency. "Development Program for Nuclear Generating Capacity," K. Iida, Federation of Electric Power Company. "Activities of the Institute of Nuclear Materials Management and Some Thoughts on Nuclear Public Relations," C.M. Vaughan, Institute of Nuclear Materials Management.

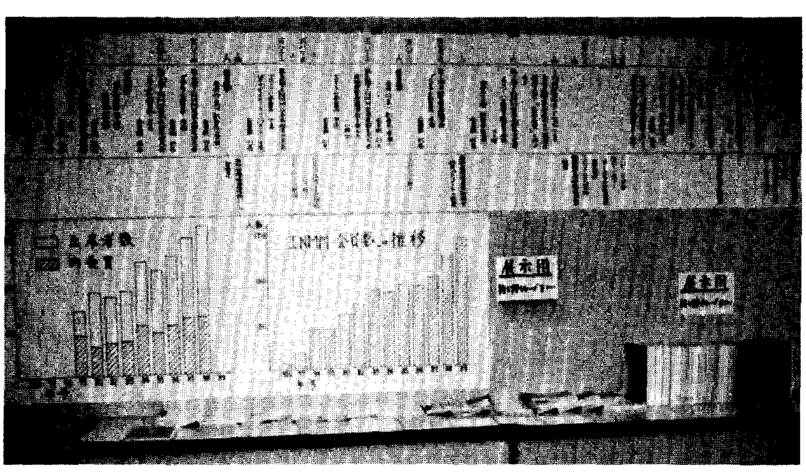
Session 1: H. Kawamuto, JGC Company, Chairman. "Advanced Containment and Surveillance Systems of the Plutonium Fuel Production Facility at PNC," K. Matsuyama, Power Reactor Nuclear Fuel Development Corp., et al. "Surveillance System Using the UW (Under Water) CCTV," T. Hayakawa, Power Reactor Nuclear Fuel Development Corp., et al. "Concept of Advanced Containment and Surveillance System," H. Kawamoto, Japan Nuclear Fuel Service Co., et al.

Session 2: H. Nishimura, Japan Atomic Energy Research Institute, Chairman. "Development of a Real Time Simulation System to Demonstrate the Use of the Near-Real-Time Materials Accountancy," H. Ihara, Japan Atomic Energy Research Institute, et al. "Method of a Process Monitoring Facilitated to a Bulk Handling Facility," S. Masuda, Nuclear Materials Control Center, et al. "Method of Material Balance by Estimation for Unmeasured Inventory in Process," Y. Sato, Nuclear Materials Control Center, et al.

Mr. Yousuke Nakae, Atomic Energy Commission of Japan.

Session 3: H. Okashita, Japan Atomic Energy Research Institute Chairman. "Development of Automated Analytical System for Input Solution Sample by Isotopic Dilution Method," M. Takahashi, Nuclear Materials Control Center, et al. "The Measurement Method for the Determination of Fissile Material Content in Solid Wastes from Reprocessing Plant," K. Mizushima, Mitsubishi Metal Corp., et al.

Session 4: M. Hirayama, Toshiba, Chairman. "Experience in Accounting and Management of Nuclear Material at the JAERI Plutonium Fuel Research Facility," J. Abe, Japan Atomic Energy Research Institute, et



Japan Chapter Meeting exhibits included a time line chart highlighting significant events in the Japan Chapter's progress and bar charts indicating its growth, both since its early organization.

al. "Achievement of Safeguards Application at Plutonium Conversion Development Facility," K. Ishikawa, Power Reactor Nuclear Fuel Development Corp., et al.

Session 5: S. Yamagami, Mitsubishi Metal Corp., Chairman. "Development of an Expert System for the Understanding of Evaluation Criteria for SIR," Y. Yokota, Nuclear Materials Control Center, et al. "A Simulation Study in Evaluating the Effectiveness of Safeguards System—Characteristic Analysis of a Diverted Centrifuge Cascade," T. Okamoto, Tokyo Univ., et al.

Session 6: H. Ihara, Japan Atomic Energy Research Institute Chairman. "On-line Computer Material Accountancy System of Plutonium Fuel Production Facility of PNC," H. Yamamoto, Power Reactor Nuclear Fuel Development Corp., et al. "Origin Control System of Nuclear Material at PNC Plutonium Fuel Facility," S. Inose, Power Reactor Nuclear Fuel Development Corp., et al.

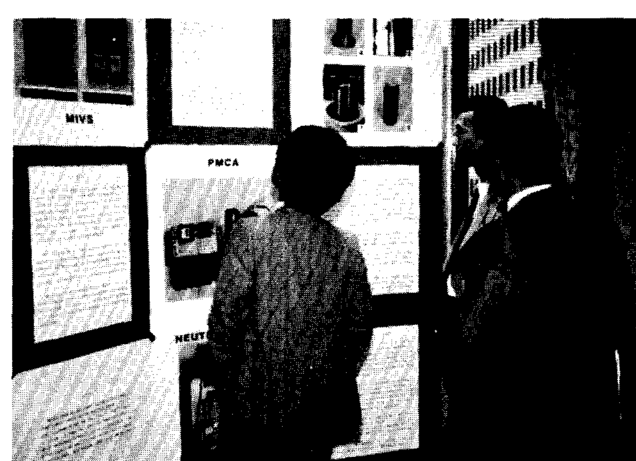
Session 7: K. Tsutsumi, Nippon Electronics Co., Ltd., Chairman. "Nuclear Fuel Cycle Evaluating System," T. Shimamura, Nuclear Policy Research Society. "Specific Features of Nuclear Materials Accountancy and Control for Nuclear Fuel Cycle Safety Research Engineering Facility," I. Takeshita, Japan Atomic Energy Research Institute.

Session 8: M. Kajiyoshi, Power Reactor Nuclear Fuel Development Corp., Chairman. "Development of the Ultrasonic Method for Identification of Spent Fuel Assemblies in JOYO Facility," Y. Fujita, Power Reactor Nuclear Fuel Development Corp. "Study of NCC Application to PWR Fuel Assemblies," K. Suzuki, Mitsubishi Nuclear Fuel Co., Ltd.

The Meeting also included an Exhibition and General Business Meeting. Mr. Roy Cardwell, INMM Member at Large and Constitution and Bylaws Committee Chairman was the invited speaker. Cardwell addressed "Current and Future Activity Interface Between the INMM and its Overseas Chapters." Also present at the meeting were Past President Charles Vaughan and INMM Member at Large Dennis Mangan. The financial report was presented by Y. Seki, Treasurer, and the chapter activities report was presented by Takeshi Osabe, Secretary. A banquet followed the business meeting.

Program Chairman Mr. Hiroyoshi Kurihara, Power Reactor Nuclear Fuel Development Corp.

Mr. Roy Cardwell, and Mr. Charles Vaughan present Japan Chapter Chairman Dr. Mitsuho Hirata with a plaque commemorating the Japan Chapter's 10-year Anniversary and its association with the Institute of Nuclear Materials Management.



The Japan Chapter 10th Annual Meeting included an exhibition of safeguards products and services.

Copies of the Proceedings of the 10th Annual Meeting of the Japan Chapter of the INMM are available from the Secretary of the Japan Chapter upon request.

Journal Translation Services

Abstracts of the JNMM papers and messages from the Journal technical editor and INMM Chairman have been and continue to be translated into Japanese and distributed to Japan Chapter members beginning with Vol. XVII, No. 1 (October 1988).

Membership

As of June 1989, the Japan Chapter had 145 members, increasing by 21 since September 1988. Members are from the following organizations:

Industry 70
Scientific Institutions 59
Universities 6
Government 5
Electric Utilities 4
Media 1

N14 Committee

The annual N14 Committee meeting was held June 11, 1989 in Washington, D.C., prior to PATRAM.

Seven new members were approved by letter ballot.

Joseph Stiegler, Sandia National Laboratories, is chairing an Ad Hoc Committee to review the negative ballots received on the scope change proposed to include non-nuclear hazardous materials or waste only. The Committee procedure will be to (1) expand knowledge base; (2) survey the field for what is happening with other groups; (3) identify needs or areas for N14 contribution; and (4) add more expertise to the committees.

Dr. Shin Park, Oak Ridge Gaseous

Diffusion Plant, is chairing a committee organized to develop a computer code for thermal evaluation of UF_6 cylinders.

Revisions to the N14 Procedures Manual were mailed to manual recipients. An additional 50 manuals were prepared, making a total of 150.

A Writing Group chairperson is needed for a proposed standard N14.26 "Inspection and Preventative Maintenance of Packaging for Radioactive Materials." Anyone interested should contact INMM or N14 Chair.

Specific Standard Highlights

N14.1 *Packaging of Uranium Hexafloride for Transport*

Suggested changes for a proposed addendum have been submitted for N14 Committee balloting.

N14.2 *Tiedowns for Transport of Fissile and Radioactive Containers Greater Than One-Ton Truck Transport*

Dr. Robert E. Glass, Sandia National Laboratories, has agreed to chair the Writing Group and work on this proposed standard is continuing.

N14.7 *Guide to the Design and Use of Shipping Packages for Type A Quantities of Radioactive Materials* Work on this draft is continuing.

N14.23 *Design Basis for Resistance to Shock and Vibration of Radioactive Materials Packages Greater than One Ton in Truck Transport*

Work on this draft is continuing.

N14.30 *Design, Fabrication and Maintenance of Semi-Trailers Employed in the Transport of Weight-Concentrated Radioactive Loads* The N14 Committee closed the balloting of the proposed standard on February 15, 1990.

Fifty specialists from the United States, Canada, England, and France attended the second INMM workshop, "The Use of Computers in Security" held in Oak Ridge, Tennessee April 3 and 4, 1989.

The program featured keynote speaker Mike Seaton, President of Risk Reduction Consultants, who discussed "Access Control Ineffectiveness," and a plenary session of three demonstrations. Jayne Ward of SNLA presented SENLEX, a system been developed to automatically place intrusion detection sensors for physical security systems; Paul Stoudenmire, EG&G Energy Measurements, presented TADD, a computer-based decision making system for tactical field commanders in threat scenarios; and Therese Renis, LANL, presented the new ACCESS analytic system for evaluating safeguards and security in place in a facility. The latter has been developed to replace the current SAVVI and ET systems.

Sixteen workshop sessions were held during the two day meeting which included overview of new equipment and technology; image processing, recognition, and enhancement; robotics; microprocessor sensor controls; graphics; record keeping and report generation; artificial intelligence; analysis programs, smart sensor technology; and computer security.

Jayne Ward, Plenary Speaker, Sandia National laboratories, Albuquerque, New Mexico, U.S.A. and Wayne Morrison, Conference Co-Chair, Martin Marietta Energy Systems, Oak Ridge, Tennessee, U.S.A.

New Trends in Safeguards Measurement Technology[a,b]

E.A. Hakkila
Safeguards System Group
Los Alamos National Laboratory
Los Alamos, New Mexico, U.S.A.

ABSTRACT

Safeguards measurement technology in the past has concentrated on improving precision and accuracy, including making available better standards and applying measurements to an ever increasing variety of materials. These will continue to play an important part in the future. However, other forces also will drive the skills of the measurement technologist. Process changes including larger facilities with higher throughputs, more automation of facility operation, and proposed changes in nuclear materials accounting techniques, such as near-real-time accounting, will impact safeguards measurement development.

Larger plant throughputs, health and safety, and waste management requirements will influence development of in- or at-line measurement procedures, often to flowing solutions. Both nondestructive assay and conventional analytical methods are being applied to meet these new challenges.

I. WHAT DRIVES IMPROVEMENTS IN MEASUREMENT TECHNOLOGY

Improvements in safeguards measurement technology in the past have concentrated on improving precision and accuracy, including making available better standards, and on applying measurements to an ever increasing variety of materials. These considerations will continue to be important in the future, but other forces will drive the measurement technologists. Changes in process operations and new plant designs, often driven by health and safety considerations, will make material less accessible for measurement. Larger plants with greater throughput and increased inventory will require more frequent measurements, often with demands for increased precision and accuracy and requirements for reduced waste volumes.[1] Increased use of automation and robotics for process control and operation will make material even more difficult to access.

Changes in nuclear materials accounting practices will increase measurement demand. Techniques such as near-real-time accounting, process monitoring, and running book inventory will require more frequent measurements, often in process streams with less time for sampling and laboratory analysis. Measurements must be performed *in situ*, often in a harsh environment for instruments.

This paper will attempt to review some of the techniques that are being studied and that could be incorporated into future measurement schemes. It is not intended to be a comprehensive review of measurement technology.

II. FUTURE TRENDS IN MEASUREMENT TECHNOLOGY

A. Physical Methods

Physical measurement methods (for example, weight, density, conductivity, temperature) have been an important part of process control. They are becoming more and more attractive for safeguards as the demand for more rapid and less intrusive methods increase.

1. Density. In-tank bubbler density probes can be used for rapid in-line determination of uranium and plutonium concentrations. Using electromanometers, precision of 1-5% relative (1σ) can be obtained, depending on how accurately the density can be converted to concentration. Off-line laboratory densimeters can provide precision to better than 1%. The uranium concentration in fuel of known burnup agrees to better than 0.23% relative to Davies-Gray titration.[1] Work in improving the density to concentration conversion is being performed in many areas (see, for example, Ref. 2).

Density probes in pulsed columns can be used to determine heavy element concentration without sampling, provided the aqueous to organic feed ratio and acid concentration are known.[3]

2. Weight. The quantity of liquid in tanks normally is determined by volume measurement. This requires careful tank calibration and recalibration and is subject to effects such as temperature, tank buckling, and tank internals. Recent work at Dounreay has shown that with proper design to isolate tanks from other process equipment, weighing using load cells can provide a rapid, accurate measure of liquid contents. This type of system is being installed for input and product accountability tanks at the new Thorp reprocessing plant.

A novel use of mass measurement for in-line measurement of concentration is being developed at Los Alamos.[4] A chelating agent specifically sensitive to actinides is incorporated on the surface of a mass sensitive device such as an acoustic wave device or a quartz microbalance. The absorption reaction is reversible and therefore sensitive to concentration.

B. Nondestructive Assay (NDA)

Over the past 15 years, much of the improvement in increasing speed of analysis by permitting measurements in-line has come about from the improvements in NDA. Techniques include gamma-ray spectrometry, neutron assay using active or passive methods, absorption-edge densitometry, and calorimetry.

1. Gamma-Ray Spectrometry. Measurement of fissile materials from their unique gamma-ray signatures has become standard in the nuclear industry. A novel application that would permit on-site verification of input accountability samples in reprocessing plants is being investigated jointly by the U.S. and Japan. The technique is known as isotope dilution gamma-ray spectroscopy (IDGS).[5] A portion of the solution is spiked with a known amount of plutonium (^{239}Pu or ^{244}Pu can be used). Unspiked and spiked samples are absorbed onto resin beads to separate plutonium from uranium and fission products. The beads are analyzed for plutonium isotopes using low-energy gamma rays in the 40-150 keV region. The total plutonium can be related to plutonium concentration in the accountability tank. The principle of the method is similar to isotope dilution mass spectrometry but does not require the expensive equipment and can be performed by less skilled analysts. The method is under test and evaluation at the Tokai reprocessing plant in Japan.

2. Neutron Methods. Passive and active neutron assay have been applied for over 20 years to analysis of a variety of samples by NDA. Recently application of active neutron assay to flowing streams has been investigated in both the U.S. and France. In one application,[6] waste streams are monitored for ^{235}U with a flow rate of 80 L/hr. For concentrations of 0.356 g/L, a precision of 1.7% was reported with a sensitivity better than 0.02 g/L. The instrument is designed to run unattended for up to 3 months.

3. Absorption-Edge Densitometry/X-Ray Fluorescence. Absorption-edge densitometry has been used for almost 30 years for analysis of fissile solutions. Recent combination of the K-edge technique with x-ray fluorescence analysis has made this a primary means of analyzing input dissolver solutions for reprocessing plants, both for safeguards[7] and process control.[1] The method is attractive because it can be applied to uranium, plutonium, and other transuranics over a large concentration range (K-edge for high concentrations, x-ray fluorescence for low concentrations) and in the presence of high impurity concentrations including fission products, and it produces no waste streams.

A unique extension of K-edge densitometry involves the use of internally generated gamma rays for the measurements. This has been dubbed "the poor man's densitometer" because only a detector is needed for measurement.[8]

C. Chemical Methods for Analysis

Chemical methods have been used for safeguards primarily because, in general, they provide better accuracy and precision than NDA methods. They suffer from being time consuming; they require highly skilled analysts; and because of facility and national safety requirements, safeguards samples must be transported from the facility to the national or international safeguards laboratory.

Recent developments in applying analytical methods in- or at-line are making them more appealing for on-site safeguards use.

1. Electrometric Methods. For high precision assay of plutonium, potentiometric and coulometric methods are used, with coulometry preferred where waste generation is a problem.[1] Samples must be removed from the process.

Recently an in-line voltametric method has been developed for determining uranium and plutonium.[9] A gold-platinum electrode pair is operated by a computer-controlled potentiostat. The technique has been applied at Dounreay to flowing streams to measure plutonium. Detection sensitivity is 0.02 g/L. Uranium concentration varies between 30 and 200 g/L and HNO_3 concentration between 1 and 3 M without adversely affecting the measurement. Precision of 5% was reported but probably could be improved if the measurement is made in a static cell.

The near-real-time determination of uranium and plutonium using an in-line flowing coulometer has been reported.[10] The cell uses a carbon fiber working electrode and a platinum counter electrode with a flow rate between 0.2 and 1 ml/min. It has been used to monitor concentrations from pulsed columns.

2. Spectrophotometric Methods. Classical spectrophotometry requires removal of samples to the laboratory where chemical manipulations may be performed to stabilize the desired chromogenic species prior to measurement. With the introduction of fiber optics and chemical sensors, spectrophotometric measurements now can be performed on- or at-line. The general topic of chemical sensors based on fiber optics has been reviewed in numerous publications, for example, References 11-13.

The measurement of HNO_3 concentration in process streams is required for process control and for safeguards where plutonium concentration is determined by density or spectrophotometry. An acid sensor that operates in 1-9 M HNO_3 is being developed.[14] A suitable indicator such as chromazurol S is encapsulated in a suitable polymer such as polybenzimidazole polyimide. The technique is being tested in the presence of actinides.

The spectrophotometric measurement of the multiple valences of uranium and plutonium has been used in the laboratory for many years. The various spectrophotometric peaks are measured and concentrations determined by curve matching techniques. Using fiber optics, the technique has been applied on-line for process control at several reprocessing plants, for example, Reference 15-17.

An optical fiber laser spectrophotometer was developed for in-line measurement of the different oxidation states of uranium and plutonium.[18] Five different dyes are used to measure the five species: U(IV), U(VI), Pu(III), Pu(IV), and Pu(VI). Nitric acid is measured by electrical conductivity.

A novel variation on the technique was described recently to eliminate the use of the multiple dye lasers.[19] Three narrow-pass optical filters are used to measure three components simultaneously in-line. The precision is approximately 2-3% and has been applied in both organic and aqueous reprocessing plant streams.

3. *In-Line Fluorimetry for Uranium.* Fluorimetry has been the standard technique for many years for laboratory measurement of low concentrations of uranium. Using optrodes and a pulsed Nd:YAG laser, uranium is determined in flowing or static solution using fluorimetry.[20] The method is applicable in flowing solutions in the concentration range of 200 ppm to 10 g/L with a precision better than 10%. Concentrations in tanks can be determined to better than 1%.

4. *Laser Isotope Breakdown Spectroscopy.* In laser isotope breakdown spectroscopy, a laser is focused through a suitable window onto a flowing solution to produce a hot spark plasma. The technique has been demonstrated on flowing uranium solutions with concentrations between 0.1 and 300 g/L. The precision for measuring 10 g/L of uranium is 0.8% with a 3-min analysis time.[21] The technique is being investigated for plutonium.

5. *Improvements in Mass Spectroscopy.* Regardless of improvements in on-line or at-line NDA and chemical procedures, mass spectrometry will continue to be the method of choice for many safeguards applications, especially dissolver input solutions. No other methods can compete in providing quantitative information both on isotopic and total element concentration. Methods are being investigated for improving the quality of the measurement by improved filament preparation and through use of a metal spike.[22] This is a joint project between the EURATOM standards laboratory at Geel and the Los Alamos National Laboratory.

6. *Rapid Chemical Separations.* The use of ion exchange on resin beads was developed in the 70s as a rapid means of obtaining small samples of uranium and plutonium from dissolver solutions for mass spectrometric analysis.[23] As noted in Ref. 5, the resin bead separation is being applied to gamma-ray measurements. Other rapid techniques are being investigated for obtaining samples for destructive as well as NDA applications. High-speed ion exchange using vacuum extraction has been developed at Savannah River.[24]

High-pressure liquid chromatography has been developed at Chalk River[25,26] and Marcoulle.[1,27] The method could replace resin beads for obtaining samples from reprocessing input solutions and high-level wastes.

Los Alamos is investigating a separation using reverse phase liquid chromatography with alpha-hydroxisobutyric acid.[28]

III. DEVELOPMENT OF LARGE AUTOMATED FACILITIES/INTEGRATION OF PROCESS CONTROL AND SAFEGUARDS

The increased emphasis on reduction of operator radiation exposure as well as on tighter process control is resulting in changes in safeguards design philosophy. The safeguards system must be designed as an integral part of the facility, taking into consideration facility process control features. Process monitoring, for example, is being incorporated into most of the new large nuclear facilities under construction and is being retrofit into many of the older facilities.[29,30] In fact, many of the analytical and NDA techniques discussed in the previous section are being developed to provide near-real-time information for process control; safeguards systems designers must learn to apply measurement technology already in place or being developed. In some cases, this will require developing methods to authenticate operator instruments; in the ideal situation process designers and safeguards experts will work together to assure satisfactory dual use of instruments.

Two examples of the dual use philosophy are the new special recovery project at Savannah River and the new mixed oxide (MOX) fuel fabrication facility at Tokai.

The Savannah River system incorporates NDA and conventional process control technology to provide near-real-time process control and safeguards information.[31,32]

The Tokai system was developed jointly by the facility operator, the IAEA, and the instrument developers. Because the facility is completely automated to eliminate human contact with nuclear material, all instruments are designed to operate automatically in unattended mode. The system design was the topic of a special session at the 1989 national meeting of the Institute of Nuclear Materials Management.[33-41]

Even in instances where the complete system is not automated, there is pressure to automate individual operations that are dangerous for the operator. Such an example is the development of robotic systems to prepare samples for mass spectrometric analysis of reprocessing plant input solutions.[42,43]

IV. SUMMARY

Safeguards measurement requirements are changing to emphasize more rapid measurements, preferably with minimal sample manipulation and human contact. Emphasis in the past on rapid measurements has been left to NDA experts. Of course, NDA will continue to play an important role because of the inobtrusiveness as well as the speed of the measurements. However, with new innovations in chemical analysis, there is more and more development to apply technology that once was considered "bench top" chemistry directly in- or at-line. This is being done with little sacrifice in precision and accuracy on the part of the measurement technologist.

[a] This paper is based on an Invited Lecture at the Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology, Karlsruhe, FRG, June 5-9, 1989.

[b] This work supported the U.S. Department of Energy, Office of Safeguards and Security.

REFERENCES

1. R. Schott, "Analytical Methods without Waste?" in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Invited Lecture.
2. S. Sakurai and S. Tachimori, "Modified Density Equation for Aqueous Solutions with Plutonium(IV), Uranium(VI), and Nitric Acid," Japan Atomic Energy Research Institute publication JAERI-M-88-127 (June 1988).
3. M.H. Ehinger, "Operating Experience with Pulsed Column Holdup Estimators," in *Nuclear Safeguards Technology 1986* (International Atomic Energy Agency, Vienna, 1987), Vol. I, pp. 139-149.
4. W.P. Carey, V.T. Hamilton, P. Mendoza, L.E. Wangen, W.H. Smith, B.S. Jorgensen, G. Jarvinen, and P. Smith, "Chemical Sensors," in Los Alamos National Laboratory Chemistry Division Annual Report (1988).
5. T.K. Li, "Feasibility Study of Plutonium Isotopic Analysis of Resin Beads by Nondestructive Gamma Ray Spectrometry," *Proc. Seventh Annual Symposium on Safeguards and Nuclear Material Management*, Liege, Belgium, May 21-23, 1985 (European Safeguards Research and Development Association, 1985), ESARDA 19, pp. 245-248.
6. P.M. Rinard, T.W. Crane, T. Van Lyssel, K.E. Kroncke, C.M. Schneider, and S.C. Bourret, "A Delayed Neutron Monitor for a Liquid Waste Stream with High Gamma-Ray Intensity," to be presented at the American Nuclear Society Topical Meeting on Nuclear Criticality Safety Margins, San Francisco, California, November 26-30, 1989.
7. H. Ottmar, H. Eberle, L. Koch, R. DeMeester, and E. Kuhn, "Field Demonstrations of an X-Ray Densitometer for Uranium and Plutonium Input Verification in Reprocessing," in *Nuclear Safeguards Technology 1986* (International Atomic Energy Agency, Vienna, 1987), Vol. I, pp. 201-211.
8. S.T. Hsue, "Novel Methods to Determine Plutonium Concentration," in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Abstract 57.
9. D.C.J. Skea and E. MacKay, "A Voltametric System for In-Line Heavy Metal Measurements in Nuclear Fuel Reprocessing Plants—Development and Operational Experience," in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Abstract 70.
10. S. Saitoh, N. Hayashi, Y. Wada, and Y. Ohuchi, "Development of Pu and U Ion Concentration Analysis System Using In-Line Flow Coulometer," in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Abstract 93.
11. W.R. Seitz, "Chemical Sensors Based on Fiber Optics," Anal. Chem. *56*(1), 16A-34A (1984).
12. J. Janata and A. Bezegh, "Chemical Sensors," Anal. Chem. *60*, 62R-74R (1988).
13. G. Boisde, F. Blanc, and J.J. Perez, "Chemical Measurements with Optical Fibers for Process Control," Talanta *35*, 75-82 (1988).
14. W.P. Carey, B.S. Jorgensen, and M.D. DeGrandpre, "An Evanescent Field Sensor Design Based on Immobilized Indicators for High Acidities," submitted to Anal. Chem.
15. C.N.N. MacKay, C.L. Mills, and T.W. Kyffin, "On-Line Fiber-Optic Spectrophotometry in a Plutonium Pulsed Column Pilot Plant," in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Abstract 74.
16. D.R. Van Hare, P.E. O'Rourke, and W.S. Prather, "Applications of Fiber-Optic Spectrophotometry at the Savannah River Plant," in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Abstract 91.
17. D.L. Baldwin and R.W. Stromatt, "Plutonium, Uranium, Nitrate Measurements in Purex Process Streams by Remote Fiber Optic Diode Array Spectrophotometry," presented at the 1987 Plutonium/Uranium Recovery Operations Conference, Kennewick, Washington, October 15, 1987; Pacific Northwest Laboratory report PNL-SA-15318.
18. B. Schlosser, "An Optical-Fibre Laser Spectrophotometer for On-Line Measurements," Analytica Chim. Acta *190*, 265-269 (1986).
19. J. Burck, K. Kramer, and W. Konig, "Fiber Optic Modification of the Process Monitor SPECTRAN for In-Line Measurements in Nuclear Fuel Reprocessing," in "Second Karlsruhe International Conference on Analytical Chemistry in Nuclear Technology: Abstracts," Kernforschungszentrum Karlsruhe report (1989), Abstract 95.
20. R.A. Malstrom, "Uranium Analysis by Remote Fiber Fluorimetry," Savannah River Laboratory report DP-1737 (June 1988).
21. R.G. Gutmacher, D.A. Cremers, and J.R. Wachter, "Continuous Measurement of Uranium Concentrations with the Laser Spark," *Proc. Third International Conference on Facility Operations—Safeguards Interface (American Nuclear Society, Inc., La Grange Park, Illinois, 1988), pp. 141-143.*
22. R. Perrin, "Preparation of Mass Spectrometry Filaments for Interlaboratory Evaluation," in *Los Alamos Safeguards and Security R&D Program Bimonthly Management Report for April/May 1989*, Los Alamos National Laboratory memorandum N-DO/SG-89:93 (June 8, 1989).
23. J.A. Carter, R.L. Walker, R.E. Eby, and C.A. Pritchard, "A Simplified Method for Preparing Micro-Samples for the Simultaneous Isotopic Analysis of Uranium and Plutonium," in *Safeguarding Nuclear Materials, Proceedings of a Symposium* (International Atomic Energy Agency, Vienna, 1976), Vol. II, pp. 461-469.
24. S.L. Maxwell, III, "High Speed Ion Exchange Techniques for Neptunium, Plutonium, and Uranium Impurity Assays," presented at the 12th Actinide Separations Conference, Naperville, Illinois, May 8-11, 1988.
25. C.H. Knight, R.M. Cassidy, B.M. Recoskie, and L.W. Green, "Dynamic Ion Exchange Chromatography for Determination of Number of Fissions in Thorium-Uranium Dioxide Fuels," Anal. Chem. *56*, 474-478 (1984).
26. R.M. Cassidy, S. Elchuk, N.L. Elliot, L.W. Green, C.H. Knight, and B.M. Recoskie, "Dynamic Ion Exchange Chromatography for the Determination of the Number of Fissions in Uranium Dioxide Fuels," Anal. Chem. *58*, 1181-1186 (1986).
27. J.P. Muller, J. Cojean, and A. Deloge, "Détermination de l'uranium dans les solutions de retraitment des combustibles irradies par chromatagrophie en phase liquide," Analusis *15*, 209-216 (1987).
28. "Rapid Separation of U and Pu in Dissolver Solutions," in "Los Alamos Safeguards and Security R&D Program Bimonthly Management Report for June/July 1989," Los Alamos National Laboratory memorandum N-DO/SG-89:108 (August 14, 1989).
29. C.A. Dahl and N.A. Liester, "The Idaho Chemical Processing Plant Process Monitoring Computer System," in *Proc. Third International Conference on Facility Operations—Safeguards Interface* (American Nuclear Society, Inc., La Grange Park, Illinois, 1988), pp. 263-269.

30. M.H. Ehinger, "Process Monitoring in International Safeguards Plants—a Demonstration," Oak Ridge National Laboratory report ORNL/TM-10912, ISPO-253 (January 1989).
31. M.P. Baker, "An Integrated Nondestructive Assay System for a New Plutonium Scrap Recovery Facility," Trans. Am. Nucl. Soc. *50*, 167 (1985).
32. A.L. Baker, "Integration of NDA Instruments into a Savannah River Plant Computer Network," Trans. Am. Nucl. Soc. *50*, 171 (1985).
33. T. Ohtani, K. Kono, H. Kaneko, S. Kashima, M. Seya, and S. Takahashi, "An Introduction to the Automated MOX Facility, PFPF," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
34. M. Seya, T. Ohtani, S. Takahashi, Y. Yamamoto, and S. Inose, "A Fully Computerized Material Accountancy System," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
35. M. Seya, S. Takahashi, K. Matsuyama, T. Asano, A. Ohkubo, T. Fujimoto, K. Nomura, and J. Ishii, "Advanced C/S Systems for the Feed and Product Storage Areas of the PFPF," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
36. C.S. Johnson, D.D. Drayer, C.S. Sonnier, T. Ohtani, M. Seya, and S. Takahashi, "Authentication Equipment for the Advanced C/S Systems," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
37. S.F. Klosterbuer, E.A. Kern, J.A. Painter, and S. Takahashi, "Unattended Mode Operation of Specialized NDA Systems," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
38. H.O. Menlove, R.H. Augustson, T. Ohtani, M. Seya, S. Takahashi, R. Abedin-Zadeh, B. Hassan, and S. Napoli, "Remote-Controlled NDA System for Feed and Product Storage at an Automated MOX Facility," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
39. M.C. Miller, H.O. Menlove, R.H. Augustson, T. Ohtani, M. Seya, S. Takahashi, and R. Abedin-Zadeh, "Remote-Controlled NDA Systems for Process Areas in a MOX Facility," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
40. M. Seya, T. Ohtani, and S. Takahashi, "A Consideration of Safeguards Equipment from an Operator's Viewpoint," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
41. M. Zendel, "How to Safeguard Automated Bulk Handling Facilities," presented at the 30th Annual Meeting of the Institute of Nuclear Materials Management, Orlando, Florida, July 9-12, 1989 (to be published in proceedings).
42. L. Koch, "New Concept for Reprocessing Input Verification," *Proc. Third International Conference on Facility Operations—Safeguards Interface* (American Nuclear Society, Inc., La Grange Park, Illinois, 1988), pp. 153-156.
43. M. Takahashi, Y. Kato, S. Uchikoshi, T. Hatakenaka, K. Yasu, and S. Nomura, "Development of Automated Analytical System for Input Solution Sample by Isotope Dilution Method," in *Proc. Eleventh Annual Symposium on Safeguards and Nuclear Material Management*, Luxembourg, May 30-June 1, 1989 (European Safeguards Research and Development Association, 1989), ESARDA 22, pp. 529-533.

Arnold Hakkila received a Ph.D. in analytical chemistry from Ohio State University in 1957. He participated in research and development in x-ray spectroscopy, analytical chemistry of actinides, and electron and ion microprobe analysis at Los Alamos until 1976 when he joined the Nuclear Safeguards Program. He now serves as Program Coordinator for International Safeguards.

Aiming at Better Physical Protection: Physical Protection in Japan

Kenji Seyama
Science and Technology Agency
Japan

Hiromasa Nakano and Mitsuaki Kajiyoshi
Power Reactor and Nuclear Fuel Development Corporation (PNC)
Japan

ABSTRACT

Japan became affiliated with the Convention on the Physical Protection of Nuclear Material on November 27, 1988. Prior to that time and during most of 1988, much work was done to create the domestic laws and regulations necessary to conform with the Convention. On May 26, 1989 Japan began enforcing the last of the regulations associated with physical protection.

The paper describes the necessity for and the status of nuclear energy in Japan, explains the process by which Japan revised its laws and regulations to conform to the Convention, and outlines the Japanese way of thinking with regard to physical protection in view of Japanese society and its history.

I. INTRODUCTION

Nuclear energy is, as it were, a sword with double edges; nuclear non-proliferation on one hand and peaceful utilization of nuclear energy on the other, or peaceful utilization on one hand and safety assurance on the other. All of these factors must be seriously taken into account if the human race wants to derive great benefit from nuclear energy. These problems are becoming more and more important because nuclear energy has been developed and utilized for the past half century and thereby has become deeply rooted in our society and economy. We must discuss in depth the problem of how to develop and utilize nuclear energy while avoiding potential hazards, and, at the same time, take necessary measures to realize the benefits.

Physical protection is considered to be an extremely important measure associated with nuclear non-proliferation and safety. Unauthorized diversion of nuclear materials by some specific groups may lead to the manufacture of nuclear bombs, whereas sabotage against nuclear materials and nuclear facilities could result in the unplanned release of large amounts of radioactive materials. It was natural that the then Secretary of State Kissinger called for the necessity of international framework related to physical protection in the 29th United Nation General Assembly held in 1974, and his recommendations were undoubtedly supported by many nations because of the terrorism occurring in many parts of the world in the 1970s.

Even though the possibility of theft or sabotage of nuclear materials is extremely small, appropriate physical protection measures must be taken, taking into account the terrible consequences if it actually occurs.

The social situation in Japan is stable at present. Although the antinuclear movements have been activated, they do not require any special action on physical protection measures. Aversion of the Japanese to nuclear bombs and radiation is extremely great, so the intentional misuse of nuclear materials will undoubtedly incur a strong reaction.

Japan is in a fairly good situation regarding physical protection from a domestic point of view. However, the factors which may give rise to troubles must be avoided as far as is possible, and even though the social situation in Japan is stable, high-level physical protection measures should still be taken.

The year 1988 was very important for Japan's physical protection, and many concrete measures were taken. In this paper these measures are described together with the history and features of physical protection in Japan.

2. HISTORY

The concept of physical protection of nuclear material was established in the mid 1970s after its necessity was recognized clearly. In the first half of the 1970s, work proceeded on the preparation of the recommendations of the International Atomic Energy Agency (IAEA) on physical protection by IAEA and in the United States laws and regulations were enacted on it. In Japan, the amounts of nuclear materials to be used, plutonium in particular, were expected to increase as peaceful utilization of nuclear energy made progress.

In 1976 the Atomic Energy Commission of Japan, which has a leading role in setting domestic nuclear energy policy, established the Advisory Committee on Physical Protection to consider physical protection matters.

The Advisory Committee members consisted of experts from the Science and Technology Agency, the Ministry of International Trade and Industry, the Ministry of Transport, the National Police Agency and the Maritime Safety Agency as well as nuclear-energy-related specialists including nuclear safety specialists. In the period 1976 to 1980 the

Advisory Committee studied physical protection as it ought to be in Japan and identified concrete measures to be taken. Upon investigation, the IAEA's recommendation on physical protection (INFCIRC 225 Rev. 1) published in June 1977 was used as the basic document, together with physical-protection-related documents made public in foreign countries—especially U.S. regulation (10 CFR Part 73)—for reference. The Advisory Committee prepared the first report in 1977 and the final report in June 1980, respectively, and promptly reported them to the Atomic Energy Commission of Japan. The report describes Japan's views on physical protection as follows:

(1) Systematic preparation of a physical protection system is extremely important in order to achieve Japan's principle that the application of nuclear energy should be limited to peaceful uses and the safety of the public should be maintained at any cost.
(2) The international efforts regarding physical protection must be fully taken into account. At the same time, since Japan must rely on foreign countries for most of its nuclear fuels, concerted efforts to improve physical protection systems enhance its ability to meet international obligations.

Based on the above understanding, the report did the following: i) recommended the roles to be played by the regulatory authorities, security authorities and industries; ii) requested close cooperation between these organizations; iii) pointed out the roles and significance of emergency response programs; iv) indicated the necessity for R & D and of the establishment of control and regulatory systems; and v) showed physical protection requirements for nuclear facilities and for nuclear material transport. Based on the report, the Atomic Energy Commission of Japan established the following policies in March 1981:

(1) The relevant government authorities should promote physical protection measures according to the above guideline.
(2) The relevant government authorities should create the physical protection system including laws and regulations.
(3) Necessary measures should be investigated in preparation for the ratification of the Physical Protection Convention.

From the mid 1970s until 1981, although the framework of a legal system was not yet established, physical protection measures equivalent to the international level were substantially taken under the powerful initiative of the Atomic Energy Commission of Japan.

The Physical Protection Convention was opened for signature to the countries interested in March 1980. Japan immediately started an investigation on how to complete the required domestic laws and regulations to join the Convention. The investigation included interpretation of the Convention, survey of domestic laws and regulations of the major countries and needed modifications to Japan's domestic laws and regulations. The major legal problem lay in some penal clauses, which have not been provided in Japanese laws, for example, punishment in Japan concerning crimes by the Japanese committed outside of Japan, making it a crime for persons to threaten the safety of the public by using nuclear materials.

An additional problem was the concern that better physical protection measures may require tighter information control, leading to some extent to an inconsistency in Japan's three principles for peaceful uses of nuclear energy: self-sufficiency, democratic application (with input from all people concerned) and openness of results, especially the latter.

In other words, the major sociopolitical problem was to solve the concern about the relationship between the principle of openness of results and information control, or about increasing police control as the result of increasing development and utilization of nuclear energy.

In February 1987, the Physical Protection Convention was ratified by Switzerland, the 21st country, and became effective. Recognizing in depth the significance of the realization of the Physical Protection Convention, Japan accelerated the investigation of the domestic laws and regulations necessary for ratification. It was decided that the new clauses of the domestic laws and regulations should include, not only those of international transport of nuclear materials necessary for the ratification of the Convention, but also those of physical protection measures for nuclear facilities; The clauses should be incorporated into the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors, which comprehensively control nuclear industries and facilities. The resultant revisions were submitted to the regular session of the Diet beginning in December 1987. Further, the bill for approval of the Physical Protection Convention was submitted to the same regular session of Diet. In May 1988, the revision of the Law was approved and the approval for the Convention was agreed. The physical protection measures for the transport of nuclear materials and those for nuclear facilities began to be enforced in November 1988, and in May 1989, respectively. Prior to these dates, the Orders of Prime Minister's Office, of the Ministry of International Trade and Industry and of the Ministry of Transport had been completed in succession. As a result, the physical protection measures were established visibly and substantially in Japan. It became possible therefore to take physical protection measures, based on the laws and regulations provided by the regulatory authorities such as the Science and Technology Agency, the Ministry of International Trade and Industry and the Ministry of Transport as well as by security authorities such as the National Police Agency and the Maritime Safety Agency. Accordingly, better physical protection measures were now requirements upon the nuclear industries.

Before the laws and regulations were enforced, physical protection of Japan had met the IAEA's guideline, and had been relatively strict in comparison with international levels. In fact, no incidents have occurred, other than mischievous telephone calls. Two reasons can be pointed out for this: First, Japan was committed to assuring the safety of nuclear facilities due to specially sensitive feelings of the Japanese for nuclear energy and radiation. In other words, safety assurance was the supreme order, therefore great attention was paid to access control, and maintenance and management of physical-protection-related facilities and equipment. Second, the working discipline in Japanese industries, including nuclear ones, is high and the employee's morale is excellent.

Japan has just finished completing the legal system regarding physical protection. To make the physical protection system more effective additional measures will be taken in the future, if necessary, taking into account changes of social and political situation and experience gained.

3. NUCLEAR POLICY

3.1 Nuclear Energy for a Prosperous Future

It goes without saying that energy provides an indispensable basis for the modern society and economy. Indeed, energy demand has increased day by day as the society and economy has advanced, except for world recessions that occurred twice due to "oil shocks". Stable energy assurance, therefore, is a common concern of every country in the world.

In the first place, conventional fossil energy resources such as petroleum, coal and natural gas are unevenly distributed on the earth. The petroleum resource, in particular, is limited and its supply tends to depend on international policies, resulting in continual instability for ensuring its supply. We have often experienced international friction or tensions over the supply of fossil energy resources.

Nuclear energy, on the other hand, can be produced by integrating a variety of advanced technologies, and can provide a path to solve the problem of stable energy supply. At present, economic security, especially the important component element, "energy security", should not be considered from the viewpoint of only one country. Nuclear energy is, as it were, a precious intellectual resource of the human race than can contribute to peace and to the enhancement of international cooperation.

Meanwhile, sufficient attention must be given to the relationship between energy and environmental problems. Combustion of fossil fuels produces a great amount of carbon dioxide, which builds up in the atmosphere, thereby causing a rise in worldwide temperature, i.e. the greenhouse effect. Combustion of the fossil fuel resources also produces nitrogen oxides and sulfides, resulting in acid rain. Nuclear energy exerts little effect on the atmosphere, and thereby can play an important role in solving the worldwide environmental problems.

According to the results of a survey carried out by OECD recently, energy consumption in developing countries has expanded. In these countries, immediate introduction of advanced technology such as nuclear energy is extremely difficult, resulting in inevitable reliance on petroleum and coal. From this standpoint, promotion of nuclear-energy utilization may be an obligation of advanced countries. Promotion of nuclear-energy utilization, moreover, is essential for using fossil fuel resources for other applications with higher added values.

Unlike countries with large amounts of domestic energy resources, Japan has no option but to apply advanced technology and utilize nuclear energy as the basic energy source. In particular, it is indispensable for Japan to establish a policy to close the fuel cycle and utilize fast breeder reactors which can convert uranium-238, accounting for 99.3% of natural uranium, into plutonium.

3.2 Major Premises for Promoting Nuclear Energy Utilization

Japan has two major premises for promoting utilization of nuclear energy; "peaceful utilization only" and "safety assurance."

Since Japan is the one country in the world that has suffered from the nuclear bombs exploded in Hiroshima and Nagasaki in August 1945, her desire for the complete abolition of nuclear weapons is stronger than that of any other country in the world. From this viewpoint, Japan has played an active role in maintaining and enhancing the nuclear non-proliferation regime by joining the "Treaty on the Nonproliferation of Nuclear Weapons (NPT)" and specifying in the Atomic Energy Act that domestic research, development and utilization of nuclear energy shall be promoted only for peaceful uses in accordance with the principles of self-sufficiency, democratic application and openness of results. Further, Japan follows the three non-nuclear principles, that it shall not possess, manufacture and let other countries bring in her territory nuclear weapons; adhering to the principles of the peaceful uses of nuclear energy has become a national consensus of Japan.

Meanwhile, Japan has promoted her development and utilization of nuclear energy on the basis of the basic guideline" ... by assuring safety" as specified in the Atomic Energy Act from the viewpoint that development and utilization of nuclear energy cannot be attained without safety assurance. Nuclear energy can be produced by integrating highly advanced technologies, which also play an important role in safety assurance. So far, no radioactive materials affecting the nearby public have been released in Japan. This fact verifies that safety of nuclear energy can be basically assured, when safety assurance measures are supported by highly advanced technology and adequate management.

Under the major premises described above, the significance of physical protection measures which prevent theft of nuclear materials and of sabotage against nuclear facilities with nuclear materials has been fully recognized, together with that of nuclear safeguards which verify nondiversion of nuclear materials to nuclear weapons. Continuous efforts should be made for further keeping physical protection measures highly effective.

4. REGULATIONS ON PHYSICAL PROTECTION OF NUCLEAR MATERIAL

As already explained in Section 2, in the period from 1988 to 1989, laws and government ordinances (Prime Minister's Office Ordinances and Ministerial Ordinances) for physical protection have been revised. The physical protection has thus changed from voluntary efforts of industry to requirements based on the laws and regulations. Technical standards of physical protection in Japan are essentially based on the IAEA's guidelines as well as guidelines included in the report by the Advisory Committee on Physical Protection of the Atomic Energy Commission. In addition to these technical standards, however, the industries handling nuclear materials are requested by law to prepare and submit to the authorities their physical protection rules and to assign a physical protection manager for each facility. By this practice, if the physical protection measures required by law are violated by the nuclear industry, the Government can issue remedial orders. Further, depending on the degree of this violation, penal regulations may be applied. Therefore, by such means, efforts are made to upgrade the quality of physical protection and to carry out the practice in Japan to perfection.

Following is a brief description of the revisions to laws and regulations.

(1) Technical Standards of Nuclear Material Protection

Industries handling nuclear materials must take appropriate measures for physical protection. Details are described clearly in the regulations. The technical standards required when using or storing nuclear materials are as follows:

1) A protection area should be established. (In the area of class 1 the area is doubly enclosed.)
2) Boundaries of a protected area should be provided with a barrier such as a fence. (Excluding the facilities of class III, the barrier is required to be of a firm structure like reinforced concrete.)
3) The persons having access to protected areas should be limited to those who need this access and to those who are reliable.
4) The articles etc. carried in and out of a protected area should be checked.
5) The protected area should be patrolled and watched by guards.
6) Information on the physical protection should be adequately controlled.
7) An emergency plan should be prepared.

In addition, technical standards required in transporting nuclear material are as follows:

1) The plans of transport should be determined.
2) A person responsible for physical protection and necessary guards should attend the transport.
3) Information on the physical protection should be suitably managed.
4) An emergency plan should be prepared.

(2) Rules of Physical Protection

An industry handling nuclear materials in its facility must prepare rules of physical protection describing measures of physical protection based on features of the particular nuclear facility. And these rules must then be approved by the Government. Beyond the application of technical standards as described in (1) above, for physical protection measures to be effective, it is necessary to establish protective measures on an individual basis according to characteristics of the particular nuclear facility. Nuclear facilities differ in their location, size and construction and moreover in type, quantity and properties of nuclear material in them and the handling methods. Therefore, these items must be reflected in the measures of physical protection actually adopted.

(3) Physical Protection Manager

Any industry handling nuclear materials in its facility must designate a physical protection manager meeting the following requirements:

1) A person capable of managing comprehensively the work of physical protection.
2) A person possessing general technical knowledge of nuclear material handling, and
3) A person possessing general knowledge of physical protection.

The designation of the manager must be reported to the Government.

In order to carry out physical protection with assurance and conduct the works rapidly and accurately during an emergency, the responsibility must be defined clearly and those concerned must possess a firm understanding of physical protection. For this purpose, it is necessary to maintain an organization for physical protection and to designate a responsible person for the physical protection. That is to say, the physical protection manager plays a role of the so-to-speak "commander" for physical protection.

(4) Arrangements for Physical Protection

When nuclear material is to be transported, arrangements must be made among those concerned regarding the date and time when the responsibility for its transport is turned over to other persons, and the means of transport. The shipper of nuclear material (in the case of its import, the recipient), therefore, prior to the start of its transport, must confirm with the Government that the arrangement has already been made. Clear definition of the responsibility for nuclear material transport is important. The concepts of the Convention on Physical Protection, which requires the confirmation of this responsibility, will thus be respected.

(5) Penal Regulations

Offenses involving nuclear materials, once such action takes place, greatly influence negatively all of society and thus impact adversely the development and utilization of nuclear energy. Therefore, the Convention on the Physical Protection has as its requirement the punishment of such criminals. The revisions provide for offenses not covered by ordinary Japanese criminal law. Accordingly, the following persons are to be severely punished:

a) A person handling illegally nuclear material and thereby endangering human life or body.
b) A person threatening human life or body by means of nuclear material.
c) A person forcing certain acts via stealing or taking nuclear materials.
d) A person committing the above offenses overseas (excluding the cases where a non-treaty national commits an offense in a non-treaty country).

(6) Roles of Government Authorities and Cooperation

In order to carry out the physical protection effectively, it is important to define clearly the respective roles for industry and Government, the roles within the Government and the means to maintain consolidated cooperation among them. Therefore, the responsibilities of Government authorities are defined by law, as follows:

a) The Science and Technology Agency is responsible for such nuclear fuel cycle facilities as fuel fabrication and reprocessing, for research and test reactors and for research and test facilities.
b) The Ministry of International Trade and Industry is responsible for commercialized nuclear power plants.
c) The Ministry of Transport is responsible for nuclear merchant ships. It must consult with National Public Safety Commission or Maritime Safety Agency when enforcing its responsibility.
d) The Science and Technology Agency or the Ministry of Transport is responsible for the regulations of transport containers of nuclear material.
e) The Ministry of Transport is responsible for the regulations of the means of transport.
f) The Local Public Safety Commission or Regional Maritime Safety Headquarters is responsible for the control of the date and time of transport, the transport route, etc.

In industry, for both nuclear material use and nuclear material transport, controls on physical protection are applied in such a way that in an emergency, security agencies can take necessary steps immediately.

Laws and regulations requiring such controls described above are already in force so that the system of physical protection in Japan would be generally recognized to be adequate, both domestically and internationally. However, considering the fact that in April this year a meeting of the IAEA's technical committee on physical protection was held in order to review INFCIRC/225/REV. 1, and further in 1992 a conference will be held to review the Physical Protection Convention, it is important that, in the future, Japan, as an advanced nuclear country, should improve its physical protection system further, and should play a more active role on physical protection activity internationally.

5. IMPLEMENTATION OF PHYSICAL PROTECTION

In the preceding chapter, the system of Japanese laws and regulations related to physical protection were briefly described.

Under such a framework of laws and regulations, a detailed description of measures that are being taken by industries for physical protection of their respective facilities is not appropriate because of its sensitive nature. Therefore, general measures taken in typical nuclear facilities of Japan will be described below.

(1) Nuclear Facilities Using Category I Nuclear Materials

1) A protected area is enclosed by reinforced concrete walls and the windows are fitted with bulletproof glass or steel lattice. Entrances and exits have steel doors, and its status (closure or opening) will be remotely checked by means of sensors. Normal entrances and exits are provided with electrical locks, the door can be unlocked by inputting a private number or inserting a magnetic card, or by both. Emergency doors can be opened only from the inside. And, major entrances such as to fuel storage are equipped with illumination and cameras so that the situation of access is constantly watched remotely. In a facility using large quantities of plutonium, the exit is equipped with a nuclear material detector and the entrance must have a metal detector for dangerous weapons. And further, in hallways there are sensors to detect moving objects. These sensors are operated at night when there are few occupants.

2) Surrounding the protected area is a peripheral protected area. The peripheral protected area is enclosed by a metallic fence. Along the outside of the fence there is a vista zone provided with illumination such as mercury lamps, so that intruders can be seen at night. There are also sensors along the fences to detect any moving objects, and the internal area along the fences is constantly surveyed with cameras. At the entrance and the exit of the peripheral protected area there is a guardhouse, so that persons and any vehicles entering and leaving the area are always checked. Entry of private cars is not permitted. The peripheral protected area is patrolled periodically by guards.

3) Persons having access to the protected area and to the peripheral protected area are classified as regular personnel and temporary personnel. The identity of the former is confirmed by such means as a personal history, a school record document and a periodical health check document; as such they are recorded in the respective areas. They all possess a magnetic card issued to them with a face photo. When entering the areas, this magnetic card is exhibited on their chest; this card is irregularly replaced with a new one. The identity of the latter is confirmed, when entering the areas, by a document with a face photo attached (a driver's license, a passport, etc.). Within the protected area, however, they are always accompanied by other regular personnel. Even regular personnel, when engaged in work handling nuclear material in the protected area, observe the so-called two-man rule. Similarly, even in the protected area, when engaged in transporting nuclear material, the regular person performing the work is accompanied by another person to verify this transport. Education and training are provided periodically to regular personnel, including especially drills on communication in an emergency.

Furthermore, sensitive information on the physical protection and custody of the door locks is securely managed.

In each workshop, a well-versed, friendly relationship among regular personnel is achieved by means of a meeting in every morning, recreational activities (such as a field day, group trips of a few days, etc.) and an interview with one's supervisor twice a year. Accordingly, in a group of several regular personnel mutual understanding is achieved on such topics as complaints, dissatisfaction, apprehension and health conditions.

(2) Nuclear Facilities Using Category II Nuclear Materials

Nuclear facilities using class II materials are the same as facilities using class I materials except that the peripheral protected area is not needed.

(3) Nuclear Facilities Using Category III Nuclear Materials

Nuclear facilities using class III materials are the same as facilities using class II materials except that constant guards are not posted and the walls of the protected area need not be as thick as in facilities using class II materials.

6. CONSIDERING THE SOCIAL SITUATION

The problem-to what extent physical protection there should be-is essentially determined by the social situation of each individual country, as described in the guidelines of IAEA. For each country to take physical protection measures on an appropriate level for nuclear facilities or the transport of nuclear materials, taking fully into consideration the particular social situation, is indeed a matter of sovereignty of that country. On the other hand, however, the practice may be an obligation of each country to the international community. At this point the following must be fully acknowledged. The development and utilization of nuclear energy is now prevalent worldwide. Therefore, if any problem occurs the effects will extend beyond the country's borders and will jeopardize the benefits of nuclear energy in all countries.

As just indicated, in Japan, physical protection measures in all nuclear industries are required both in scope and level by law. The level of physical protection measures is largely related to the social situation of each country. Therefore, in the following, features of Japan's social situation will be described.

(1) In Japan, particularly after World War II, thorough efforts were made for democratization and equality throughout the nation. The former huge financial groups were dissolved. Gradually the economic level of low-income groups was significantly raised, so that there was formed a society with little disparity in wealth. These factors are considered to have contributed to the stabilization of society.

(2) Crime and Arrest Rates in Japan

It is well known in foreign countries that there are very few crimes in Japan. For instance, Mr. David Bayley points out in writing "Forces of Order—Police Behavior in Japan and the United States" that the occurrence rate of any kind of crime or offense in Japan is less than 1/4 the occurrence rate of serious crimes in the United States. Of the serious crimes, when homicides and burglaries are compared among Japan, Europe and America, the rates in Japan are seen to be very low. Further, the respective arrest rates in Japan are also seen to be the highest. These observations should be viewed from a long-range perspective, i.e., the society of Japan is highly safe and stable.

(3) Relationship Between Police and Society

a) Policemen in Japan are generally called by people "Omawari-san-Mr. patrolman." As such the police are constantly engaged in such activities as deepening communication with other people.

b) In order to establish a safe local society, the police provide instruction to local people regarding crime prevention and criminal activities.

c) The police currently provide guidance to the security industry which has about 200,000 employees throughout the country. They also maintain mutual cooperation with police.

d) The police also provide aid to victims of crime.

(4) Some Unique Laws in Japan

In Japan there are several unique laws, not familiar to other countries, which may facilitate the practice of physical protection. There are three laws which are worth mentioning here: first, the Family Registration Act, which requests the registration of the identity of each individual Japanese; second, the Residents Register Act; seen also in other countries, which provides for the recording of residents in cities, towns and villages; third, the Firearms and Swords Control Act, which strictly controls the possession of weapons by the general population. These respective Acts will be described below.

a) Family Registration Act

The registration of the social status of Japanese people is called "family registration." The law regulating it is the Family Registration Act. Originally the family registration was aimed at purposes such as crime prevention, taxation, conscription, land administration and suppression of heretical religions. It was intended to grasp the residents' situation per "home" unit. The practice dates back to the year 575, and its purpose and contents varied from time to time. The family registration has continued to the modern age. In 1871, a modern home registration act was promulgated by the Meiji Revolutionary Government. After World War II, in 1947, according to the new Constitution of Japan, the Family Registration Act was modified by abolishing the previous definition of "home" and adopting a family unit composed of a husband and a wife and their children. In the family register are thus entered the following: (i) the permanent residence, (ii) names of each family member, (iii) dates of birth of each member, (iv) names of their true mother and father and the relations with the parents, (v) in the case of adoption, names of the foster parents and the relationship to them, (vi) in the case of the change of names in the register by marriage or adoption for example, the previous family registration, the previous family name and the reason for register change (such as birth or adoption).

As thus seen, the family registration or register is, so to speak, an official document recording notarially the social status of Japanese people. So, the document possesses presumptive power and notarial power capable of showing the truth.

b) Residents Register Act

The preparation of a residents register consisting of a "resident card" recording the information concerning a resident is an obligation of the city, town or village office established by law. On the resident card the following data is entered: the name of a resident, the date of birth, sex, the name of the person representing the household, the relationship to this person, permanent address, present address, the registration in a pollbook, and the items concerning national health insurance, national pension and children's allowance. The resident card serves the purposes of authenticating the residence of a resident and the fundamental resident services of the city/town/village office. When the place of residence is changed, this resident gets a "certificate of moving out" issued by the office of a city, town or village where he had thus far lived. He then presents this certificate to the office of the city, town or village to which he moved. The latter office then prepares the new "resident card." The office which received the certificate of moving out thus notifies the former office of this receipt. The resident card and the family register are interconnected, so that the transition in residence is registered as an appendix in the family register. As already explained, the legal (permanent) domicile is registered in the resident card. Therefore, when there is a change in the permanent residence or in the place of residence, the office of the city, town or village concerned notifies the other office of this fact, so the former office revises the family register and the resident card.

In Japan, when an industry hires a person, this person is requested to present a document certifying the permanent residence issued by the office of the city, town or village possessing the family register, and a copy of the resident card issued by the office of the city, town or village where the residence is located. This practice is utilized as means of confirming the identity of the person being employed.

The existence of a family register and a resident card thus facilitates the confirmation of the identity of people and in this manner it serves as a kind of deterrent to certain crimes.

c) Firearms and Swords Control Act

In Japan, by this act, the possession of guns, swords, blades, etc. other than those specially permitted is strictly prohibited. The prohibition of the possession of weapons by the general public dates far back in history. That is, the prohibition was initiated in the year 1588 after the introduction of rifles into the country from Europe (in 1543). Subsequently, to this day, the possession of weapons without permission has been prohibited, though there was some variation in this regulation at various times.

The existing act, the Firearms and Swords Control Act, is a revised version from 1958. As compared with its predecessor, the scope of weapons prohibition has increased, so that the regulation is more strict. The weapons prohibited by the act include the following: any kind of gun capable of projecting metallic bullets, swords or blades with blade length over 15 cm, and even air guns and knives with switch blades. The possession of such weapons is allowed only for persons permitted by specific exception provisions. When this regulation is violated, the offender is imprisoned to a term of up to three years. The exceptions for the prohibition are specified in detail and cover self-defense officials, police officers, maritime safety officials and narcotic control officers. When a citizen wishes to possess hunting guns or swords/blades as art objects, he must obtain permission from a regional public safety commission. The provisions of not permitting such possessions are given clearly, which include the following: the purpose of possession not stated by law, persons whose ages are below 14 years old, mentally deranged persons, drug addicts, persons with an unknown dwelling, those persons for whom some reason for endangering life or property of other people or security of society is established. In this connection, the provisions are interpreted in broader discretion so that the scope of permission is narrowed as far as possible. As already mentioned, the Firearms and Swords Control Act, which controls strictly the possession of guns, swords and blades, contributes greatly to the supression of crimes in Japan.

As described above, it is seen that in Japan individual persons in regional communities are classified systematically by legal authorities, and further, the system of prevention of crimes and of securing the social safety is adequately established. Such systems of social practice are highly compatible with the practice of physical protection, thereby contributing greatly to its effectiveness.

The measures of physical protection, established by law from 1988 into 1989, have resulted from the national consensus concerning the importance of the physical protection and the obligation of Japan as a member of the world community—though the measures taken were opposed by certain people, they feared that the thorough practice of physical protection measures may lead to the emergence of Japan as a police state and an information-controlled state. Therefore, it should be realized that the present system of physical protection measures is the best possible considering the current social situation of Japan.

It goes without saying, however, that constant vigilance is necessary now and in the future to protect against the possibility of society being endangered by political or social extremists, i.e. convicted felons, which occasionally takes place in Japan or by Japanese. In this respect, security authorities carefully watch their movement and thereby possess extensive knowledge of their objectives or purpose. Up to now, fortunately, there have been no signs of terrorism addressed toward nuclear facilities, partly due to the specific aversion of Japanese people concerning nuclear weapons and radiation.

ACKNOWLEDGEMENT

The authors wish to thank Mr. T. Haginoya and H. Kurihara for their cordial and valuable comments in the preparation of this paper.

Kenji Seyama earned a Master of Engineering degree from the Department of Nuclear Engineering, Tohoku University, Japan, in 1975. In 1982, Seyama was Deputy Director of the Nuclear Material Regulation Division at the Nuclear Safety Bureau, Science and Technology Agency (NSB, STA). In 1985 he was First Secretary (Science) at the Embassy of Japan in Moscow. Seyama became Director for Physical Protection of Nuclear Material Safeguards Division of the NSB, STA, in 1988 and is currently Director of the Nuclear Litigation Office at the NSB, STA.

Hiromasa Nakano graduated from the Department of Science and Literature at Toyama University, Japan in 1959. At PNC, Nakano has worked as Manager of the Planning Section in Nuclear Fuels Development Division, Director of Safeguards Office, and Director of Nuclear Fuels Development Division. In 1969 Nakano was representative of the Washington Office to PNC and in 1981 became Senior Engineer of the Uranium Enrichment Project. He is currently director of the Nuclear Material Control Division at PNC.

Mitsuaki Kajiyoshi earned a B.S. from the University of Tokyo in 1957. After being engaged in uranium mine development in the Ningyo-toge Mine, Kajiyoshi worked in radiation safety and nuclear waste management primarily in the O-arai Engineering Center of PNC from 1963 to 1981. Since 1982 he has been involved in safeguards and physical protection in the Nuclear Material Control Center and subsequently at PNC. He is currently senior staff member of the Nuclear Material Control Division, PNC.

Gamma Ray Assay of a Waste Drum for the Determination of Plutonium Amount (III)

Johkun Akatsu, Takaumi Kimura, Hiroshi Mutoh
Japan Atomic Energy Research Institute
Tokai-mura, Ibaraki-ken, Japan

ABSTRACT

A waste drum was assayed in a static measurement of the ^{239}Pu gamma ray. A couple of NaI (T1) detectors are set opposite to each other. The object, a 200 liter drum, is put vertically at the center, keeping a given interspace between the drum side and each detector. The system is almost mirror image symmetrical. The gamma ray activity is accumulated for 3 minutes with both the detectors at the same time. The ^{239}Pu amount is estimated from the sum of both counting values. The gamma ray influence of ^{241}Am coexisting with plutonium is eliminated in the system. The gamma ray attenuation of ^{239}Pu by the wastes is also corrected with the use of an external source of ^{137}Cs. The system was applied to the assay of 86 drums carrying 40 to 175 kg of plutonium-bearing wastes. ^{239}Pu weight can be evaluated within $\pm 25\%$ error in the range of 0.02 to 10 g to a drum.

1. INTRODUCTION

Nondestractive assay of plutonium in 20 liter waste cartons has been previously carried out by a gamma ray scanning technique at the plutonium handling facility in the Japan Atomic Energy Research Institute (JAERI)[1-3]. This time, a convenient technique for 200 liter drum was needed for a dismounting campaign of glove boxes used in plutonium handling[4-6]. Four glove boxes having 5-10 m^3 were dismounted in the facility. Two were mainly made of stainless steel (SUS-304, 4 mm in thickness) and had 10 mm thick acrylic windows, respectively. The others were made of aluminum (10-30 mm in thickness) and also had front windows with the same material. They were cut into small pieces by a saw in a greenhouse, sealed hermetically in polyvinyl chloride bags and contained in drums.

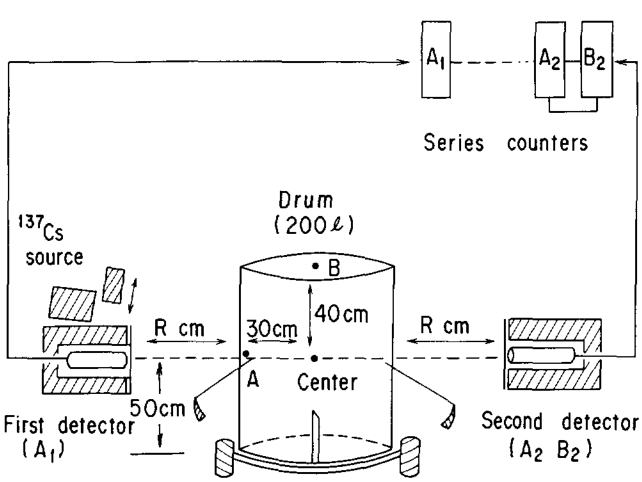


Figure 1. Schematic view of ^{239}Pu assay system

In the present work, attention will be paid to develop a convenient technique for the plutonium assay of 200 liter waste drums.

2. EXPERIMENTAL

2.1. Materials

Gamma ray sources containing 0.02, 0.04, 0.06 and 0.08 g of plutonium were used for calibrating. The isotopic abundances of ^{239}Pu, ^{240}Pu and ^{241}Pu in them were 97.6, 2.30 and 0.07 atom % in January 1980, respectively. Others, 0.18, 1.0, 1.5, 1.7, 4.8, 7.6, 8.6 and 10.0 g of plutonium were also used. The contents of ^{239}Pu in them were over 90%, respectively. All of the plutonium-bearing wastes were sealed up doubly in polyvinyl chloride bags each of 0.3 mm in thickness, and contained in 200 liter drums (SUS-304, 1.2 mm thickness, JIS-Z-1600), with polyethylene inner vessels of 3 mm thickness. Most of the plutonium samples used in the facility contained ^{239}Pu in the range of 84-91 atom %.

2.2. Measuring system

A pair of NaI(T1) scintillation detectors (3″ × 3″) face each other as shown in Fig. 1. The front and four sides of each are sealed with a lead sheet of 1 mm and lead blocks of 50 mm in thickness, respectively. They are named the first (left) and second (right), individually. A drum to be assayed is carried by its carrier to the center, and put vertically on the floor together with the carrier, keeping a given interspace between each detector and the side of the drum. The arrangement was chosen to make the counting efficiencies at all positions in the drum equal, as described in 3.1. A module counter, A_1 is connected to the first, and dual counters of A_2 and B_2 to the second. All of them operate at the same time with master-slave connection. The ^{239}Pu gamma ray (356-450 keV) as seen in Fig. 2 is measured during 3 minutes by A_1 and A_2 and the gamma ray in the 470-790 keV region is measured by B_2 at the same time to get a value for the background activity in the 356-450 keV region. The net values obtained from A_1 and A_2 are added to give the ^{239}Pu amount corresponding to the plutonium in the drum.

3. RESULTS AND DISCUSSION

3.1. *Mirror image symmetrical measurement*

The object to be assayed is bulky in comparison with the detectors. Plutonium also may be randomly located along the wastes in a drum. It was considered that counting efficiencies at different positions in a drum would be made nearly equal by selecting the interspace between the side of the drum and each detector. As shown in Fig. 1, the side point, A and top point B (and the opposite) in a drum correspond with the highest and lowest efficiencies, respectively. In Fig. 3(a), their efficiencies are compared with that of the center as a function of the interspace R (cm) between the drum side and each detector. $(E.R.)_p$ represents the Efficiency Ratio of the two points, where $(E.R.)_p$ at the center is regarded to 1.0. Solid and broken curves show the results obtained by measuring and calculating from a geometrical point of view, respectively. Both gamma ray intensities from A and B points are equal within ±25% error to that of the center, when the interspace, R is more than 50 cm. In Fig. 3 (b), the whole Efficiency Ratio $(E.R.)_w$ compared with that of the center is observed by setting 11 samples of plutonium at arbitrary positions in a drum. The whole activity can be evaluated within ±25% error in comparison with that at the center, when R is more than 50 cm. These experiments suggest that a static measurement will be possible for the assay of a 200 liter drum. R is kept to 50 cm in the present work.

3.2. *Gamma ray influence of ^{241}Am*

A sizable amount of ^{241}Am, the decay product of ^{241}Pu (Half life 14y) always exists in plutonium-bearing wastes. It emits many weak gamma rays in the 300-800 keV region as well as at 59 keV. In Fig. 2, the gamma ray spectra of ^{239}Pu and ^{241}Am in the 300-800 keV region are shown with solid and broken lines, respectively. When the ^{239}Pu activity in the 356-450 keV region is measured by A_1 and A_2, the activity of ^{241}Am in the region also is measured by the counters. The third counter, B_2 was employed in order to estimate the gamma ray activity due to ^{241}Am in the 356-450 keV region. The working region, 470-790 keV, was decided as follows. Using a pure source of ^{241}Am, its activity was counted for 3 minutes at the same time by A_1, A_2 and B_2. Each value stood in the relation of $\underline{A}_1 \approx \underline{A}_2 \approx \frac{1}{2}\underline{B}_2$, where $\underline{A}_1$, $\underline{A}_2$ and $\underline{B}_2$ designated the counting values obtained from the counters of A_1, A_2 and B_2, respectively. The relationship, of course, does not depend on the

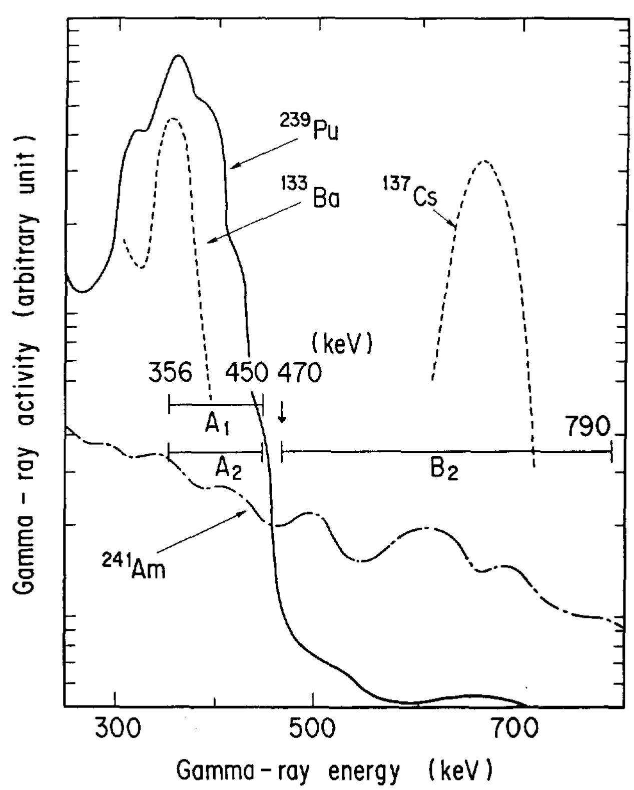


Figure 2. Gamma-ray spectra of ^{239}Pu, ^{241}Am and (^{133}Ba, ^{137}Cs) in 300-800 keV region

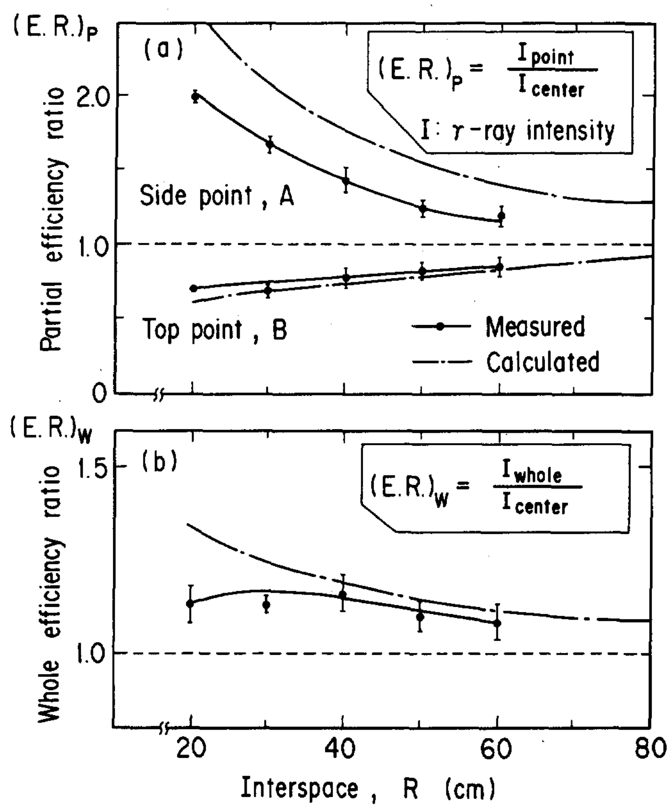


Figure 3. ^{239}Pu counting efficiencies of (a) arbitrary points and (b) the whole, compared with the center

gamma ray intensity of ^{241}Am. $\underline{B}_2$ will stand for the background values counted already in $\underline{A}_1$ and $\underline{A}_2$. On the other hand, the gamma rays from a plutonium sample are low enough in the 470-790 keV region, compared with that at 356-450 keV. Hence, the net ^{239}Pu counting value can be substantially given as $(\underline{A}_1 \times \underline{A}_2 - \underline{B}_2)$/ 3 min. A calibration curve is made, as is shown in Fig. 4, when plutonium samples are put in the air at the center of a drum position.

3.3. Gamma ray attenuation

Attenuation occurs in the gamma rays of ^{239}Pu by the wastes. Its correction was achieved by use of an external source, ^{137}Cs (662 keV). In Table 1, both ratios, $(I/Io)_{Pu\text{-}239}$ and $(I/Io)_{Cs\text{-}137}$ are obtained between steel plates and the air, where I and Io designate the gamma ray intensities passing through the steel and air, respectively. About 10% of ^{239}Pu- and ^{137}Cs-gamma rays are reduced with a SUS-304 drum. Next, paper, rags, rubber, polyvinylchloride sheets and sand were contained in 5 drums, respectively, in order to make a curve of the correction factor, f. A known amount sample of plutonium was put at the center in each of them. The activity was measured during 3 minutes by the counters, A_1, A_2 (and B_2). The counting value obtained from each was compared with the value counted in the air. Hence, five values of $(Io/I)_{Pu\text{-}239}$ are given. The external Cs-137 source (1 M Bq), sealed with lead blocks of 50 mm in thickness, was set on the top of the first detector (Fig. 1). When the front shutter was opened, the gamma ray was emitted in a beam from the 8 mm collimator. The gamma rays passing slopewise through the air and one of the drums provided above were counted for 3 minutes by the B_2 counter (Fig. 2), in order to get the values of $(I/Io)_{Cs\text{-}137}$. From the results obtained above, $(Io/I)_{Pu\text{-}239}$ vs. $(I/Io)_{Cs\text{-}137}$ is plotted in Fig. 5. On the curve in this figure, a value of f is given as the correction factor of a drum.

A drum assay is carried out by two successive steps. First, the ^{239}Pu gamma rays from a drum to be assayed are measured for 3 minutes by A_1 and A_2, keeping the shutter of the external source closed. In this case, B_2 counter is used to get a substitute background value mainly due to ^{241}Am. Second, the front shutter of the external source is opened. The activity is counted for 3 minutes by B_2, in order to determine an f value for the drum. Hence, the ^{239}Pu counting value is corrected as,

Net ^{239}Pu activity (3 min.) = $(\underline{A}_1 + \underline{A}_2 - \underline{B}_2) \times f$

A plutonium weight corresponding to this value will be given on the curve in Fig. 4.

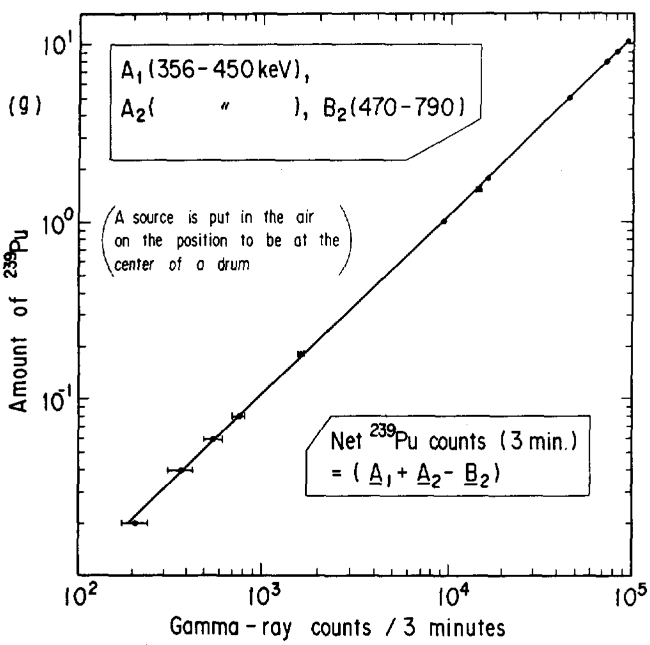


Figure 4. Calibration curve (the amount of ^{239}Pu vs. gamma ray counting value in 356-450 keV region)

Table 1
Gamma-ray attenuation of the external source (^{137}Cs) with steel material

Material	Thickness (mm)	Attenuation (I/I_0) Cs-137	(I/I_0) Pu-239
Steel	1.2 (drum)	0.90 ± 0.01	0.95 ± 0.07
SUS-304	1.2 (")	0.88 ± 0.01	0.93 ± 0.04
"	2.4	0.89	
"	4.8	0.84	
"	8.8	0.70	
"	13.6	0.60	
"	22.4	0.47	
"	27.2	0.41	

4. ASSAY OF A WASTE DRUM

4.1. Verification of the counting system

Ten drums carrying artificial wastes were provided by packing rags, rubber and polyvinylchloride sheets at random. Each contained a 0.18 g sample of plutonium at an arbitrary position and was assayed twice in the system. The results obtained are shown in Table 2. The second assay was carried out after the drum was rotated 90° from that of the first. All of them are determined within ±25% error.

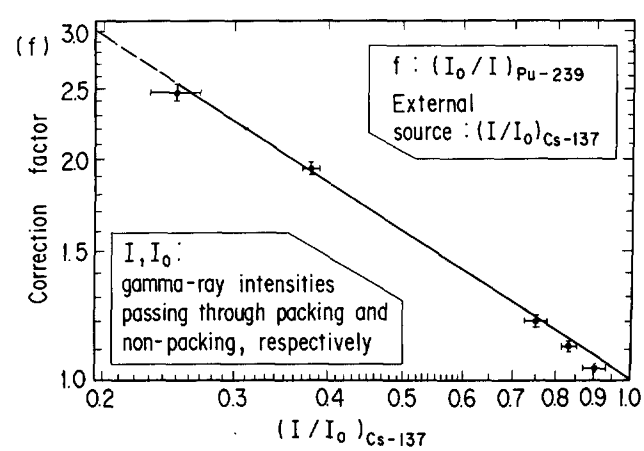


Figure 5. Correction factor for ^{239}Pu counting value based on the external source of ^{137}Cs (662 keV)

4.2. Application

Waste drums generated by dismounting the glove boxes were 86 in number and had 40 to 175 kg in weight. After being labeled with No. tags, each was assayed twice at different angle positions. The results of the first two and last two drums are shown in Table 3. The two values of each are very similar. None of the other 82 drums needed special treatments in the system.

CONCLUSION

The objective was develop a technique of plutonium assay for 200 liter waste drums. A couple of detectors were set opposite to each other. A drum was carried to the center between them, and put vertically on the floor together with its carrier, keeping the interspace of each detector to the drum side at 50 cm. The whole arrangement was symmetrical, and made counting efficiencies of any positions in the drum almost equal. Thus, the assay could be carried out without scanning.

Two counters, A_1 and A_2 connected to each detector worked for 3 minutes at the same time for the measurement of the ^{239}Pu gamma ray. Its amount was determined from the sum of both counting values obtained. The calibration curve in Fig. 4 was made, after the detectors being supplied with 1,000 volts had stood for more than one month in a room of about 25° C. Occasionally, the system was also checked with a 0.37 M Bq ^{133}Ba source (Fig. 2). The counting value for 3 minutes corresponded to that of ^{239}Pu sample having 1.3 g. The plutonium amount could be determined in a wide range, since the gamma ray influence of ^{241}Am wa always eliminated in the present system.

Gamma ray assay may be carried out with rather simple apparatus in comparison with others, such as of neutron measurements. However, the gamma ray in 356-450 keV region is often reduced seriously by the waste material. The correction is important to get a reliable evaluation[7]. In the present work, the attenuation was corrected every time by the use of a ^{137}Cs external sources. The relation of correction factor to weight of a drum, obtained as the result of 86 drum assays, is shown in Fig. 6. There are three groups named as A, B and C in the figure. The wastes in A, B and C groups were of vinylchloride sheets, steel plates and aluminum thick plates, respectively. In the figure, an f value of the waste drum contained with such as steel plates could be obtained from its weight on the curve in Fig. 6.

The detectors in the system are always supplied with 1,000 volts for anytime assays. The ^{239}Pu amount can be determined within ±25% error in the range of 0.02-10 g of plutonium. The system is also applied to plutonium assay of smaller volume samples than 200 liter drums without changing the geometric arrangement.

Table 2
Determination of ^{239}Pu amount (180 mg) in artificial wastes

1st measurement (^{239}Pu : 180 mg)				2nd measurement (in a different position)			
^{137}Cs (I/I_0)	f	Counts x f	^{239}Pu (mg)	^{137}Cs (I/I_0)	f	Counts x f	^{239}Pu (mg)
0.47	1.67	978 x 1.67	174	0.59	1.44	1166 x 1.44	179
0.75	1.22	1251 x 1.22	162	0.75	1.22	1334 x 1.22	173
0.88	1.10	1299 x 1.10	161	0.88	1.10	1372 x 1.10	169
0.65	1.34	1314 x 1.34	198	0.65	1.34	1201 x 1.34	181
0.82	1.15	1449 x 1.15	177	0.79	1.17	1532 x 1.17	191
0.65	1.34	1314 x 1.34	188	0.72	1.25	1202 x 1.25	160
0.65	1.34	1201 x 1.34	181	0.70	1.26	1188 x 1.26	169
0.70	1.26	1239 x 1.26	175	0.82	1.15	1449 x 1.15	187
0.82	1.15	1404 x 1.15	181	0.88	1.10	1488 x 1.10	176
0.87	1.10	1488 x 1.10	185	0.87	1.10	1340 x 1.10	168
		(177 ± 11)				(176 ± 9)	

Table 3
Determination of ^{239}Pu amount in actual wastes

Drum No.	(Kg)	Cs-137 (I/I_0)	f	Counts / 3 min $(A_1 + A_2 - B_2) \times f$	Found ^{239}Pu (mg)	Note
1	58.8	0.58	1.45	67 x 1.45	< 20	(In a different position)
		0.74	1.22	93 x 1.22	< 20 ←	
2	50.4	0.45	1.72	339 x 1.72	62	
		0.53	1.55	406 x 1.55	66	"
85	112	0.22	2.76	355 x 2.76	110	
		0.20	2.96	385 x 2.96	123	"
86	53.0	0.54	1.53	8,329 x 1.53	1,350	
		0.52	1.56	8,507 x 1.56	1,400	"

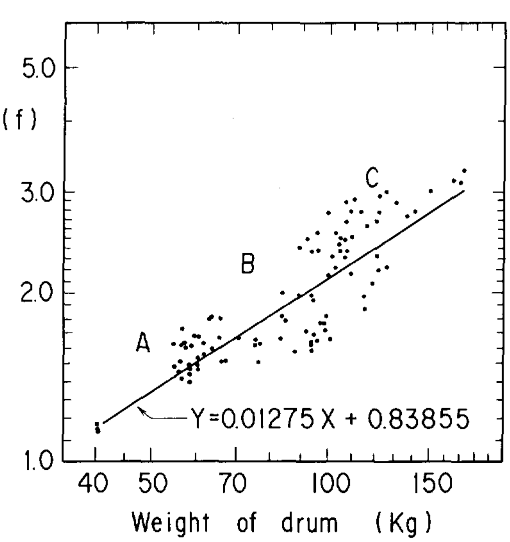


Figure 6. Correction factor obtained from 86 drums containing actual wastes

REFERENCES

1. J. Akatsu, "Determination of Pu amount in a waste carton by gamma ray measurement", *Jour. JNMM*, X(4), (1981), 22.
2. J. Akatsu, Y. Kobayashi, T. Kimura, "Nondestructive determination of ^{239}Pu in wastes by application of gamma ray measurements", *Jour. Radioanal. Nucl. Chem. Letters*, 86(3), (1984), 159.
3. J. Akatsu, "Acid digestion of Pu-bearing combustible waste", JAERI-M 85-213, (in Japanese) (1986), p. 95.
4. L.V. East, R. Gatti, S. Wawrowski, "Automated gamma ray scanning system for waste drum assay", *Jour. JNMM*, V(3), (1976), 137.
5. N. Bardy, P. Ruffet, M. Cance, "Measurements of ^{239}Pu of waste in drums of 200 liters by passive gamma-, neutron-counting and active 14 MeV pulsed neutrons methods", CEA-CONF-9043 (1987).
6. A.P. Colarusso, J.H. Audas, J.M. Bieri, et. al., "Mobile nondestructive assay system", *Jour. JNMM*, XVI (1987), 375.
7. R. Swennen, "Verification of measured quantities of plutonium in solid wastes", IAEA-R-1453-F, ETR-291 (1976).

Johkun Akatsu has been working in the field of chemistry at the Japan Atomic Energy Research Institute since 1961. He earned his degree in chemistry from Tohoku University in 1976. Akatsu is a senior scientist at the Institute currently working on the separation chemistry of TRU.

Takaumi Kimura is a research scientist at the Japan Atomic Energy Research Institute where he has worked since 1981. Kimura has been researching the solution chemistry and non-destructive assay of TRU. He received a degree in chemistry from Kyushu University in 1989.

Hiroshi Mutoh has been working at the Japan Atomic Energy Research Institute since 1960. A professional in the field of analytical chemistry, Mutoh has been performing cooperative studies on the impurity analysis in TRU.

Density of Water for Tank Volume Calibration

Frank E. Jones
Potomac, Maryland, U.S.A.

ABSTRACT

A simple yet very precise equation for the calculation of water density in the temperature range 15 °C to 60 °C. is presented. The density values used in developing the equation are from the 1975 Kell formulation, corrected for air saturation. The equation is recommended for use in tank volume calibration.

INTRODUCTION

In the volume calibration of accountability tanks and other tanks using water as the calibrating fluid, the density of water at various temperatures is desired in most cases. In this paper a simple yet very precise equation for the calculation of density of water at temperatures in the range 15 °C to 60 °C. is presented.

DENSITY CALCULATION EQUATION

The formulation which has been used for the calculation of the density of water is that of Wagenbreth and Blanke (Wagenbreth and Blanke, 1971), WB, for *air-free* water. The WB formulation is a polynomial of fifth degree in temperature, °C, on the 1968 International Practical Temperature Scale.

In 1975, Kell (Kell, 1975) published a new formulation for the density of *air-free* water at a pressure of one atmosphere, 101.325 KPa, valid from 0 °C to 150 °C "that is in improved agreement with most data sets" including a revision of data published by Kell and Whalley (Kell, Whalley, 1965) in 1965.

Unless water is just freshly distilled, air will be absorbed and ultimately the water will be air saturated. Wagenbreth and Blanke (Wagenbreth and Blanke, 1971) calculated the correction for the difference between the density of air-free water and the density of air-saturated water.

In the present work, the WB correction has been applied to values of density calculated using Kell's 1975 formulation. The resulting values for air-saturated water, ρ_{as}, then were fitted over the temperature range 15 °C to 60 °C to a polynomial of fifth degree in temperature in °C.

The resulting equation is

$$\rho_{as} = 998.47654 + 0.279971\, t - 2.14356 \times 10^{-2}\, t^2 + 4.37094 \times 10^{-4}\, t^3 - 5.44028 \times 10^{-6}\, t^4 + 2.72562 \times 10^{-8}\, t^5, \quad (1)$$

where ρ_{as} is in kg m^{-3}, and t is in °C. Equation (1) applies to air-saturated water at a pressure of one atmosphere in the temperature range 15 °C to 60 °C.

Kell (Kell, 1975) has also developed equations for the calculation of the isothermal compressibility of air-free water. In the context of tank volume calibration the dependence of water density on pressure can be ignored; therefore, equation (1) can be used independent of pressure.

Equation (1) was used to calculate water density in the range 15 °C to 60 °C. The results are tabulated in Table 1. The Kell values, Kell values corrected for air saturation, values calculated using equation (1), and the difference between equation (1) and the Kell values corrected for air saturation are listed in the table. The estimate of standard deviation of the difference is 0.0070 kg m^{-3}, which is 7.1 parts in 1 million, which is negligible for tank volume calibration.

SUMMARY AND CONCLUSIONS

An equation, an interpolation formula, to be used to calculate density of water for tank volume calibration is presented. The equation is simple and very precise. It applies to air-saturated water in the temperature range 15 °C to 60 °C, independent of reasonable pressure. Since absorbed air in air-saturated water results in a decrease in water density of 35 parts per million or less, any error due to departure from air saturation is negligible in the tank volume calibration context. Impurities in the water used for calibration can affect the density of water, the effect of course depends on the concentration and characteristics of impurities.

REFERENCES

Kell, G.S., and Whalley, E., Phil. Trans. Roy. Soc., *A258*, 565 (1965).
Kell, G.S., J. Chem. Eng. Data, *20*, 97 (1975).
Wagenbreth, H., and Blanke, W., PTB Mitt. *81*, 412 (1971).

Table 1
Water Densities

Temp. °C	Kell ρ kg m⁻³	Kell ρ + air. sat. kg m⁻³	Eq. (1) ρ kg m⁻³	Diff. kg m⁻³
15	999.0996	999.0976	999.0736	−0.0240
16	998.9430	998.9413	998.9309	−0.0104
17	998.7749	998.7735	998.7729	−0.0006
18	998.5956	998.5945	998.6004	+0.0059
19	998.4052	998.4043	998.4143	+0.0100
20	998.2041	998.2035	998.2152	+0.0117
21	997.9925	997.9921	998.0040	+0.0119
22	997.7705	997.7703	997.7812	+0.0109
23	997.5385	997.5384	997.5476	+0.0092
24	997.2965	997.2965	997.3034	+0.0069
25	997.0449	997.0449	997.0492	+0.0043
26	996.7837	996.7837	996.7855	+0.0018
27	996.5132	996.5132	996.5124	−0.0008
28	996.2335	996.2335	996.2305	−0.0030
29	995.9448	995.9448	995.9399	−0.0049
30	995.6473	995.6473	995.6409	−0.0064
31	995.3410	995.3410	995.3336	−0.0074
32	995.0262	995.0262	995.0183	−0.0079
33	994.7030	994.7030	994.6950	−0.0080
34	994.3715	994.3715	994.3639	−0.0076
35	994.0319	994.0319	994.0251	−0.0068
36	993.6842	993.6842	993.6785	−0.0057
37	993.3287	993.3287	993.3244	−0.0043
38	992.9653	992.9653	992.9626	−0.0027
39	992.5943	992.5943	992.5933	−0.0010
40	992.2158	992.2158	992.2158	+0.0006
41	991.8298	991.8298	991.8320	+0.0022
42	991.4364	991.4364	991.4400	+0.0036
43	991.0358	991.0358	991.0406	+0.0048
44	990.6280	990.6280	990.6337	+0.0057
45	990.2132	990.2132	990.2194	+0.0062
46	989.7914	989.7914	989.7977	+0.0063
47	989.3628	989.3628	989.3686	+0.0058
48	988.9273	988.9273	988.9324	+0.0051
49	988.4851	988.4851	998.4890	+0.0039
50	988.0363	988.0363	988.0387	+0.0024
51	987.5809	987.5809	987.5816	+0.0007
52	987.1190	987.1190	987.1178	−0.0012
53	986.6508	986.6508	986.6478	−0.0030
54	986.1761	986.1761	986.1715	−0.0046
55	985.6952	985.6952	985.6895	−0.0057
56	985.2081	985.2081	985.2021	−0.0060
57	984.7149	984.7149	984.7097	−0.0052
58	984.2156	984.2156	984.2128	−0.0028
59	983.7102	983.7102	983.7118	+0.0016
60	983.1989	983.1989	983.2075	+0.0086

Frank E. Jones is a physicist and independent consultant, having retired from the National Bureau of Standards (now the National Institute of Standards and Technology) in 1987. He has been actively engaged in tank volume calibration for more than 10 years. He designed, directed and participated in the first definitive tank calibration at the Savannah River Site as well as many other tank calibrations. He also performed a definitive in-tank measurement of solution density. He served as deputy office chief in the NBS Nuclear Safeguards Program. He has authored more than 50 technical papers, holds two patents, and lectures on various subjects. Jones earned a master's degree in physics from the University of Maryland and has done doctoral work in meteorology at the same university. He was a consultant to the writing group for American National Standard ANSI N15.19, "Volume Calibration Techniques for Nuclear Material Control."

Safeguards and Security Concerns for New Processing Facilities

F.B. Davis
Westinghouse Savannah River Company
Aiken, South Carolina U.S.A.

ABSTRACT

Savannah River Site (SRS) has recently designed two new facilities that will contain category I quantities of nuclear material. Learning from past experiences, one of the primary concerns of the facility design team is to factor safeguards and security systems into the initial design so that the risk of theft from the operating facility will be reduced to an acceptable level without the need for costly changes during construction or retrofits thereafter. SRS has been using a modified Master Safeguards and Security Agreement (MSSA)[1] evaluation to determine the safeguards and security systems that must be in place for facility startup. An example of this approach is discussed.*

BACKGROUND

Savannah River Site was designed and built primarily for the production of tritium and plutonium. The plutonium is produced by irradiation of depleted uranium slugs in heavy water moderated reactors. After irradiation both the depleted uranium slugs and the enriched uranium fuel tubes are shipped to one of two Separations Areas for recovery. Both F and H Separations Areas were originally designed to separate plutonium from irradiated uranium; however, after a short period of operation, the H-Area flowsheet was modified to allow processing of the enriched uranium fuel tubes. The uranium solution product was shipped to Oak Ridge, until recently, for conversion. The Department of Energy has suspended shipments of liquid uranium solution and directed Savannah River Site to convert the liquid to a solid form for future shipments to Oak Ridge. The conversion process will be performed in an existing facility which is called the Uranium Solidification Facility.

The canyon facility, where the actual separation of uranium from other isotopes is accomplished, contains category IID quantities of SNM (enriched uranium solutions at concentrations of less than 25g/l). The Uranium Solidification Facility portion of the building will contain category IC quantities of uranium.

DISCUSSION

One of the primary concerns in the construction of a new facility that will contain large quantities of attractive materials is adequate protection against the theft of SNM so that the risk is acceptable while at the same time keeping the cost of safeguards and security systems at a reasonable level. In other words: When is enough enough? In order to answer this question for the design team and management, a group of employees was assembled to perform a modified MSSA[1] analysis. The team consisted of Safeguards and Security Department, USF Project Liaison team, Safeguards & Security Project Division, USF Production, and Production Technical Support personnel. These employees were knowledgeable about the Department of Energy's Safeguards and Security requirements, facility constraints, and systems to protect against specific vulnerabilities.

The modified MSSA[1] approach taken was to use the MSSA evaluation methodologies; ET[2] (Evaluation Tool) and SAVI[2] (Systematic Analysis of Vulnerability to Intrusion) to perform analysis of the level of risk under the current design. Possible alternatives were selected and analyzed to determine the most cost effective combination of measures to achieve the desired goal.

Areas that were reviewed by the task team that are generic to the analysis of any new facility were credibility of targets, task time to obtain a category I quantity of material, assigned consequence values, and facility design. Several assumptions were made since facility layout, design and material handling procedures had not been finalized, but these assumptions were documented for future reference. The objective was not to quantitatively determine a risk factor for operating the facility; it was to ensure that all Safeguards and Security concerns were addressed by the group and, if needed, corrective actions taken to mitigate unacceptable risks.

Several generic recommendations were proposed to reduce the risks. They included:

- Limiting the amount of material to less than Category I outside the vault. Material which is difficult to obtain because of its chemical form or the stage of the process was not included as attractive material.
- Material surveillance procedures, such as the two-man rule, when material is handled outside of a glovebox or processing line.
- Physically limiting access to the processing areas.

- Segregation of duties: Material handlers cannot monitor and remove waste: personnel taking inventory cannot have routine access to the material being inventoried, etc.
- Hardware to enforce use of the two-man rule in locations that contain a Category I quantity of attractive material.

There were four major benefits from performing this type of analysis. (1) All personnel involved were thoroughly educated on the Department of Energy safeguards and security requirements for a Category I facility. They also became knowledgeable about the Uranium Solidification Facility strengths and vulnerabilities. (2) Involving a group of people in the analysis and design of Safeguards and Security systems led to innovative design that integrated physical security with safeguards systems and led to more cost effective recommendations. (3) Major decisions which would effect the design of the facility were resolved in the early planning/design stages which will minimize the need for costly scope changes or facility retrofits. (4) The last benefit is the strong base provided for the MSSA.

SUMMARY

Savannah River has used this modified MSSA analysis to analyze the vulnerabilities associated with new facilities and facilities that are in stand-by condition to determine the cost of upgrading the facility for storage or use of special nuclear material. It has provided us with valuable insight into necessary upgrades before decisions were made that could not be reversed or altered without a great deal of expense. We plan to continue performing these analyses for new/modified facilities so that Safeguards and Security systems are well planned, efficient and cost effective.

REFERENCES

1. INMM 29th Annual Meeting Proceedings "Overview of the US DOE Master Safeguards and Security Agreement Program," M.P. Billings, et. al. pg. 19.
2. INMM 29th Annual Meeting Proceedings, "An Integrated Approach to Validation of Safeguards and Security Program Performance," W.O. Altman and John S. Hurt pg. 112.

* "Savannah River Site" was formerly referred to as "Savannah River Plant."

The information contained in this article was developed during the course of work under Contract No. DE-AC09-76SR00001 with the U.S. Department of Energy.

Fran B. Davis is a Nuclear Material Representative for the DuPont Savannah River Site. She received a B.S. in Health Physics from the University of Lowell, Lowell, Mass. Davis has held a number of progressing positions throughout the organization since her employment 13 years ago. She has been assigned to the Material Control and Accountability organization since 1985.

Evaluation of Special Nuclear Material Monitoring Instruments

■

K.O. Bowman
Mathematical Sciences Section
Engineering Physics and Mathematics Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee U.S.A.

S.A. Wallace
Development Division
Y-12
Oak Ridge, Tennessee, U.S.A.

■

ABSTRACT

A statistical method to protect against the loss of strategic special nuclear material (SSNM) is presented. A simplified step by step approach to the test procedure is described.

1. INTRODUCTION

Strategic special nuclear material (SSNM) is protected using several layers of physical and administrative controls. In a facility having both enriched and depleted uranium, extensive control is exercised to prevent a diversion of the SSNM, but assurance must also be provided that depleted material is not being removed inasmuch as its loss would indicate the possible loss of SSNM through surreptitious substitution. One option for identifying loss of material is to place walkthrough monitors at the pedestrian exits leaving the perimeter of the security boundary enclosing the uranium processing area. Within this security perimeter are the SSNM areas having tight control and restricted access. The monitors for the SSNM are within buildings and are in the benign environment of a working area. Perimeter monitors on the other hand are located at the boundary rotogates and are subject to the ambient conditions varying with the seasons.

For these monitors testing for performance and reliability is different from that used for the material access area (MAA) monitors. Because of their location and the presence of an ever-changing temperature and humidity environment, the functionality testing must be capable of *in situ* testing to a criterion which is relaxed relative to the MAA testing. A protocol of testing has been evaluated using a multichannel analyzer (MCA) operated in the multichannel scaler (MCS) mode of operation. For the particular Personnel Portal Monitors (PPMS) tested, there are four plastic detectors of nominal thirty-one inch height, six inch width, and one and a half inch thickness. A record of the stability of the monitor is generated by accumulating 4095 consecutive, one second measurements of the count activity. From this history the mean and variance are calculated and a comparison is made to verify that a Poisson model is reasonable, i.e. that the mean is equal to the variance within a statistical tolerance. The data taken on several pillars shows that this criterion is not met when the sum of all four detectors is presented to the MCS. The distribution of the background counts does not reject the hypothesis of a normal distribution, but the variance is consistently greater than the mean. The microprocessor algorithm, used in portal monitors for determining a background against which a decision is made as to whether an occupancy measurement infers the presence of source material, operates on a small set of measurements and continuously updates a new background measurement while dropping out the oldest measurement. For this analysis the background is taken to be derived from the 64 background samples taken prior to an occupancy. Data are presented and statistical analysis made of the personnel monitor fielded on the perimeter portals at our facility. Functionality is determined from the MCS data, while normality is tested using the 64 point data. Periodic testing of the 64 measurement data values for normality allows a decision to be made as to whether the monitor is operating properly.

2. POISSON HYPOTHESIS

The Poisson distribution has the properties that $\mu'_1 = \mu_2 = \mu_3 = \lambda$, and $\mu_4 = \lambda + 3\lambda^2$, where λ is a Poisson parameter, μ'_1 is the mean, and μ_2, μ_3, μ_4 are the central moments of the Poisson distribution.
The statistics $\bar{x} = \sum x_i / n$ and $s^2 = \sum (x_i - \bar{x})/(n-1)$

have the properties $E(\bar{x}) = \mu'_1,\ Var(\bar{x}) = \mu_2/n$;

$$E(s^2) = \mu_2,\ Var(s^2) = \{\mu_4 - \mu_2^2(n-3)/(n-1)\}/n .$$

Clearly the variation of the sample variance is greater than that of the mean.

Figures and tables for Poisson probabilities with large means are available (Bowman and Leach, 1983). The tables give values for Poisson variates; 75(25)1000(50)2500, with 30 probability levels, 0.000005, 0.00001, 0.000025, 0.00005, 0.0001, 0.00025, 0.0005, 0.001, 0.0025, 0.005, 0.01, 0.025, 0.05, 0.1, 0.25, 0.75, 0.9, 0.95, 0.975, 0.99, 0.995, 0.9975, 0.999, 0.9995, 0.99975, 0.9999, 0.99995, 0.999975, 0.99999, and 0.999995, and sample sizes 1(1)5.

The various probability levels of confidence regions are shown in the figures.

3. DO THE DATA SUPPORT THE POISSON HYPOTHESIS?

Justification of using the normal approximation depends upon the assessment of the underlying true distribution and the correct assessment of how large the sample size needs to be (also note that the mean and variance define a normal density and these parameters are independent). It is important to assess the properties of the sample data carefully.

We have examined 23 sets of data taken from the PPMS, each sample size being 4094 or 4095. The question to be answered is "do the data come from a Poisson distribution."

Table 1 shows the mean, variance, standard deviation, skewness ($\sqrt{b_1}$) and kurtosis (b_2) statistics of the data. For every sample, the variance is greater than the mean, which could imply that the true distribution is more dispersed than the Poisson distribution.

The possibility that the generalized Poisson distribution (Bowman and Shenton, 1985) is an alternate analysis methodology to fit the data better than a Poisson distribution; a comprehensive treatment of the subject is given by Consul, 1989. The generalized Poisson distribution is generated by the transformation in the probability generating functions (p.g.f.'s)

$$t = ug(t), \quad f(t) = \{\psi(u)\},$$

$t = ug(t)$ implied $t = \Psi(u)$ under certain restrictions.
For the generalized Poisson distribution,

$$g(t) = e^{\lambda_2(t-1)}, \quad (0 \le \lambda_2 < 1)$$

$$f(t) = e^{\lambda_1(t-1)}, \quad (0 < \lambda_1)$$

so that $f(\cdot)$ and $g(\cdot)$ both generate Poisson variates.
The p.g.f. of the Generalized Poisson distribution is

$$h(u) = e^{-\lambda_1} + \sum_1^{\infty} \frac{\mu^s}{s!} \frac{d^{s-1}}{dt^{s-1}} \left\{ \lambda_1 e^{\lambda_1(t-1)} \cdot e^{s\lambda_2(t-1)} \right\}_{t=0},$$

leading to the probability function

$$P_x(\lambda_1, \lambda_2) = \frac{\lambda_1(\lambda_1 + x\lambda_2)^{x-1} e^{-(\lambda_1 + x\lambda_2)}}{x!}, \qquad (x = 0, 1, 2, \cdots)$$

with mean and variance

$$\mu_1' = \lambda_1/(1-\lambda_2), \quad \mu_2 = \lambda_1/(1-\lambda_2)^3.$$

Note how these increase as λ_2 tends to 1^-. Clearly $\mu_2 > \mu'_1$. If $\lambda_2 = 0$ the generalized Poisson reduces to the Poisson distribution.

We estimate $\mu_1' = E(\sum x_i/n)$, $\mu_2 = E\{\sum(x_i - \bar{x})^2/n\}$ using χ and m_2.

If σ is the population s.d., what is the best approach to approximate the 4σ deviation from the mean? The generalized Poisson including the Poisson distribution approaches the normal distribution when the parameter λ_1 is large. The estimates of λ_1 from 23 data sets are all large; therefore we use a normal approximation to the probabilities.

A test of departure from normality using the skewness and kurtosis of the data show the data from Post 3100.810, Post 3100.817, Post 3180.819 and Post 3080.815 have outliers or they are not distributed normally.

For the other sets of data, we do not reject normal distribution, ie, $N(\mu, \sigma)$ and take the 4 sample standard deviation to be the 4σ point. If those data are in fact normally distributed the probability of $\chi > 4\sigma$ is 0.00003167. Previously, it has been assumed that the data are distributed as the Poisson distribution and the standard deviation was estimated by taking the root of the mean. For example, in the case of Post 3.722, the 4σ point would be taken to be $4 \times \sqrt{\chi}$, and the probability that χ is greater than this value is 0.00008496, which is 2.7 times greater than the probability obtained by using the standard deviation.

To compute the exact or much more accurate probability of the generalized Poisson or Poisson distribution is not possible at the present time. But there are available about 78000 data points from 19 sets of data, after excluding the four apparently non-normal sets. If we assume a probability that the data is greater or less than 4 σ points to be 2×0.00003167, then about 5 out of 78000 should be outside of these limits. There are actually 8 of these, and the corresponding relative frequency is 0.000103, corresponding to a deviation of 3.88σ.

Also it should be noted, that Post 3080 produces longer tailed distributions than the other posts and as noted previously Post 3100 produces outliers. These monitors should be examined.

4. SELECTION OF TEST PROCEDURE

4.1 Inspection of Data

The 23 sets of data of sample sizes 4094 or 4095 from the SNM monitor were examined and it was concluded that they are not Poisson distributed. Previously the data were considered as being Poisson distributed and tested accordingly. The over dispersal of the discrete data can be

Table 1
Statistics of Data—Sample Sizes 4094 or 4095

Identification	$\bar{x}$	m_2	i.d.	s.d.	$\sqrt{b_1}$	b_2	(a)	(b)
POST3.722	1269.05	1432.84	1.13	37.85	0.03	3.07	0	1
POST3100.810	1410.36	1716.24	1.22	41.43	0.43	5.25	*	*
POST3120.810	1281.08	1402.86	1.10	37.46	0.08	2.98	1	1
POST3140.810	1216.28	1249.83	1.03	35.35	0.02	3.13	1	2
POST3160.809	1112.60	1124.13	1.01	33.53	0.06	3.06	1	1
POST3180.809	1043.71	1102.29	1.06	33.20	0.12	3.30	1	3
POST3200.809	986.08	1001.64	1.02	31.65	0.04	3.12	1	1
POST3220.810	959.41	1028.37	1.07	32.07	0.02	3.03	0	0
POST3240.810	915.92	1007.53	1.10	31.74	0.04	3.09	0	0
POST3040.812	1559.71	1784.25	1.14	42.24	0.01	3.04	0	0
POST3060.812	1471.80	1597.93	1.09	39.97	0.11	3.00	0	0
POST3080.812	1390.49	1593.61	1.15	39.92	0.03	3.18	2	3
POST3260.810	880.15	899.12	1.02	29.99	0.01	2.97	0	0
POST3280.811	847.05	849.38	1.00^+	29.14	0.08	3.02	0	0
POST3300.811	840.69	876.81	1.04	29.61	-0.03	3.02	0	0
POST3320.811	809.68	819.26	1.01	28.62	0.02	3.09	1	1
POST3340.811	782.40	806.98	1.03	28.41	0.05	2.93	0	0
POST3040.815	1628.98	1772.03	1.09	42.10	0.04	2.91	0	0
POST3060.815	1511.62	1767.57	1.17	42.04	0.05	3.02	0	0
POST3080.815	1429.71	1559.32	1.09	39.49	0.11	3.24	2	2
POST3100.815	1435.32	1533.23	1.07	39.16	0.04	3.02	0	0
POST3100.817	1390.11	3760.95	2.71	61.33	13.50	302.44	*	*
POST3100.818	1576.42	1696.07	1.08	41.18	0.13	3.09	1	1

Number of times (a) $x \gtrless \bar{x} \pm 4(s.d.)$, (b) $x \gtrless \bar{x} \pm 4\sqrt{\bar{x}}$.
$\bar{x} = \sum x_1/n$, $m_r = \sum(x_i - \bar{x})^r/n$, $\sqrt{b_1} = m_3/m_2^{3/2}$, $b_2 = m_4/m_2^2$.
i.d. = index of dispersion = $m_2/\bar{x}$.

analyzed using a generalized Poisson distribution. Then the question to be answered is "What kind of test should be used when the sample size is 64?"

We assume the data come from a generalized Poisson distribution with unknown parameters λ_1, and λ_2 with $(0<\lambda_1, 0\leq\lambda_2<1)$. As λ_1 becomes large the distribution approaches a normal distribution. We have examined 23 sets of data each of size 64. Statistics from those samples are shown in Table 2.

Table 1 may be regarded as referring to a parent population. Table 2 refers to samples taken from it.

4.2 How to find the 4σ point

1. Use the omnibus test of departure from normality (Appendix, step 5), T, where

$$T = X_s^2(\sqrt{b_1})+X_k^2(b_2),$$

and for $n=64$, the statistics are:

$$X_s(\sqrt{b_1}) = 3.4196 \sinh^{-1}(\sqrt{b_1}/0.9570),$$

$$X_k(b_2) = -1.8899 + 1.9059 \sinh^{-1}\{(b_2-2.3413)/0.5652\},$$

$$\sqrt{b_1} = m_3/m_2^{3/2}, \quad b_2 = m_4/m_2^2, \quad \sinh^{-1}(y) = \ln\{y+(y^2+1)^{1/2}\},$$

$$m_r = \sum\frac{(x_i-\bar{x})^r}{n}. \quad (r=2,3,4)$$

The omnibus test is the first of its kind to take into account skewness (lack of symmetry) and kurtosis (peakedness) and is simple to implement even on a small computer. This test is based on the χ^2 goodness of fit test and uses equivalent normal deviates for each $\sqrt{b_1}$ and b_2 (Bowman and Shenton, 1986). If T is greater than the specified α level of the χ^2 distribution with 2 degrees of freedom, reject the hypothesis that the distribution can be taken to be normal. Here we use $\alpha=0.001$ or $\chi 2^2=13.8155$. We found that data of Post 3100.817 are not distributed normally. If the test is rejected, take new samples and repeat the procedure.

Table 2
Statistics of Data—Sample Size 64

Identification	$\bar{x}$	s.d.	$\sqrt{b_1}$	b_2	$\sqrt{\bar{x}}$	i.d.
POST3.722	1255.61	40.71	-0.71	4.45	35.43	1.32
POST3100.810	1403.52	36.51	0.21	2.53	37.46	0.95
POST3120.810	1268.30	32.03	0.11	2.81	35.61	0.81
POST3140.810	1210.36	28.55	0.25	2.58	34.79	0.67
POST3160.809	1100.95	29.93	-0.07	3.01	33.18	0.81
POST3180.809	1036.63	31.12	-0.03	2.61	32.20	0.93
POST3200.809	976.36	28.66	-0.17	3.28	31.25	0.84
POST3220.809	943.11	36.67	0.13	2.54	30.71	1.43
POST3240.810	913.31	32.78	-0.28	2.64	30.22	1.18
POST3040.812	1556.22	34.36	-0.27	3.55	39.45	1.76
POST3060.812	1459.88	34.31	-0.11	2.65	38.21	0.81
POST3080.812	1380.23	45.97	-0.11	2.21	37.15	1.53
POST3260.810	878.38	30.93	0.54	3.09	29.64	1.09
POST3280.811	845.34	30.31	0.15	3.22	29.07	1.09
POST3300.811	836.59	25.61	0.37	2.41	28.92	0.78
POST3320.811	810.14	29.90	0.11	2.70	28.46	1.10
POST3340.811	781.28	30.27	0.39	2.68	27.95	1.17
POST3040.815	1619.59	45.52	0.56	2.97	40.24	1.28
POST3060.815	1493.16	34.56	0.43	2.88	38.64	0.80
POST3080.815	1427.42	41.51	-0.15	2.74	37.78	1.21
POST3100.815	1425.73	36.74	0.12	3.45	37.76	0.95
POST3100.817	1489.47	370.98	3.09	10.69	38.59	*
POST3100.818	1559.77	36.79	-0.16	2.21	39.49	0.87

2. If we accept the hypothesis of the test of departure from normality, (i.e. decide the data are approximately normal) and if the variance is greater than the mean, then use $4\sqrt{(\text{variance})}$ for the 4σ point.
3. If we accept the hypothesis of the test of departure from normality, but the variance is less than the mean, then use $4\sqrt{\bar{x}}$ for the 4σ point. If the sampled variance were less than the sampled mean, this would imply $\lambda_2<0$, but with distribution we know $0\leq\lambda_2<1$, so we assume $\lambda_2=0$.

With this scheme, the trip points of sample size 64 and those of sample sizes 4094 or 4095 did not differ much; in fact, they are surprisingly close to each other.

4.3 How to prevent a false-alarm, but recognize a true alarm

Using statistic to decide between two hypotheses experimenters can make two kind of errors. One error is called a type I error (with probability usually denoted by a) and in this case is a false-alarm. The other error is called type II error (with probability usually denoted by β which occurs when in fact a true alarm occurs, but is considered a false alarm. Table 3 shows how many incidents will occur for different trip points when the mean of the background distribution is 1225, and the relation to the alternate hypothesis. If a reading comes from the alternate distribution the monitor should detect this with a certain probability. The probability is called the power of the test. Ideally we like to maximize the power $(1-\beta)$ and minimize the probability of a type II error, β.

Suppose the trip point is $1225 + 4\sigma$, then the incident of false-alarms is one in 31,575, or has probability of 0.00003167. However if the alternate distribution has mean $1225 + 6\sigma$, then one in 31 cases will incorrectly be considered a false alarm; the probability of this incident is 0.0323. If the importance is not to misclassify a true alarm, then the trip point must be decreased. Figures 1a, 1b, and 1c show the probability of a type II error in the shaded areas. If the trip point is as large as the mean $+10\sigma$, then essentially all the true alarms would be considered as false alarms, i.e. the probability of a type II error is 100% and the power of the test is zero. Figures 2 and 3 show that there is no point in considering alternative means such as $\bar{\chi}+8\sigma$ and higher, since the underlying distributions are almost disjoint.

Table 3
Trip Point $= \bar{\chi} + s\,\sigma$

s	One Incident of false alarm in	One Incident of True Alarm but considered false, with alternate mean equal to 1225+6σ	1225+7σ	1225+8σ	1225+9σ	1225+10σ
2.576	200	1,283	3.7×10^4	2.0×10^6		
3.0	741	354	7.7×10^3	3.1×10^5	2.3×10^7	3.0×10^9
3.4	3.0×10^3	123	2.0×10^3	6.0×10^4	3.4×10^6	3.4×10^8
3.8	1.4×10^4	48	574	1.3×10^4	5.7×10^5	4.4×10^8
4.2	7.5×10^4	21	189	3.3×10^3	1.1×10^5	6.4×10^6
4.6	4.7×10^5	10	70	927	2.3×10^4	1.0×10^6
5.0	3.5×10^6	6	30	294	5.6×10^3	1.9×10^5
6.0	1.0×10^9	2	6	28	268	4.8×10^3
7.0	7.8×10^{11}	1	2	6	27	245
10.0	1.2×10^{23}	1	1	1	1	2

If the trip point is set at $\bar{x} + 3\sigma$, a probability of a type I error is 0.0013 and probability of type II error is .00279 or twice as large as the probability of a type I error.

For example, suppose we have 4000 subjects go through the monitors each day, or 28,000 each week. If it is permissible to have 1 false alarm each week, then the trip point should be set to mean + 4σ. If the same subject goes through the monitor again the probability he exceeds the trip point again is almost nil (0.00000001). Also suppose the smallest amount of material to be detected is mean + 6σ, and the incident of someone carrying the material occurs once a week, or 52 times a year; then about 2 times per year, the subject with material will go through without detection.

For another example, if one one false alarm per year is desired, the trip point will be mean + 5σ. Suppose the smallest amount to be detected is mean + 6σ, and once a week an individual passes through the monitor with materials. Then more than twice in each quarter (every three months) a subject will pass through the monitor without detection.

Finally if the trip point is set as mean + 10σ, then there will be no false alarms, but even if the material to be carried out is as large as mean + 10σ, it will pass through the monitor with a 50-50 chance of being undetected.

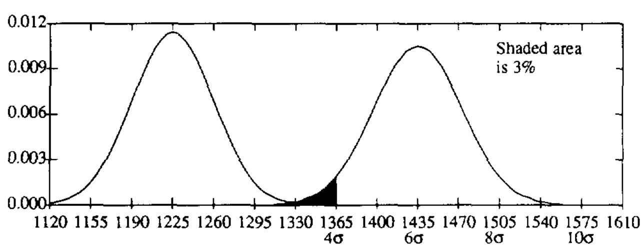


Figure 1a. Alternative mean is $\bar{x} + 6\sigma$ and trip point $1225 + 4\sigma$

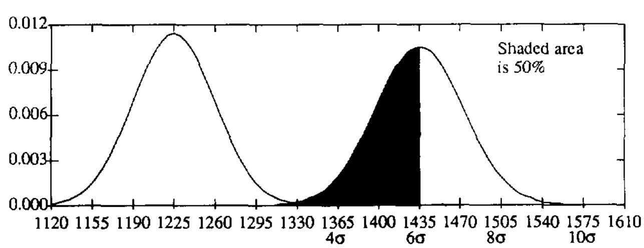


Figure 1b. Alternative mean is $\bar{x} + 6\sigma$ and trip point $1225 + 6\sigma$

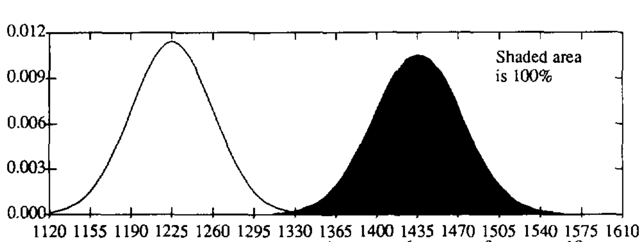


Figure 1c. Alternative mean is $\bar{x} + 6\sigma$ and trip point $1225 + 10\sigma$

5. RECOMMENDED ACTION

An unnecessary false alarm and its investigation involves unnecessary expenditure, but it must detect a true alarm with high probability. One effective plan is to set up a two stage monitoring system. First one has a trip point of mean + 2.576σ ($\alpha = 0.005$); 5 subjects in 1000 will exceed the trip point. Those five will go through a second monitor which has the same trip point as the first one. The probability that a subject exceeds the trip point twice is $(0.005)^2$ or one in 40,000. But this prevents the missclassification of material going through the monitors undetected. If the smallest material to go through the monitor is $\bar{x} + 6\sigma$, the probability of missclassification is 0.0008. Each situation should consider the sensitivity vs. false positive, and determine the probability rationally for each scheme.

APPENDIX

How to test Departure from Normality

1. Assume your set of data could be approximated by normal distribution. Then, we can compute 4 moments of skewness and kurtosis statistics for sample size n.

$$\mu_1(\sqrt{b_{1N}}) = 0,$$

$$\mu_2(\sqrt{b_{1N}}) = \frac{6(n-2)}{(n+1)(n+3)},$$

$$\mu_3(\sqrt{b_{1N}}) = 0,$$

$$\mu_4(\sqrt{b_{1N}}) = \frac{108(n-2)(n^2+27n-70)}{(n+1)(n+3)(n+5)(n+7)(n+9)}.$$

$$\mu_1(b_{2N}) = 3(n-1)/(n+1),$$

$$\mu_2(b_{2N}) = \frac{24n(n-2)(n-3)}{(n+1)^2(n+3)(n+5)},$$

$$\mu_3(b_{2N}) = \frac{1728n(n-2)(n-3)(n^2-5n+2)}{(n+1)^3(n+3)(n+5)(n+7)(n+9)},$$

$$\mu_4(b_{2N}) = \frac{1728n(n-2)(n-3)(n^5+207n^4-1707n^3+4105n^2-1902n+720)}{(n+1)^4(n+3)(n+5)(n+7)(n+9)\cdots(n+13)}.$$

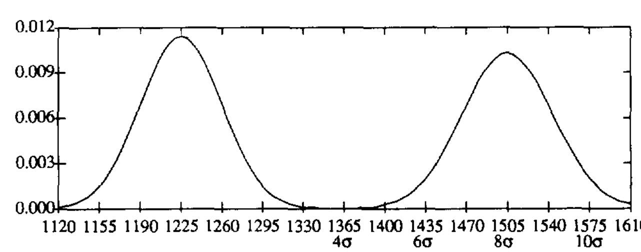


Figure 2. Alternative mean is $\bar{x} + 8\sigma$

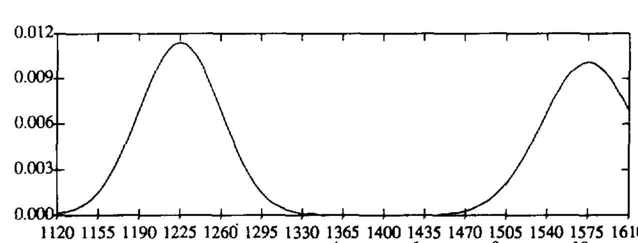


Figure 3. Alternative mean is $\bar{x} + 10\sigma$

Compute $\sigma = \sqrt{(\mu_2)}$, $\sqrt{\beta_1} = \mu_3/\mu_2^{3/2}$ and $\beta_2 = \mu_4/\mu_2^2$ of skewness and kurtosis.

We use four-moment fits of the Johnson translation system of distributions to approximate the distribution of $\sqrt{b_1}N$.

Find the parameters of the Johnson translation system of distributions using a method developed by Bowman and Shenton (1980).

$$\delta_1, \lambda_1 \text{ for } \sqrt{b_{1N}}, \ (\gamma_1, \zeta_1 = 0).$$

We repeat the same procedure to approximate the distribution of b_{2N}, and find the parameters of the Johnson translation system of distributions

$$\gamma_2, \delta_2, \lambda_2, \zeta_2 \text{ for } b_{2N}.$$

The shorter version of a computer program is included.

2. Take a sample of size n. We have a set of data $\chi_1, \chi_2, \cdots \chi n$.

3. Compute first 4 moments of data.

$$m_r = \sum_1^n \frac{(x_i - \bar{x})^r}{n}, \text{ where } \quad \bar{x} = \sum_1^n \frac{x_i}{n} \text{ and } (r = 2,3,4).$$

4. Compute $\sqrt{b_1 s}$ and $\sqrt{b_2 s} \cdot \sqrt{b_1 s} = m_3/m_2^{3/2}$, and $\sqrt{b_2 s} = m_4/m_2^2$.

5. Compute a test statistic for the omnibus test of departure from normality (Bowman and Shenton, 1975).

$$T = X_s^2(\sqrt{b_{1s}}) + X_k^2(b_{2s})$$

where

$$X_s(\sqrt{b_{1s}}) = \delta_1 \sinh^{-1}(\sqrt{b_{1s}}/\lambda_1),$$

$$X_k(b_{2s}) = \gamma_2 + \delta_2 \sinh^{-1}\{(b_{2s} - \zeta_2)/\lambda_2\}$$

$$\sinh^{-1}(y) = \ln\{y + (y^2+1)^{1/2}\}.$$

6. If T is greater than the specified α level of χ^2 distribution with 2 degrees of freedom, reject the hypothesis that the distribution is normal.

Percentage Points of χ^2 Distribution with 2 d.f.

α	25%	20%	10%	5%	2.5%	1%	0.5%	0.1%
χ^2	2.77259	3.21888	4.60517	5.99146	7.37776	9.21034	10.5966	13.8155

Johnson S_U fit Subroutine

```
      subroutine johnsu(u1,sig,rb1,b2,gam,delta,lambda,
     * zeta,uy,sigy,itype,ifail)
c
c     input parameters (on return, unchanged)
c       u1 = mean of distribution
c       sig = sigma of distribution
c       rb1 = skewness
c       b2 = kurtosis
c     output parameters
c       gam, delta, lambda, zeta
c       itype = 1.....Sb distribution
c       itype = 2.....lognormal distribution
c       itype = 3.....Su distribution
c     error messages
c       ifail = 1.....rb1, b2 in the impossible area
c       ifail = 2.....rb1 is greater than 9
c       ifail = 3
c       ifail = 0 on successful computation
c
c     this program computes uy and sigy of su distribution
c
      implicit real*8(a-h,l,o-z)
      dimension h1(10),h2(10),u(2)
      data h1/1.333848465690817d00, -5.455870858760243d-1,
     * 4.120727348534858d-1, 4.557065299738849d-2,
     * -7.219603313144450d-2, 2.459166955114776d-2,
     * -3.989549653042761d-4, 1.018227677593445d-3,
     * -8.686256219859072d-4, 2.000771886697820d-4/
      data h2/1.000000000000000d00, -3.621879838877379d-1,
     * 2.677096382861022d-1, 2.215014552020006d-2,
     * -3.727562379795881d-2, 1.266073347716621d-2,
     * -9.985226235607946d-5, 2.517660829639101d-4
     * -2.555913695361249d-4, 6.266097479093280d-5/
         pi = 4d0*datan(1d0)
         const = 1d0/dsqrt(2d0*pi)
         b1 = rb1*rb1
c
c     find beta2 value on the lognormal line
c
      ome1 = 1d0
      do 60ij = 1,100
      ome2 = 1d0 + b1/(ome1 + 2d0)**2
      dd = dabs(ome2-ome1)
      if(dd.1t.1d-7) go to 65
   60 ome1 = ome2
   65 b21 = ome2**2*(3d0 + ome2*(2d0 + ome2))-3d0
c
      if(b2-b1-1d0.1e.0d0) go to 200
      if(b2.gt.b21) go to 50
      if(b2.eq.b21) go to 500
      if(b1.1t.1d0)ii = 1
      if(b1.ge.1d0.and.b1.1t.4d0)ii = 2
      if(b1.ge.4d0.and.b1.1e.9d0)ii = 3
      if(b1.gt.9d0) go to 300
      itype = 1
      return
  200 ifail = 1
      return
  300 ifail = 2
      return
  400 write(6,5)
    5 format('computing sb moments failed')
      return
  500 itype = 2
      return
   50 itype = 3
      s2 = b2-3d0
      d5 = h1(1) + h1(2)*b1 + h1(3)*s2 + h1(4)
     *b1**2 + h1(5)*b1*s2 +
     * h1(6)*s2**2 + h1(7)*b1**3 + h1(8)*b1**2*s2 +
     * h1(9)*b1*s2**2 + h1(10)*s2**3
      d6 = h2(1) + h2(2)*b1 + h2(3)*s2 + h2(4)
     *b1**2 + h2(5)*b1*s2 +
     * h2(6)*s2**2 + h2(7)*b1**3 + h2(8)*b1**2*s2 +
     * h2(9)*b1*s2**2 + h2(10)*s2**3
      dum = 2d0*b2-2d0*b1*d5/d6-2d0
      omega = dsqrt(dsqrt(dum)-1d0)
```

```
delta = dsqrt(1d0/dlog(omega))
c1 = omega**3 + 3d0*omega**2 + 6d0*omega + 6d0
c2 = omega**4 + 3d0*omega**3 + 6d0*omega**
   2 + 7d0*omega + 3d0
c3 = omega**5 + 3d0
*omega**4$
   mp6d0*omega**3 + 10d0*omega**2
*  + 9d0*omega + 3d0
ca = (omega-1d0)*c1*8d0-8d0*s2
cb = (omega-1d0)*c2*8d0-8d0*s2*(omega + 1d0)
cc = (omega-1d0)*c3-2d0*(omega + 1d0)**2*s2
dum = cb**2-4d0*ca*cc
dum1 = (-cb + dsqrt(dum))*0.5d0/ca
dum2 = (-cb-dsqrt(dum))*0.5d0/ca
if(dum2.gt.dum1) dum1 = dum2
co = dlog(dsqrt(dum1/omega) + dsqrt(dum1/omega + 1d0))
if(rb1.1t.0.d0.and.co.1t.0d0) co = -co
if(rb1.gt.0d0.and.co.gt.0d0) co = -co
if(rb1.eq.0d0) co = 0d0
gam = co*delta
ro = dsqrt(omega)
uy = -ro*(dsinh(co)
sigy = dsqrt(0.5d0*(omega-1d0)*(omega*dcosh(2d0*co)
*  + 1d0))
lambda = sig/sigy
zeta = u1-uy*lambda
return
end
```

ACKNOWLEDGEMENT

The author acknowledges the Y-12 Development Division for supporting this work under contract DE-AC05-84OR21400 with the Martin Marietta Energy System, Inc.

REFERENCES

1. Bowman, K.O. and Leach, E. (1983). *Confidence Limits for the Expectation of a Poisson Variable: Figures and Tables,* ORNL/CSD-115, Oak Ridge National Laboratory.
2. Bowman, K.O. and Shenton, L.R. (1975). "Omnibus" Test Contours for Departures from Normality Based on *sartb*$_1$ and b_2, *Biometrika,* 62, 243-250.
3. Bowman, K.O. and Shenton, L.R. (1980). Evaluation of the Parameter of S_U by rational fractions, *Commun. Stat. Computa.,* 9, 127-132.
4. Bowman, K.O. and Shenton, L.R. (1985). The Distribution of a Moment Estimator for a Parameter of the Generalized Poisson Distribution, *Commun. Stat. Computa.,* 14, 867-893.
5. Bowman, K.O. and Shenton, L.R. (1986). Moment $(\sqrt{b_1}, b_2)$ Techniques, *Handbook of Goodness of Fit Techniques,* ed., R.B. D'Agostino and M. Stephens, Marcel Dekker, Inc. 277-327.
6. Consul, P.C. (1989). *Generalized Poisson Distributions: Properties and Applications,* Marcel Dekker, Inc., New York.

Dr. Kimiko O. Bowman is a senior scientist in the Mathematical Sciences Section of the Engineering Physics and Mathematics Division at Oak Ridge National Laboratory. Dr. Bowman's research interests are estimation theory and computational approaches to statistical inference using supercomputers. She has been an author and co-author of more than 150 technical publications and three books. Dr. Bowman is a fellow of the Institute of Mathematical Statistics, the American Statistical Association, and the American Association for the Advancement of Science. She is an elected member of the International Statistical Institute. She earned an M.S. and Ph.D. in statistics from Virginia Polytechnic Institute and State University, and an Engineering Doctorate in Mathematical Engineering from Tokyo University. She is the only non-Japanese citizen to have earned a doctorate in engineering from Tokyo University.

Steven Wallace received a B.S. in Physics from Purdue University, in 1962. Since 1968, he has been on the staff of the Development Division of the Y-12 Plant, currently operated for the U.S. Department of Energy by Martin Marietta Energy Systems, Inc. He is an author/co-author of four patents. In recent years, Wallace has focused his development activities on safeguards and security, and radiological and environmental monitoring.

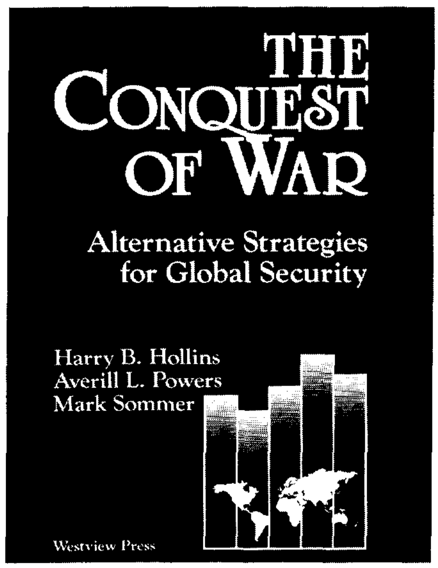
Engineering Peace

***The Conquest of War: Alternative Strategies for Global Security* by Harry B. Hollins, Averill L. Powers, and Mark Sommer, Westview Press, Boulder, Colo., 1989, 244 p.**

The year 1989 ranks, like the years 1789, 1815, 1919, and 1945, as a watershed in the affairs of nations when a previous world order has disintegrated and a new one has yet to be established. The relaxing of Soviet hegemony over Eastern Europe and the virtual disappearance of the cold war provide opportunities for creating a more sane world order that have not existed for the past 45 years. The creation of such a system will require the utmost in wisdom, vision, pragmatism, and flexibility on the part of political leaders of all the major countries. In this context, the appearance of the book *The Conquest of War: Alternative Strategies for Global Security* at this time is significant.

Much of the material in this book should be of particular interest to specialists in the area of nuclear safeguards. Nuclear safeguards, which involves science, technology, public administration, politics, and, in the case of international safeguards, diplomacy, shares many common elements with arms control activities and with activities of broader scope whose purpose is the attainment of common security among nations. For this reason, many safeguards professionals have acquired a deep interest in arms control and related subjects, and, in some instances, are contributing new approaches and technology in these areas.

In *The Conquest of War* the authors provide a comprehensive overview and history of the approaches and institutions that have been proposed over the last few decades for the achievement of common security. By necessity, the book is an introduction to the subject, and accordingly, does not treat any individual area in great depth. In particular, specialists may find that the subject of verification technologies is afforded only a rather brief treatment. This may reflect the reality that the technical problems of arms control may prove more readily soluble than the political tasks of changing existing institutions and creating new ones.



The book consists of four parts: 1. An introduction which describes the problems to be overcome and presents the essential requirements for a system which will achieve the desired goals, 2. An analysis of the potential utility of the United Nations as an instrument for achieving global security, and a description of six alternative approaches to this goal, 3. Issues common to all of the above approaches, namely verification technology, international law, and the problems of converting a heavily defense-based economy to other, civilian activities, and 4. Proposals of the authors for integrating the different approaches into a common security system.

Much of the discussion in the introduction covers topics that are self-evident, including the extreme costs of modern warfare in human and material terms, the survival of war as an instrument of national policy, and the basic requirements for its elimination, but they are nevertheless worth stating. Throughout history, was has served two purposes, aggrandizement and self-protection. Its persistence is understandable when we consider that until very recently it was a zero sum game that was immensely profitable for the winners; for example, in the centuries prior to 1945 the European colonial powers had acquired enormous power and wealth by utilizing warfare, or the threat of war, to acquire raw materials, markets, and the labor of subject peoples, and to deny these assets to rival countries. World War II originated, to a certain degree, in an attempt by several of these rival nations to gain access to this exclusive club. The dissolution of colonialism in the years after 1945 has led to a world economy which may be thought of as a level playing field with relatively equal access to raw materials and markets for all players. In this situation, national prosperity is achieved through technology, education, and social and cultural conditions conducive to high productivity, rather than through military power, and many small and medium-sized countries with negligible military establishments have managed to prosper. Thus the sole remaining rationale for maintaining a military establishment is self-protection, rather than economic advantage. The value of this attribute of military power has been continually eroded by the continuing increase in the destructiveness and lethality of modern weapons; while it is generally accepted that a nuclear exchange between two countries would be suicidal it is not as commonly recognized that advances in military technology have made conventional warfare ever more costly—the firepower of a modern infantry division is ten times greater than that of its World War II counterpart, for example. The achievement of security solely through military means thus has become increasingly dangerous and costly, while the gains to be realized from the use of military power have diminished simultaneously. In this situation the potential benefits to be realized from pursuing alternate means for achieving national security are large indeed.

The authors make a number of interesting comments in this section on what are, effectively, the boundary conditions for a viable common security system. They make the important point that when a social institution is abolished, the essential functions performed by that institution must be performed by other, newly-created institutions. When slavery was abolished in the United States, for example, the vigorous, free-market economy that had evolved in the northern states provided a viable replacement for the slave-based economy that had been eliminated. Similarly, if war and the use of military power as an instrument of national policy are to be eliminated, the essential functions they have performed for nation-states will have to be provided by other institutions. New means will have to be provided to resolve international conflicts, and countries will need alternate means to achieve the security previously provided by their military establishments. To a certain extent, this security may be obtainable only through cooperation with (former) adversaries. The essential goals of such a system for common security are:

- To avoid nuclear war
- To avoid conventional war
- To prevent proliferation of nuclear weapons
- To reduce military spending

Given the imperfect nature of all political institutions, it is essential that such a system be robust, able to function and provide the minimum necessary level of security in all situations.

In the next section, Chapter 3 deals with a prospective usefulness of the United Nations as a model and a starting point for the organizations and institutions that will be required for a common security system. There is an interesting discussion of the evolution of the UN from its organizing principle of armed collective security (which was never adopted in practice) to its current peacekeeping role. Although the weaknesses of the UN are well known, it is the only existing international organization dedicated to the achievement of global security, and it has achieved some significant successes in the area of conflict resolution, in particular, in the Middle East, the Congo, and Cyprus. The authors discuss the peacekeeping activities of the UN in some detail; the attributes and practices of successful UN missions establish a tradition with obvious utility in future conflict-resolution activities.

Chapter 4 describes the sweeping disarmament plan devised by two distinguished American lawyers, Grenville Clark and Louis B. Sohn. Clark's accomplishments extended over many years—in 1915, in anticipation of the eventual involvement of the United States in the war in Europe, he had played a key role in the establishment of the training camps at Plattsburg, New York, where 80 per cent of the officers who later served in France received their training. Sohn was a law professor who later occupied the prestigious chair of Bemis Professor of Law at the Harvard Law School. The principal features of the Clark-Sohn plan included a number of revisions of the United Nations charter, including a greatly strengthened General Assembly, major modifications in the Security Council, an expanded and strengthened world judicial and conciliation system, and a permanent UN Peace Force several hundred thousand strong. The plan envisioned the complete elimination of all national military establishments. Although the Clark-Sohn plan was never seriously considered in the political realm, it nevertheless influenced the thinking of a number of political leaders, especially during the early years of the Kennedy administration. At that time, extensive negotiations were carried on between John J. McCloy, President Kennedy's disarmament advisor, and Valerian Zorin, the Soviet ambassador to the United Nations. In the end these negotiations failed to bear fruit because of irreconcilable differences in the philosophies of the two powers over the issues of inspection and verification, and subsequent negotiations focused on the much narrower issue of arms control.

Chapter 5 deals with the question of minimum deterrence—a policy under which a nation maintains only the minimum number of nuclear weapons necessary to inflict unacceptable damage on an adversary in the event of a nuclear exchange. The government of France has adopted such a policy unilaterally, maintaining only enough warheads to render an attack by the Soviet Union unprofitable. It is evident, however, that the Soviet Union and the United States will adopt such a policy only on the basis of a mutually satisfactory agreement. In the years from the Eisenhower administration to the present a number of defense experts have examined this policy, considering the reduction of nuclear arsenals to levels ranging from 400 to 2000 warheads. The authors discuss the key issues that underlie a viable agreement in this area, namely the "mix" of delivery systems that will lead to maximum stability and the strengthening of conventional forces, largely in Western Europe, to maintain the required level of security.

Chapters 6 and 7 deal with two closely related topics, qualitative disarmament and nonprovocative defense. By qualitative disarmament is meant the planned multilateral reduction in offensive armaments on the basis of negotiated agreements. Nonprovocative defense, on the other hand, is the unilateral structuring of the defense forces of a single country so as to eliminate the capability for offensive operations against neighboring countries while at the same time preserving the ability to inflict unacceptable losses on an invading force. Sweden, Switzerland, and Yugoslavia have adopted this policy. These concepts clearly are central to current thinking about the defense of Western Europe and with respect to possible mutual reductions in the levels of NATO and Warsaw Pact forces.

The authors present an interesting history of the development of the concept of qualitative disarmament. In 1931 the great military strategist Liddell Hart, who had already developed the theory of the employment of armored forces which later played a decisive role in World War II, was asked by his government to formulate an official policy to be presented at the disarmament conference to be held in Geneva the following spring. In a complete about face from his previous work, he developed a sweeping plan for the elimination of all categories of offensive weapons. This plan was presented by the British government at the Geneva conference, was subsequently adopted and put forth by President Herbert Hoover, and gained wide acceptance, including support from France, the Soviet Union, Germany, and Italy. Finally, however, in the face of opposition from conservative elements in the British government, the plan failed to be adopted. Although the plan was further supported by Franklin Roosevelt in 1933, Germany commenced to rearm, and the opportunity for its implementation was lost. One can only speculate what course European history might have taken had Liddel Hart's plan been adopted in 1932.

Most readers will find the Chapter 8, on civilian-based defense (passive, non-violent resistance), while in itself interesting, less relevant to current global security concerns than most of the other material in the book. The authors do make the important point that in today's world, even the most authoritarian regimes cannot ignore the popular will, citing the example of the Solidarity movement in Poland, and the success of a mass movement of civilians in the Philippines in heading off a civil war between defecting military forces and forces loyal to President Marcos. They also cite an interesting example of the first known successful feminist rebellion, a strike (similar to the fictional one conducted by the women of Athens and Sparta in Aristophanes' Lysistrata) carried out by the women of the Iriquois Nation in the seventeenth century which forced the men of the tribe to cease their traditional warfare.

Chapter 9, on strategic defense, reviews the arguments for and against such systems, discussing the technical problems, the effect of such systems on the stability of the system of mutual deterrence, and their probable cost. Readers who have followed the public debate on the Strategic Defense Initiative during the last several years will already be familiar with most of this material.

The second section called "Keeping the Peace: Issues Common to All Approaches" contains three chapters on verification, international law, and the problems associated with the conversion of a defense-based economy to other activities. The rather short chapter on verification treats all of the principal verification techniques and the problems faced in their implementation. The material will be familiar to most readers. The chapter on international law consists of a lucid essay written two decades ago by Roger Fisher. It deals largely with the question of the voluntary compliance of individual nations with international law, an issue critical to the validity of any system of alternative security. The chapter on economic conversion summarizes the results of a number of studies on the important question, frequently raised, of the impact of the conversion of our defense industries to other types of economic activity. This is by no means a hypothetical question. The two largest public works programs in the world—the Soviet and American defense programs—have been funded, on the Soviet side, by denying their citizens goods and services viewed as necessities in the west, and on the American side, by massive annual budget deficits resulting in the acquisition of an enormous public debt, with, concurrently, a very low rate of saving and investment in what is, increasingly, an aging industrial base. Clearly, neither of these courses of action are sustainable over the long term, so that eventually, major reductions in defense spending are inevitable. The chapter discusses the resources that would be released in the conversion process, possibilities for their utilization, and the mechanisms for carrying out the conversion process.

In the third section of the book, "Proposals for Transformation," the authors present their proposal for a common security system, which is a synthesis of the approaches explored in Part 1. While one may question individual arguments in this section, its overall sanity and reasonableness are evident.

The Conquest of War: Alternate Strategies for Global Security is a comprehensive and balanced treatment of the major concepts that have been developed over the last six decades on achieving world peace. It is a useful introduction to the subject. The extensive bibliography should be useful for those who wish to pursue individual topics further.

Walter Kane, Brookhaven National Laboratory, Upton, New York, U.S.A.

Posts Vacant in the IAEA

The Department of State, the U.S. Arms Control and Disarmament Agency and the Department of Energy have initiated a program to improve recruitment of U.S. nationals for employment in the IAEA.

In an effort to support this program, *JNMM* will publish IAEA vacancies.

Department of Administration

Division: Personnel *Section:* Personnel Management *Position:* Head of Unit *Grade:* P-4 *Vacancy* #89/092 *Opened:* 19 Dec 1990 *Closing:* 19 April 1990

Department of Nuclear Energy and Safety

Division: Nuclear Safety *Section:* Engineering Safety Section *Position:* External Hazard Prevention Specialist *Grade:* P-5 *Vacancy* #89/079 *Opened:* 7 Nov 1989 *Closing:* 7 Mar 1990

Division: Nuclear Fuel Cycle & Waste Mgmt *Section:* Nuclear Materials & Fuel Cycle Technology *Position:* Mining Engineer *Grade:* P-4 *Vacancy* #89/082 *Opened:* 7 Nov 1989 *Closing:* 7 Mar 1990

Division: Nuclear Safety *Section:* Radiation Safety Section *Position:* Environmental Protection Specialist *Grade:* P-4 *Vacancy* #89/091 *Opened:* 19 Dec 1989 *Closing:* 19 Apr 1990

Department of Research and Isotopes

Division: *Position:* Head Chemistry Unit *Unit:* Agency Laboratories, Seibersdorf *Grade:* P-4 *Vacancy* # 89/084 *Opened:* 28 Nov 1989 *Closing:* 28 Mar 1990

Division: Physical & Chemical Sciences *Section:* Nuclear Data *Position:* Data Service Specialist *Grade:* P-2 *Vacancy* #89/087 *Opened:* 28 Nov 1989 *Closing:* 28 Mar 1990

Department of Safeguards

Division: Development & Technical Support *Section:* Development & Field Support *Position:* Instrumentation Engineer *Grade:* P-4 *Vacancy* #89/085 *Opened:* 28 Nov 1989 *Closing:* 28 Mar 1990

Division: Concepts & Planning *Section:* System Studies *Position:* Safeguards Analyst *Grade:* P-4 *Vacancy* #89/086 *Opened:* 28 Nov 1989 *Closing:* 28 Mar 1990

Division: Development & Tecnhical Support *Section:* Instrumentation Development & Field-Support *Position:* Nuclear Instrumentation Specialist *Grade:* P-5 *Vacancy* #89/088 *Opened:* 19 Dec 1989 *Closing:* 19 Apr 1990

Division: Division of Operations B *Section:* OB 3 Section *Position:* Unit Head *Grade:* P-5 *Vacancy* #89/089 *Opened:* 19 Dec 1989 *Closing:* 19 Apr 1990

Division: Division of Operations B *Section:* OBP Section *Position:* Unit Head *Grade:* P-5 *Vacancy* #89/090 *Opened:* 19 Dec 1989 *Closing:* 19 Apr 1990

Department of Technical Co-operation

Division: Technical Co-operation Implementation *Section:* Fellowships & Training Section *Position:* Fellowship Officer *Grade:* P-3 *Vacancy* #89/080 *Opened:* 7 Nov 1989 *Closing:* 7 Mar 1990

Division: Technical Co-operation Programmes *Section:* Africa Section *Position:* Area Officer *Grade:* P-4 *Vacancy* #89/081 *Opened:* 7 Nov 1989 *Closing:* 7 Mar 1990

Division: Technical Co-operation Programmes *Section:* RCA Office *Position:* RCA Coordinator *Grade:* D-1 *Vacancy* #89/083 *Opened:* 21 Nov 1989 *Closing:* 21 Mar 1990

How to Apply

Applications must include a vacancy notice number, and should be mailed to the United States Mission to the International Atomic Energy Agency, Kundmanngasse 21, 1030 Vienna, Austria (Attention Ronald Bartell). After U.S. Government endorsement is given, the Mission will forward the application to the Division of Personnel at the IAEA.

U.S. Candidates must also send a photocopy of the original application to: (for positions in the Department of Safeguards) P.O. Box 650, Brookhaven National Laboratory, Upton, NY 11973, (for all other positions) IO/T/SCT, Rm. 5336, Department of State, Washington, D.C. 20520.

For more information contact Mr. W. Porter, Department of Energy, (202) 586-8253, FTS 586-8253. Potential applicants should leave their name, address, and position in which they are interested. DOE will then forward a package of information on the IAEA and the position for which they applied.

ADVERTISER INDEX

EQUIPMENT, MATERIALS & SERVICES

Portable PLUS Spectroscopy Workstation

Canberra Nuclear Products Group (Meriden, CT and Schaumburg, IL) announces the Portable PLUS, a portable and battery-powered integrated spectroscopy workstation. The system mates a Laptop Personal Computer with the Model 1150 Portable PLUS Acquisition Unit. The Laptop PC runs AccuSpec MCA analysis software.

The Portable PLUS is designed for Germanium gamma spectroscopy. The Acquisition Unit features 4K memory, 2^{24} 1 counts per channel, a 100 MHz ADC and a programmable high voltage power supply. The ASAP Radionuclide Analysis Package can be added to resolve more difficult spectra.

Contact Canberra Nuclear Products Group at 800/243-3955.

Zoom TV Inspection for High Radiation Environments

Imaging and Sensing Technology Corp (ISTC) introduces its integral zoom TV inspection system, the ETV-1255, a camera specifically designed for inspection and surveillance in high radiation environments.

The ETV-1255 zoom camera can tolerate a gamma dose rate of 2×10^6R, and a cumulative radiation dose of 10^8R. It features remote controls for the zoom lens (12mm to 72mm), iris (f1.8 to f16), and focus (1 inch to infinity).

Resolution of the system is 550 TV lines/raster height. The ETV-1255 will operate in air or underwater.

ISTC supplies miniature TV inspection systems for a variety of applications, such as reactor vessel inspection, nuclear fuel inspection, fueling support operations, pipe inspection and geotechnical inspections.

For more information, contact ISTC, 607/796-3372.

CALENDAR

March 12-16, 1990
Seminar on Nuclear Science for Peace and Development, Kampala, Uganda *Sponsor:* Organization of African Unity and the Economic Commission for Africa *Contact:* Organization of African Unity, P.O. Box 3243, Addis Ababa, Ethiopia

March 19-23, 1990
Materials Accounting For Nuclear Safeguards, Los Alamos Inn, Los Alamos, New Mexico USA *Sponsor:* U.S. Department of Energy, Los Alamos National Laboratory *Contact:* Los Alamos National Laboratory, Los Alamos, New Mexico USA 87545, phone (505) 667-7777, or FTS-843-7777.

March 21-23, 1990 has been rescheduled
"The Quiet Revolution: Innovations in Low-Level Waste Management," This international symposium on low level radioactive waste issues will be rescheduled in early spring or summer of 1991 in Chicago, Illinois USA *Sponsor:* Illinois Department of Nuclear Safety, Springfield, Illinois, USA *Contact:* Illinois Department of Nuclear Safety (217) 785-9900.

April 4-5, 1990
26th Annual Meeting of the National Council on Radiation Protection and Measurements, Mayflower Hotel, Washington, D.C. USA *Sponsor:* National Council of Radiation Protection and Measurements *Contact:* NCRP, 7910 Woodmont Ave., Suite 800, Bethesda, Maryland, USA 20814, phone (301) 657-2652.

April 8-12, 1990
International High-Level Radioactive Waste Management Conference & Exposition, Caesar's Palace Hotel, Las Vegas, Nevada, USA *Sponsor:* American Nuclear Society and the American Society of Civil Engineers *Contact:* ANS Meetings Dept., 555 N. Kensington Ave., La Grange Park, Illinois, USA 60525, phone (708) 352-6611.

April 9-11, 1990
23rd Japan Atomic Industrial Forum (JAIF) Annual Conference, Kyoto International Conference Hotel, Kyoto, Japan *Sponsor:* JAIF *Contact:* JAIF, Dept. of Planning and International Affairs, 1-13, Shimbashi 1-chome, Minato-ku, Tokyo 105, Japan, phone (03) 508-2411, ext. 54, or (03) 508-9056, fax (03) 508-2094.

June 4-7, 1990
Emerging Technologies For Hazardous Waste Treatment, Atlantic City, New Jersey USA *Sponsor:* American Chemical Society *Contact:* Dr. D. William Tedder (404) 894-2856.

June 10-15, 1990
1990 ANS Annual Meeting (and Nuclear Power & Technology Exhibit), Opryland Hotel, Nashville, Tennessee, USA *Sponsor:* American Nuclear Society *Contact:* General Chair Donald B. Trauger, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee USA 37831-6254, phone (615) 576-6730.

September 30-October 3, 1990
International Symposium on Handling Hazardous Materials/Wastes: Social Aspects of Facility Planning and Management, Harbour Castle Westin Hotel, Toronto, Canada *Sponsor:* Institute For Social Impact Assessment *Contact:* Ingrid Norrish, Conference Management Director, Social Aspects Symposium, phone (416) 675-3111, ext. 4459 or fax (416) 675-0135.

October 3-5, 1990
Spectrum '90: Nuclear and Hazardous Waste Management International Topical Meeting, Hyatt Regency Hotel, Knoxville, Tennessee USA *Sponsor:* American Nuclear Society Fuel Cycle and Waste Management Division, the ANS Oak Ridge/Knoxville Section and the University of Tennessee *Contact:* Technical Program, Spectrum '90, P.O. Box 1342, Oak Ridge, Tennessee USA 37831 or phone Earl McDaniel (615) 574-0439 (FTS-624-0439) or Karl Notz (615) 574-6632 (FTS-624-6632).