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# NUCLEAR MATERIALS MANAGEMENT

25
SAFEGUARDS
INMM
RELIABILITY
ASSURANCE
YEAR ANNIVERSARY 1959-1984

Journal of the
INSTITUTE
OF
NUCLEAR
MATERIALS
MANAGEMENT

# FEATURE ARTICLES



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# EDITORIAL

**DR. WILLIAM A. HIGINBOTHAM**
Brookhaven National Laboratory
Upton, New York

From time-to-time, and when it seems to be appropriate, the INMM and the Isotopes and Radiation Division of the American Nuclear Society organize a topical conference on some aspect of safeguards. The latest of these was held on Hilton Head Island, S.C., from November 28 through December 2. The topic was "The Process—Safeguards Interface," that is, to determine what progress has been made in matching safeguards R & D to the actual needs of national governments and the IAEA and in achieving safeguards objectives at the plant level. This is obviously an important subject.

The organizers of this special conference deserve a great deal of credit for the idea of the conference and for carrying it out so effectively. They were able to obtain the presence and the participation of a substantial number of the nuclear facility personnel who are subject to domestic and international safeguards in the U.S., Euratom and Japan, who not only reported on their experiences, but also on the contributions which they have made to safeguards techniques.

In the past there has been a tendency for officials to define safeguards requirements and for R & D groups to design instruments, without paying much attention to just how nuclear facilities really operate, resulting in inefficiency and frustration. These problems are gradually being overcome, as this meeting demonstrated, at least as regards cooperation between facility and R & D personnel. However, there still appears to be some distance between these applied safeguards groups and the officials who define the policies in the U.S. Although the Department of Energy was reasonably well represented and DOE personnel presented two papers, the Nuclear Regulatory Commission sent two observers and no other U.S. Government Agencies were represented at all. This lack of participation was surely not the fault of the organizers.

Summaries of most of the papers were printed before and distributed at the meeting. The full text of all the papers will be published in the near future, thanks to the interest and support of the Office of Safeguards and Security, U.S. Department of Energy. This volume will be of considerable interest to the technical people who were not able to attend and hopefully will be read by the officials who did not take the time to attend the meeting.



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# LETTERS TO THE EDITOR

Dear Sir:

Last year's Winter issue of Nuclear Materials Management contained an article by L. W. Kruse and B. Domingues[1] that reported their observations of shortcomings in the counting statistics of commercial radiation monitors for detecting diversion of special nuclear material. In particular, their Table I listed discrepancies between measured and predicted variance as large as a factor of 14 in commercial monitors that they had examined. I was quite interested in this result because it indicates that false alarms can occur much more frequently than in a properly operating monitor where the predicted and measured variance are identical. If this type of operation existed in field use, the excessive false alarm rate could lead to a lessening of confidence in a monitor's operation and a likelihood that significant alarms might be ignored.

To determine the significance of the Kruse-Domingues results, I visited four DOE facilities that use radiation portal monitors for personnel security monitoring and examined the performance of 19 individual monitors. Each type listed in the article was well represented. I was able to examine the counting statistics with a small hand-held instrument called a variance analyzer[2,3]. The variance analyzer attaches to the logic signal line entering the monitor's control and decision electronics. The analyzer makes a series of counts from which it calculates the variance and mean for the group. The variance is compared to its expected value, the mean, and the comparison result is displayed. The comparison procedure continues as long as desired during which time it averages results to obtain higher precision. Typical results of my investigation fell in the range $1.07 \pm 0.07$ which tells me that these radiation monitors with typical field maintenance are indeed operating properly with normal counting statistics.

While the expected problem did not materialize, I did find local problems in operating and maintaining the monitors. The one that seemed particularly important is that a microprocessor used in the first digital portal monitor controllers, an Intel 4004, is no longer commercially available. Should this chip fail, the only solution is to replace the entire controller with today's model. Many users are reluctant to take that step because today's prices are very much higher than when the original monitor was purchased. To help solve the dilemma, I would like to encourage any of the readers having excess monitoring equipment or unneeded spare parts containing the Intel 4004 to contact me in Los Alamos.

Finally, I would like to mention that the fewest problems with monitor operation are likely to occur when the monitor's operation is checked with radiation sources on a regular basis so that problems are discovered and quickly repaired. And repairs are most quickly made when adequate spare parts inventory and well trained technicians are available. It is quite important that monitor calibration and maintenance be assigned to technicians who will become proficient in the task and remain on the job for a long period of time. The alternative, treating the job as a step in career development, does not always make adequate time available for thorough training in calibration and maintenance procedures.

I would like to hear about any other monitoring shortcomings that the readers may have experienced.

I can be contacted by mail or phone at the following:

Mr. Paul E. Fehlau
Los Alamos National Laboratory
Advanced Nuclear Technology Group
MS-J562
Los Alamos, NM 87545
Comm: 505/667-5372 or 4839

Sincerely,

P. E. Fehlau

Ref. 1. L. W. Kruse and B. Dominguez, "Development of an Improved Monitor for Portal Detection of the Unauthorized Removal of Special Nuclear Material,", Nuclear Materials Management *4*, 42, 1982.

Ref. 2. P. E. Fehlau and G. S. Brunson, "Coping with Plastic Scintillators in Nuclear Safeguards," IEEE Transactions on Nuclear Science *NS-30*, 158, 1983.

Ref. 3. K. V. Nixon and C. Garcia, "Hand-Held Pulse-Train-Analysis Instrument," IEEE Transactions on Nuclear Science *NS-30*, 331, 1983.

# ENRIGHT JOINS INET

Peter J. Enright has joined INET Corporation of Sunnyvale, California, as Computer Applications Manager. In this capacity, Mr. Enright is responsible for technical direction of all INET computer applications engineering activities. The computer applications group specializes in real-time data acquisition and analysis, information display, and control for complex industrial operations. This includes the design, development, installation and testing of systems for nuclear plan applications, such as safety parameter display systems.

# CARR JOINS JAI

E. R. Johnson Associates, Inc. (JAI) of Reston, Virginia announces the appointment of John A. Carr as Manager of Waste Disposal Systems. Prior to joining JAI Mr. Carr was associated with the Battelle Project Management Division, Office of Nuclear Waste Isolation (ONWI) from 1978-1983. Mr. Carr was Lead Project Manager for nuclear waste packaging facilities and package design. ONWI is a prime contractor to the Department of Energy National Waste Terminal Storage Program (NWTS) with the objective to site, design, develop, and license a repository for the permanent disposal of high level and transuranic waste.

# CHAIRMAN'S COLUMN

**JOHN L. JAECH**
Exxon Nuclear Company, Inc.
Bellevue, Washington

### Looking Ahead

The November meeting of your Executive Committee held in Columbus, Ohio, birthplace of your Organization, focussed on plans for the future. The timing was especially appropriate since the upcoming annual meeting to be held in Columbus on July 15-18, 1984 is the 25th such meeting, an occasion not only to reflect on the past, but also to plan for the future.

Where are we headed? Recognizing that a responsible answer to this question requires careful deliberation, the Long Range Planning Committee (LRPC) chaired by Sam McDowell addressed the question in a series of meetings in recent years. Their final report was delivered to the Executive Committee in July, 1982, and in the succeeding months a proposed action plan to meet the goals set forth by the LRPC was developed. This action plan was referred back to the LRPC for their further comments, and all elements of long range planning came together at Columbus in November, 1983 for Executive Committee approval. After careful consideration, your leadership voted unanimously to pursue a course of action on several fronts that may be characterized as one of growth and expansion. Our newly adopted logo that focusses on the words "safeguards-physical protection-waste management" indicates our goal of significantly broadening our membership base. In a sense, there is no real alternative to expanding our memberships in the directions indicated by this new logo. Responsible management of nuclear materials embraces these elements; we cannot remain the leading professional organization in nuclear materials management without including all aspects of such management.

Such expansion will require the efforts of all our members. Any organization that plans for growth must appeal to each individual member to provide assistance. The Membership Chairman can accomplish very little without the dedicated active cooperation of everyone. If we would each individually seek out one new member, our growth would be phenomenal. Such growth is not an unrealistic hope; it is an achievable goal.

Why expand? Why grow? Why broaden? The answer is very simple. To be in a position where we can continue to offer technical workshops on a broad range of topics related to nuclear materials management; where educational course offerings can be expanded; where monographs on specific subjects of concern can be published; where annual meeting programs can be expanded to provide broader appeal; where new programs not yet conceived can be developed to serve our memberships more fully, and to further the nuclear industry; to perform our various committee activities—to be in this position requires a broad base of membership support. I firmly believe that your organization is at the crossroads; we must expand or we face extinction. This feeling is shared in varying degrees by your Executive Committee and by the members of the Long Range Planning Committee.

One final point. We discussed in Columbus how best to get the membership to recognize the benefits of being an INMM member. Some wise soul, I don't recall who, mentioned in this discussion that perhaps we are approaching this subject from the wrong perspective. Perhaps we need to recall the words of John Kennedy spoken in another context. To paraphrase, "Ask not what the INMM can do for you; rather ask what you can do for the INMM". The fact is that our profession needs your support; the nuclear industry needs your support. By your membership in the INMM, you are demonstrating that you believe in the need for responsible nuclear materials management, in all its aspects, and that you believe in nuclear energy. Won't you join forces with others who believe as you do? The bottom line is that we need you. Please answer the call, accept the challenge, be a vital part of your organization. I make this earnest plea because I have strong convictions that the INMM must survive, that to survive we must expand, and that to expand we need your support.

# SAFEGUARDS COMMITTEE REPORT

**ROBERT J. SORENSON, CHAIRMAN**
Battelle Pacific Northwest Laboratories
Richland, Washington

The Safeguards Committee and its subcommittee have held several meetings since the last report to the INMM membership. The full Safeguards Committee met in mid-September in Washington, D.C. In conjunction with that session the Safeguards Committee also met with Mr. Robert Burnett, Director of the Division of Safeguards, and members of his staff at the NRC. Most of the meeting with NRC was spent discussing the status of NRC's Safeguards rulemaking:

**LEU Reform Rule**
The results of the recent meeting between the LEU Subcommittee and the NRC regarding the LEU Reform rule were briefly reviewed by Mr. Robert Dube. The ACRS has asked to review the rule and will do so concurrently with the NRC Office reviews. These reviews may take two months, but Mr. Dube still expects to submit the final package to the Commission by early 1984. We do not expect any further comment by the INMM.

**Non-Power Reactor Rule**
This rule was published for comment in July. The TRTR group met in October in Boston to discuss the rule. The proposed rule, which deals with research reactors which use Category I material, is basically a security measure which potentially effects fourteen reactors. For fuel at 100 Rem/hr, the requirements are equivalent to those for Category II.

**Transportation Rules**
Two safeguards rules are being revised. Changes were proposed to 10 CFR 40, 70, and 73 to require assurance to countries signatory to International Convention that the U.S. will protect material in international shipments. The rule change will require that transient shipments of Cat I, II, III and source material be protected. The main impact will result from including some 2000 additional shipments of source material in the reporting system.

The second rule being changed is a modification to the spent fuel rule, 10 CFR 73.37, which takes into account new risk estimates from sabotage of spent fuel shipments. A peer review is underway by the U.S. Army Ballistic Research Lab at Aberdeen. The peer review is not expected to alter the lowered risk estimates of Sandia and Battelle.

**Power Reactor Rules**
The several power reactor rules were clarified. Three main rules are being developed. The Insider Rule package, which involves access authorization, some special requirements and miscellaneous amendments, has gone to the Commission.

The Access Authorization rule dates from 1977. The rule replaces the current ANSI Standard 18.17. The relationship between safety and safeguards in power plants continues to be reviewed. A special hearing board has made recommendations, and legislation has been written by the NRC to allow criminal history information from the FBI to be used by licensees in selecting personnel. The DOJ endorses this legislation, and it is expected to be both permanent and enacted by Congress. The same criteria will be applied to both permanent and temporary workers. This rule could affect the fuel vendors who provide personnel to work at reactors during fuel outages. The new vital island concept, which requires that the five reactor areas must always be in separate islands, was also discussed.

Also reviewed at the meeting with Mr. Burnett were the results of a meeting of several utilities with the Government Liaison Subcommittee to discuss the recent IAEA experience at U.S. reactors. The meeting was useful in clarifying several issues and airing utility problems in the implementation of the U.S. officer.

A discussion with the NRC was held on their plans regarding regionalization. The Committee was assured that major licensing actions, like the LEU reform rule, will be handled at the headquarters level. Responsibility for part 70.32 changes, which are already being handled in Regions I and II, will transfer to the other regions by October, 1984. In the 1985-1986 timeframe, Part 70.34 changes may be also handled by the regions. The NRC is taking several steps to assure that uniformity between the regions will prevail and that an orderly transition will occur.

**Physical Protection Subcommittee**
The new subcommittee on Physical Protection, Chaired by Kitu Krishnamurthy, held their first meeting on September 16, 1983 in Silver Spring, Maryland. Anticipated subcommittee activities include:

- Hold periodic meetings with the NRC to discuss the various proposed rules.
- Develop position statements on relevant issues and specific implementation action problems.
- Review and discuss physical protection as it applies to nuclear fuel cycle facilities including non-power reactors, spent fuel storage, and transportation.
- Review and discuss technological and state-of-the-art advances in physical security.

The first meeting was attended by 10 people representing utilities, NRC, AE's, and a national laboratory. Mr. Tom Allen of the NRC gave a presentation on the "Insider Rule" currently before the commission. His explanation of the background and intent of the proposed rules was followed by specific discussion on issues involved.

During the second meeting of the subcommittee, also held in Silver Spring, Maryland on November 30, 1983, Mr. Allen summarized the status of the Insider Rule. He stated that the Commission raised several questions on the proposed rule during their last meeting in October, 1983; and as a result, the NRC was preparing an "Auxiliary Paper" on the subject for the benefit of the Commissioners. It was anticipated that this paper would be presented to the Commissioners early in 1984, and that it was expected that the commissioner's directions would be received by April 1984. The Commissioners held a special public hearing to hear views from special interest groups on the Insider Rule. The subcommittee unanimously decided that it would be appropriate to present their views to the Commissioners. The statement submitted to the Commissioners at their December 1, 1983 hearing is enclosed as Attachment 1.

**Government Liaison Subcommittee**
The Government Liaison Subcommittee, chaired by Dick Duda, met several times this fall. Recent actions include:

- Utility and Government Agencies Meeting—A meeting was arranged among U.S., IAEA-inspected utilities, utilities to be inspected, the NRC, the Department of State, and ACDA to discuss past concerns and how to address possible concerns in forthcoming inspections by the IAEA.

- Letters to Congressional Committees—The Safeguards Committee, which is responsible for providing expertise when requested, sent the attached letter (Attachment 2) offering INMM expertise on safeguards to both congressmen and committee staffs. To date, we have received a request from a staff member on the House Armed Services Committee who would like a briefing in late January or February, 1984. This briefing is being developed.

**Questions and Answers Booklet**
Under the direction of Jim deMontmollin, a new Question and Answer (Q&A) booklet entitled "Nuclear Material Diversion" was prepared in an effort to improve upon an ANS Q&A booklet which the Committee felt was inadequate. The audience is the general public, thus, the approach was to write the booklet with a less technical bent and with fewer questions than the ANS version. Our next step is to determine how best to package and distribute this booklet.

The next meeting of the Safeguards Committee is scheduled for April, 1984. Please contact me or one of the members if you have any questions or would like additional details concerning any of the topics under consideration.

## ATTACHMENT 1

## SUMMARY

### Statement to the NRC Commissioners on the Insider Rulemaking (10 CFR 73.56) December 1, 1983

This statement has been prepared by the Physical Security Subcommittee of the Safeguards Committee of the Institute of Nuclear Materials Management (INMM) and represents the unanimous recommendation of the Subcommittee's membership.

The INMM is an international, professional organization devoted to safeguards and security in nuclear fuel cycle plants including power reactors. Its membership of around 800 is drawn from utilities, national laboratories, DOE facilities, architect-engineers, nuclear fuel manufacturers, the government and reactor manufacturers. The INMM has established a standing Committee on Safeguards. Its Subcommittee on Physical Security, which is sponsoring this statement, includes representatives of four nuclear utilities, contractors and consultants to the nuclear industry, and one national laboratory.

The Insider Rule has a long and tortuous regulatory history. The proposed rule and its predecessor have been subjected to one round of public comment, hearing board deliberations, continuing NRC staff development and refinement, Safety/Safeguards Committee scrutiny, and GAO Analysis. Throughout this long regulatory process, NRC's reactor licensees have struggled to be responsive to the Commission's *and* industry's concerns about the insider threat. The industry accepted, for example, NRC's early endorsement of the ANSI standard for security at nuclear power plants (N18.17) and began development of access authorization programs. In the absence of a federal regulation having the force of law, however, the success achieved by licensees in implementing their programs has been variable.

When the proposed rule was better defined about two years ago, reactor licensees began to review their access authorization programs in accordance with the anticipated components of the package now before the Commission.

Discussions with NRC licensing staffs led, in some cases, to formalization of screening commitments in licensee security plans. Operating license applicants, particularly, have had problems addressing this evolving issue in their security plan submittals. In the meantime, acquisition of background information on applicants was becoming more difficult as more and tighter privacy constraints were enacted throughout the country. Industry was beginning to recognize that standardization of the access authorization process is in its best interest because uniformity is the basis for the reciprocity desired by the industry. The Physical Security Subcommittee has been exploring the feasibility of INMM's making a more direct contribution to the success of recent initiatives to acquire FBI criminal history data and to develop a Nuclear Employee Data System. continued on page 8

continued from page 7

During this period, the nuclear power industry has cooperated with the NRC staff by providing formal and informal input to the regulatory process. A "good faith" effort has been made by the industry to be responsive to a rule that has been "just around the corner" for seven years. We now ask that the Commission demonstrate its responsiveness to the industry it regulates by approving publication of the proposed rule for public comment, with or without psychological assessment. The industry we represent wants to settle the issue. Some of us have screening programs that would remain in place irrespective of your decision and some do not, but *all* of us want and, we think, deserve, at a minimum, the opportunity to inform you of our positions on this matter. Publication of the rule would also allow us to contribute to resolution of two other long-standing, unresolved issues: pat-down searches and vital area designation and protection.

In summary, the INMM Physical Security Subcommittee endorses publication of the Insider Rule for public comment. We want the issue resolved so that the vacillation may end and we all may refocus our efforts on the matters that most concern us all—safe and secure operation of nuclear power plants.

### ATTACHMENT 2

In the implementation of U.S. policies on nuclear energy, questions may arise concerning the safeguards and security associated with nuclear materials and nuclear facilities. I am pleased to offer you the resources of the Institute of Nuclear Materials Management to assist you and your Committee as you may address those questions.

The Institute is an association of professional personnel actively engaged in material control and accounting and physical protection for materials and facilities. Founded in 1958, the Institute currently has a membership of around 800, with expertise and considerable relevant nuclear experience in accounting, auditing, chemistry, physics, statistics, engineering sciences, industrial security administration, management principles, data processing, education, legal, and associated disciplines required for safeguarding of nuclear materials and facilities. Various ad hoc Institute groups have actively participated for over two decades in the development of safeguards standards as embodied in legislation and regulations.

The Institute will be pleased to identify individuals with expertise in specific aspects of material accounting, material control, and/or physical protection. At your request, we will provide background information on the same subjects or, as you may require, our Safeguards Committee will provide a technical review and critique of documents or publications. The Institute can also identify sources of information for congressional committee staffs and could provide, upon request, names of members who could provide expert technical witnesses for testimony on any aspect of safeguards, domestic or international.

If we could be of assistance to you, please contact the Chairman of INMM's Safeguards Committee, Robert J. Sorenson, at (509) 376-4437.

# WHY MEMBERSHIP IN INMM?

**D. W. WILSON**

"Why me?" That was the question I asked INMM Chairman John Jaech a few months ago when he called and asked me to become membership chairman. My initial reaction was not unlike that of being asked to become the "get-the-goodies" chairman for the local church bazaar. After all, INMM has been around for a quarter of a century, and by now anyone who wanted to become a member of the Institute would surely be a member. From where would the new membership come? As importantly, how would we even maintain membership in the face of increased dues? I admit that my reaction was myopic and based more on ill-conceived emotion than on actual fact. Fortunately, I had the good sense to tell John I would think about his offer and get back to him shortly.

As I pondered the possibilities, my mind turned to my own involvement in INMM which began some 15 years ago. My initial interest had been somewhat selfish and was predicated on the assumption that it could "do something" for me, perhaps help solve some of my problems in handling nuclear materials. The terms "safeguards", "accountability", "materials management", and "measurement error" had taken on meanings somewhat different than those given in Webster's. I came to find answers to questions and solutions to problems. What I found were challenges and, more importantly, a group of dedicated—if not perfect—people who were not only also looking for answers but were offering a few solutions.

My education came swift but not without unexpected involvement: ANSI committee assignments, standing and ad hoc committees, papers at the annual meetings, articles in the Journal, membership on the Executive Committee, and others. So what have I received from my membership? Well, I have had my share of frustrations with procedures, system inertia, and the like. But there has been also a lot of satisfaction, even a few answers to some of my questions. Happily, I have received more than I have given, and much more than had I not given at all. But the most valuable resource I have acquired is people. People who are dedicated to the goal of making nuclear materials safe and useful to others. People who I have the privilege of calling friends. A happy consequence of time is that the industry matures as the people mature. The Institute of today is not the Institute of 15 years ago, *and it is certainly different than the founders envisioned.*

So just what does the Institute offer today to a current or prospective member? Well, a standard answer is to point out (as is done in the new membership brochure) the annual meetings, the growing number of regional chapters throughout the world, the growing number of Technical Working Groups in specialty areas, the training courses, the certification program, the graded membership, the special recognition and awards program, the sponsorship and support of nuclear standards development, and the publications, including the Journal. However, the real answer lies in the knowledge that the individual member can contribute and develop and influence in a real sense as part of a group of similarly motivated world experts in matters of safeguards, waste management, and transportation. The degree of personal involvement is limited only by personal commitment and desire.

As I revisited these reasons for my own membership, it occurred to me that there are indeed reasons why current members should stay members and increase their opportunity for service and self-development and that these same reasons apply to nonmembers who should become involved. The cost of membership—pennies a day, as some would put it—is hardly the major consideration for any member when the whole picture is placed in perspective. Activity and giving are key to successful membership.

So, having responsored myself to the INMM cause so to speak, I called Chairman Jaech back and told him that I didn't know much about being a membership chairman but that if he still wanted me to, I'd be honored to give it the old college try. I heard him chuckle a little, as if to remind me that I hadn't known much about the standards work or the safeguards committee or the Executive Committee or the annual meeting or the certification program or the Journal when I first got involved with them either; but somehow I'd learn. When I finish my assignment, the INMM should be a little bit better for it than when I started; I certainly will be. That's a benefit of membership!

So now I turn to you, the Institute membership, and invite you to revisit your reasons for membership. Hopefully, you are having a satisfying experience. However, if perchance you are not, it might be well to look in the mirror and ask yourself if you are giving more than your annual membership fee (you get that much back automatically). The question is, are you getting more back in the way of the intangibles: associations, friendships, insights, doors opened, problems solved, personal development. When the answer to that question is yes, your reasons for membership become clear and unquestioned.

Now, are there those who can yet benefit from membership in the INMM? The answer must be a decided YES! There are many who sit on our periphery, who participate in our standards committees, who attend our annual meetings, who attend our workshops and training sessions but have yet to complete the steps towards membership. There are others who are heavily involved in safeguards, waste management and transportation who have yet to understand what the Institute has to offer. All that is needed is a transfer of appropriate information to these individuals and organizations. And the Institute is doing something about that. Yet our biggest potential for "spreading the gospel" comes in the form of our current membership. If each member would educate only one potential member to the benefits to the nuclear community of his or her active membership, the individual would be benefitted, the Institute would be strengthened, and the cause of nuclear materials management would be furthered.

I challenge each of you to revisit the purpose of your membership, and then act in a responsible way to give more of yourself and your knowledge to the environment of the INMM. Who knows, maybe you will be the next one to get a call from Chairman Jaech, a committee chairman, or an individual contributor to INMM activities asking you to do something, perhaps a little out of your comfort zone. Do yourself a favor and say, "Yes!" That's one of the key benefits of your membership. Then while you are riding high, go out and give a membership application to one of your nonmember associates. That will be to his or her benefit. Be happy in doing!!

# CALLING ALL SPOUSES TO COLUMBUS

There's lots to do in Columbus July 15 to 18, 1984.

1. Come with your spouse and help celebrate INMM's Silver Anniversary. (It all started here in Columbus.)

2. Participate in the spouses' continental breakfast each morning; make new friends and renew friendships.

3. Visit Columbus' fascinating museums—
- Columbus Museum of Art.
- COSI—Center of Science & Industry.

4. Experience the research activities at Battelle Memorial Institute.

5. Tour the Anheuser Busch Brewery.

6. Browse and shop at
- German Village
- Ohio Center and Retail Mall at The Hyatt Regency.
- Ohio Village
- French market area.

7. Be entertained at Scioto Downs.

8. See the animals at the progressive Columbus Zoo, and let them see you. (See the twin baby gorillas born November 1983.)

9. Spend a day (before or after) at Kings Island (near Cincinnati).

10. Take advantage of the opportunity to view slides of the INMM delegation's trip to China.

11. Group activities will be tailor-made at the Conference to meet your special interests.

These and many more activities are available in Columbus. You'll want to be there!

If you want more information, please contact me through:
John L. Jaech
(206) 453-4377
600 108 Avenue NE., C-00777
Bellevue, WA 98009

Alyce Jaech
Spouses' Program Coordinator
25th Annual INMM Meeting—July, 1984

# NUCLEAR PRESENTATIONS

(See page 14)

E. R. Johnson, E.R. Johnson Associates, Inc., presented a paper entitled "The Federal Interim Storage Program", which he co-authored with J. A. McBride, at the Civilian Radioactive Waste Management Information Meeting in Washington, D.C. on December 14, 1983.

E. R. Johnson, E.R. Johnson Associates, Inc., was interviewed on the British Broadcasting Corporation (BBC) radio on December 8, 1983 as part of a series the BBC is running on nuclear fuel reprocessing and waste management.

# INMM CALENDAR OF EVENTS

**APRIL 17-19, 1984**
Packaging and Transportation
of Radioactive Materials
Hyatt Regency Washington, Washington, D.C.

**MAY 7-9, 1984**
Nuclear Power Assembly Conference
Nuclear Power Assembly, Washington, D.C.

**MAY 7-11, 1984**
Selected Topics in Statistical Methods for Special Nuclear Material Control
Battelle Columbus Laboratories, Columbus, Ohio

**MAY 14-18, 1984**
ESARDA 6th Annual Syposium on Safeguards and Nuclear Material Management
Venice, Italy

**JULY 15-18, 1984**
INMM 25th Anniversary Annual Meeting
Hyatt Regency Columbus, Columbus, Ohio

**SEPTEMBER, 1984**
Decontamination and Decommissioning Seminar
Washington, D.C.

**OCTOBER, 1984**
Insider Threat—Physical Protection TWG
(Site and Date to be Announced)

**JULY, 1985**
INMM Annual Meeting
Albuquerque, New Mexico

# THE SECRETARY'S REPORT

**VINCENT J. DeVITO**
Secretary

As provided for in Article III—Election of Officers, Section VI, I hereby notify each member of the results of the FY-1984 election ballot. The following officers were elected:

| | |
|---|---|
| Chairman | John Jaech |
| Vice Chairman | Yvonne Ferris |
| Secretary | Vince DeVito |
| Treasurer | Robert Curl |

The following two individuals were elected as members of the executive committee:

Thomas Shea
Robert Sorenson

# AWARDS COMMITTEE REPORT

The Awards Committee Report in the 1983 Summer Journal erroneously omitted the presentation of the 1980 Distinguished Service Award to Louis Doher. And, the Distinguished Service Award for 1979 was presented to W. A. Higinbotham (rather than in 1980). On behalf of the Awards Committee Chairman, we regret this oversight.

# AN INVITATION TO INMM MEMBERS

The Institute is inviting members who give speeches and presentations to service organizations, religious groups, student groups, legislators and the like to notify the Executive Director of such activity so it can be reported in the Journal. Similarly, the Institute would like to know the details of technical papers presented by its members, appearances at Congressional or other hearings, and appearances on radio and television so that these can also be reported in the Journal. If you participate in any of the aforementioned activities, please call or write:

Mr. John Messervey
Executive Director
Institute of Nuclear Materials Management
Sperry Univac Plaza, Suite 720-South
8600 West Bryn Mawr Avenue
Chicago, Illinois 60631
(312) 693-0990

and advise him of the following:

- Title of presentation
- Group to which presentation was made
- Location (city and state) of presentation
- Date of presentation
- Any comments or observations that might be appropriate.

See example on page 9.



# VIENNA CHAPTER REPORT

**TOM BEETLE**

### June

We had perfect weather for a walk through the Donau Park to the Au Restaurant for our annual General Meeting and luncheon. After a brief review of our 1982-83 activities and a report that we are still financially solvent, the Executive Committee elected for 1983-84 was announced:

| | |
|---|---|
| Chairman | Tom Beetle |
| Vice Chairman | Dino Pontes |
| Treasurer | Cathy Morimoto |
| Secretary | Norm Beyer |
| Member-at-Large | Winston Alston |
| Member-at-Large | Jim Lovett |
| Past Chairman | Les Thorne. |

Our after-luncheon speaker was Dr. Hideo Kuroi, General Manager, Safeguards and Related R&D Office, JAERI, Japan. As a Member-at-Large on the Executive Committee of the Japan Chapter of INMM, he brought us up to date on their activities. They have one member more than the Vienna Chapter, but that is understandable because the population of Japan is 125 million while that of Vienna is less than 2 million. They had a very successful Annual Meeting with technical presentations in April.

In addition to Chapter activities, he discussed deterrence, verification, and credibility as concepts for forming safeguards policy. He feels that deterrence is a weak concept, and that verification and credibility should be the basis for policy. Just as it is taking a long time to establish credibility in the nuclear industry through good safety performance, it will take a long time to establish credibility in safeguards.

### September

Our start-of-the-season heurigen was held at Heuriger Schubel-Auer in Nussdorf. For readers not familiar with the institution, an heuriger is an Austrian establishment which specializes in serving wine. The hot and cold buffet and red and white wine were enjoyed by 28 members and guests. As usual, we had difficulty preventing speeches.

### October

In October we again met in the Au Restaurant in the Donau Park. Twenty-seven members and guests were present.

Our speaker was Dr. Rex Nazare Alvez, Chairman of the Brazilian National Nuclear Commission and the Brazilian Governor on the IAEA Board of Governors. He explained that the Brazilian nuclear program has been developing for about 25 years. They have a 660 MW PWR completed, and a 1300 MW reactor planned with site preparation underway. Last year they produced 550 t of yellow cake. Though they have hydroelectric power available from the Amazon region, the long transmission distances make it uneconomical compared to nuclear power. He feels that Brazil will require substantial nuclear power capability early in the next century.

**November**

With winter approaching we moved back into the VIC restaurant for our November meeting.

Dr. Paul de Bievre from the Central Bureau for Nuclear Measurements, Geel, Belgium was our speaker. His talk included philosophical, technical, and political comments in a measurements context. He contrasted "true" values determined by human choice (e.g. laws) with "true" values determined by nature (e.g. mass). The measurement specialist endeavors to determine these true values of nature, but measurement processes yield imperfect results which are, in part, due to the human activity parts of the process. Some automation may be useful for reducing these human effects, but some human activity and responsibility should be retained in most processes. He reported that the ESARDA Working Group on Destructive Analysis has compiled a set of target values for precisions of chemical measurements that are considered to be reasonably achievable in the industry. It is now up to the safeguards authorities to say whether or not those values are sufficient for safeguards purposes.

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# TECHNICAL WORKING GROUP ON PHYSICAL PROTECTION REPORT

**JAMES D. WILLIAMS, CHAIRMAN**
Sandia National Laboratories
Albuquerque, New Mexico

The presently scheduled and planned workshops of the Technical Working Group on Physical Protection are listed below:

- Physical Protection Systems and the Insider Threat—October 1984 (tentative)
- Security Force Training—February 1985 (tentative)
- Information Display and Control Systems—(April 1985)

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**

The Twenty-Fifth Annual Meeting of INMM will be held July 15-18, 1984, at the Hyatt Regency Hotel, Columbus, Ohio. Details about submitting papers and deadline dates are presented elsewhere in this journal. In order for the physical protection area to remain a viable part of INMM, we need additional papers submitted for presentation at the annual meeting. Therefore, I solicit your help and encourage you to submit papers covering any aspects of Intrusion Detection, Entry Control, The Delay Element, Security Force Training, The Insider Threat, Information Display and Control Systems, or other areas of Physical Protection.

Two workshops have recently been successfully completed. The first was held October 18-21, 1983, at Long Beach, California, entitled "Integrating the Elements of Delay, Intrusion Detection, and Entry Control into Physical Protection Systems" and the second was held November 14-17, 1983, in Albuquerque, New Mexico, and was entitled "Security Force Training." Both of these workshops were highly successful. Additional information about them are given in later sections of this report. The successes of these workshops were due primarily to the efforts of Jim Hamilton, Goodyear Atomic, for the workshop, "Integrating the Elements of Delay, Intrusion Detection, and Entry Control into Physical Protection Systems" and the efforts of Fred Crane, International Energy Associates, and Dr. Suzanne Rountree, Sandia National Laboratories, for the workshop "Security Force Training."

**Integrating the Elements of Delay, Intrusion Detection, and Entry Control into Physical Protection Systems**

The Physical Protection Technical Working Group sponsored a workshop entitled "Integrating the Elements of Delay, Intrusion Detection, and Entry Control into Physical Protection Systems" during October 18-21, 1983, at the Hyatt Long Beach Hotel, Long Beach, California. The purpose of this workshop was to focus on technical and operational problems related to integrating the elements of delay, intrusion detection, and entry control into physical protection systems. The workshop allowed participants the opportunity to present, discuss, and exchange information on the problems associated with physical protection systems.

Fifty-nine participants from the United States, Canada, England, and Japan were in attendance. The distribution of attendees was: Department of Defense—7, Nuclear Power Plants—7, Nuclear Regulatory Commission—1, Department of Energy—4, Department of Energy Contractors—21, Engineering Firms—4, Private Security Firms—7, Suppliers—3, Secret Service—2, and Foreign (Japan, Canada, and England)—3. The registration on the evening of October 18, was followed by a get acquainted cocktail party. Wednesday morning, October 19, the opening session began with a welcome on behalf of the Institute and a brief history of the INMM with emphasis on past and future activities of the Working Group.

In an opening panel discussion the status of Physical Protection Standards presently being prepared by the various professional societies and regulations of the Nuclear Regulatory Commission, and the Department of Energy were discussed. Presentations were made by the following people: Ted Aichle, Bruce Varnado, David Rockford, Basil Steele, and J. D. Williams.

Eight consecutive workshops were held. The titles of these workshops were as follows:

1. Integrating Barriers with Entry Control in Intrusion Detection
2. Methods for Physical Protection Against Unauthorized Acts by an Insider
3. Positive Personnel Identification and Access Control
4. Alarm Assessment and Security Lighting
5. Minimizations of False Alarms by Combination of Sensor Logic
6. Special and Unique Applications of Interior and/or Exterior Sensors
7. Performance Testing and Maintenance of Intergrated Security Systems
8. Contraband and Special Nuclear Material (SNM) Detection

Each of these sessions was conducted by a session moderator who set the stage for the discussions. Every attendee was asked to identify himself and to give a brief description of his activities in that particular field. The attendees were also asked to identify at least one question or topic to be discussed by the group. Typically each session involved about fifteen people. There were no formal papers presented, but the group discussed openly and freely the successes and failures of their activities. The small group sessions were conducted Wednesday afternoon and Thursday morning. Thursday afternoon a plenary session included a presentation on access denial techniques by John Kane, Sandia National Laboratories, that was followed by a presentation on training of security personnel by Lt. Col. Ken C. Freimuth, U.S. Army Military Police School, Fort McClellan, Alabama.

Following Thursday's meetings there were product displays by five equipment vendors who had been invited by those attending the meeting. The vendors participating were GTE Sylvania, Stellar Systems, Scan Ray Corporation, Continental Page Engineers, and Southwest Microwave. At the conclusion of the vendor display, a dinner for the participants was held in the Hyatt ballroom. During the closing meeting on Friday morning, each session moderator presented a summary of the discussions held in his session. More complete summaries and a final list of attendees will be compiled into the Summary Minutes of a workshop. Copies of the Summary Minutes will be mailed automatically to each participant.

Special thanks go to Jim Hamilton, Workshop Chairman, to each of the session moderators, to the participants in the panel discussion, to those who gave talks to the plenary session, and to the vendors. The outstanding effort of all of these people was the basis for the workshop success.

**Security Force Training**

The Physical Protection Technical Working Group sponsored a workshop entitled "Security Force Training" during November 14-17, 1983, at the Marriott Hotel, Albuquerque, New Mexico. The purpose of this workshop was to focus on the qualification, training, and evaluation of security forces for federal and commercial sector nuclear facilities. The program provided participants the opportunity to present, discuss, and exchange information on the latest development in security force training and tactics. Participants also observed a small force engagement exercise which employed Sandia's Engagement Simulation System (ESS), which evolved from the U.S. Army's Multiple Integrated Laser Engagement System (MILES).

Seventy participants from the United States and France included a distribution as follows: Nuclear Power Plants—10, Private Security—31, Department of Energy—3, Department of Energy Contractors—24, Nuclear Regulatory Commission—4, Department of Defense—6, and Foreign (French CEA)—2.

Registration on the evening of November 14, was followed by a get acquainted cocktail party.

The keynote session was opened by James D. Williams, Chairman, INMM Physical Protection Technical Working Group, who introduced Fred Crane, International Energy Associates Limited, and Dr. Suzanne L. K. Rountree, Sandia National Laboratories workshop co-chairpersons. The keynote address was given by Dr. Joseph P. Indusi, Brookhaven National Laboratories. His talk was entitled "Some Controversial Issues in Security." This talk was followed by presentations entitled "Doe and NRC Security Programs;" an overview presented by William M. Kanuf, Chief, Inspection and Evaluation Staff, DOE Office of Safeguards and Security; and Sarah A. Mullen, International Energy Associates Limited. The afternoon included tours of the MILES/ESS and live-fire ranges of Sandia National Laboratories. Actual participation by the attendees in the firing of the MILES/ESS equipment was very popular and informative.

Wednesday morning, November 16, seven consecutive workshops were held. These workshops were as follows:

1. "Planning for Security Training: Transforming Duties/Responsibilities into a Training Program." The moderator for this session was Larry George, Houston Lighting and Power Company, Houston, Texas.
2. "Security Force Management: Problems and Solutions, including Security Force Motivation." Vern Hoy, Brittell and Hoy, Newport Beach, California, moderated this session.
3. "Security Force Evaluation Programs: Probationary and Routine." The moderator for this session was William D. Telfair, CRC Inc., Albuquerque, New Mexico.
4. "Classroom Training Techniques." This session was moderated by Gene Morris, Rockwell International, Hanford Patrol, Richland, Washington.
5. "Security Force Election; including NRC's Insider Rule and DOE/NRC Physical Qualifications Standards." Sarah A. Mullen, International Energy Associates Limited, Washington, D.C., moderated this session.
6. "Tactical Training: SWAT; Hostage Negotiation; Bomb Search, Chemical Agents." The moderator for this session was Frank Brittell, Brittell and Hoy, Newport Beach, California.
7. "Contingency Planning: The Impact on Training Qualifications." Robert J. Givin, Washington Public Power Supply System, Richland, Washington, moderated this session.

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After an enjoyable lunch, seven more workshops were held in the afternoon. These include:

8. "Planning for Security Training: Transforming Duties/Responsibilities into a Training Program." The moderator for this session was Larry George, Houston Lighting and Power Company, Houston, Texas.
9. "Security Force Management: Problems and Solution including Security Force Motivation." Vern Hoy, Brittell and Hoy, Newport Beach, California, moderated this session.
10. "Comparison of NRC, DOE, and Industry Standards, including Legal Issues and ANS-3.3." The moderator for this session was Barry L. Rich, DOE Office of Safeguards and Security, Washington, D.C.
11. "MILES/ESS: Reaction to the Sandia Presentation and Demonstration." The moderator for this session was Chuck Lewis, EG&G, WASC Inc., Albuquerque, New Mexico.
12. "Weapon Training Techniques." The moderator for this session was Gene Morris, Rockwell International, Hanford Patrol, Richland, Washington.
14. "Security Force Scheduling Integrating Training with Security Operations." The moderator for this session was Robert A. Gustison, United Nuclear Corporation, Montville, Connecticut.

Following Wednesday's session, a dinner for the participants was held in the Marriott ballroom. During the closing meeting on Thursday morning, an indited paper entitled "Security at Savannah River Plant" was presented by George Miserendino, Director of Safeguards and Security, DOE Savannah River Operations Office, Aiken, South Carolina. Some time was also devoted to additional presentations on DOE and NRC security programs and the DOE training facility by William N. Kanuf and Sarah A. Mullens. Later each workshop session moderator presented a summary of the discussion items of their session. More complete summaries and final list of attendees will be compiled into the Summary minutes of the workshop. Copies of the Summary minutes will be mailed automatically to each participant.

Special thanks go to Fred Crane and Suzanne Rountree, workshop co-chairpersons; to each of the session moderators; to the invited speakers; and to the participants themselves for the outstanding efforts put forth and which contributed to this workshop's success.

# NUSAC NAMES BAJADA TO QUALITY PROGRAMS DIVISION

Edwin Bajada

Reston, Virginia—Edwin Bajada has been appointed manager of Quality Services within the Quality Programs Division of NUSAC, Incorporated, a consulting firm which provides a wide range of services for the nuclear industry, government and utilities.

NUSAC President, Dr. Ralph Lumb, said Mr. Bajada's responsibilities as Manager of Quality Services will include the continued development of NUSAC's nuclear quality assurance audit and surveillance programs and the expansion of services into other quality areas in both nuclear and nonnuclear industries. He will also provide administrative and technical support to the Quality Programs Division and will report to Wilkins R. Smith, Vice President, Quality Programs.

Mr. Bajada previously served for 10 years with the Long Island Lighting Company where he was Manager of the Quality System Division and directed quality program, audit and procurement activities in support of the Shoreham Nuclear Power Station.

# NBS OFFERS FIELD FLOWMETER CALIBRATION

The National Bureau of Standards offers a field flowmeter calibration service using the NBS portable flow standard. The portable flow standard was developed for the nuclear materials processing industry. The standard consists of two meter runs each containing a set of two turbine flowmeters for liquids with flow straightening vanes upstream of each turbine, associated piping, a pump, and flexible hoses and necessary couplings to connect the runs in series with the metering station to be calibrated. In this arrangement, water is pumped in a closed circuit through the turbine flowmeters and the metering station. The response of the turbine flowmeters has been calibrated in the NBS primary flow facility. The portable flow standard carries the necessary instrumentation to determine the flowrate of water passing through the closed circuit. Thus, it provides a known flowrate of water to the metering station under test, which is isolated by blocking valves from the piping normally associated with the station. The two meter runs are 3 and 1.5 inches in diameter. The available flowrate ranges are 65 to 450 gallons/minute in the 3-inch diameter run, and 15 to 120 gallons/minute in the 1.5-inch diameter run.

The field flowmeter calibration service is available on an at-cost basis. Inquiries should be addressed to Dr. James R. Whetstone, Building 230, Room 105, National Bureau of Standards, Washington, D.C. 20234, telephone: (301) 921-3681.

# REVIEW OF ANS/INMM CONFERENCE

**JOHN F. LEMMING**

The American Nuclear Society and The Institute of Nuclear Materials Management cosponsored a conference on "Safeguards Technology: The Process-Safeguards Interface" at Hilton Head Island, South Carolina November 28-December 2, 1983. The Conference planners provided an environment that was conducive to the exchange of information and data between process designers and operators and safeguards researchers and developers.

Several presentations discussed the need for process designers and operators to cooperate in the design and implementation of effective safeguards systems. The importance of including safeguards considerations from the initial design or modification stages was emphasized. Process designers and operators and safeguards designers and specialists must cooperate to meet safeguards objectives. The process designers and operators need to understand the origins of the safeguards requirements so that the identified threats can be met. On the other hand, safeguards designers and specialists need to understand the effect their systems can have on the process.

The meeting also addressed that, when implementing techniques from the research and development laboratory, the ability of the system to perform in the process environment needs to be considered. In addition one must consider that the operating unit may have limited personnel and funding. Both groups need to understand that an improved safeguards system may lead to a better process by eliminating the need for some physical inventory shutdowns and providing information to fine tune or trouble shoot the process.

In addition to general discussions, there were approximately 60 papers which were divided into four major categories: Applied Measurement Concepts, Applied Accountability Concepts, Material Control Concepts and Information Systems. These papers presented problems and solutions to the implementation of safeguards related systems.

The proceedings of the meeting are being prepared for publication. Arnie Hakkila and his committee deserve a bravo for a job well done.

# EXAMINING COMMITTEE ANNOUNCES ADDITIONAL SENIOR MEMBERS

Roy G. Cardwell, chairman of the INMM examining committee, has announced the following additional new Senior Members:

Richard F. Duda
Yvonne M. Ferris
Glenn A. Hammond
Samuel C.T. McDowell
Kenneth E. Sanders
Ronald D. Smith

Congratulations!

# EXECUTIVE COMMITTEE MEETS IN ALBUQUERQUE

On March 8-9, 1984, the INMM Executive Committee met in formal session in Albuquerque, New Mexico. Albuquerque has been selected as the site of the 1985 Annual Meeting. Executive Committee actions included:

■ Review of program plans for the 1984 annual meeting in Columbus, Ohio. "Nuclear Materials Management— The Next 25 Years"

■ A new technical working group for Material Control and Accounting was established by Vice Chairman, Yvonne Ferris.

■ Membership in the Institute has reached 748, including 527 from the United States, 85 from Japan and 136 outside of the United States and Japan (principally Vienna).

■ The board congratulated 1984 sustaining members: EG&G Idaho, NFS, and E.R. Johnson and Associates.

■ Chairman of the By-Laws Committee, Roy Cardwell, reviewed suggested revisions in the Institute by-laws. Balloting on revised by-laws will be completed at the same time as ballots for the Executive Committee.

■ The Executive Committee thanked Certification Chairman, Fred Tingey, for his handling of the "Short Course in Nuclear Materials Management" held in Washington, D.C., February 1984. The course drew 18 participants, including 16 individuals who prepared for the certification exam. Announcement of certification exam results will be included in the next edition of *Nuclear Materials Management.*

■ The Executive Committee mapped plans to revamp the Institute's communications efforts. This includes revisions and additional material for *Nuclear Materials Management.*

■ The following individuals were elected by the Executive Committee as the first Fellows of the Institute:

W. A. Higinbotham
G. R. Keepin
J. Lovett
R. Lumb
S. McDowell
R. A. Schneider

*Congratulations*

# FOREIGN TRIP REPORT

**WILLIAM A. HIGINBOTHAM**
Technical Support Organization
Brookhaven National Laboratory
Upton, New York

**Beijing, Chengdu, Shanghai China**
**September 24—October 10, 1983**

This was an unofficial visit to China. This report is being circulated as are the official foreign trip reports, and to any other interested parties.

### Comprehensive Report

About a year ago, the Chinese Nuclear Society requested the Institute of Nuclear Materials Management (INMM) to send a delegation to China. The INMM asked Ed Johnson to arrange the visit and to head the delegation. Arrangements were made through the People to People International Citizen Ambassador Program.

For most of its 15 years the INMM has been concerned with the management of nuclear materials and safeguards. Recently it has added transportation of nuclear materials and radioactive waste management. Ed was able to obtain 15 volunteers, willing to participate and to pay or to arrange for payment of the costs. The list of experts, reasonably covering the range of topics, is given in Annex I. Each of these provided summary papers through People to People for circulation in China prior to the visit. The Chinese Nuclear Society, with assistance from the China Association for Science and Technology, planned the itinerary, which included 3 days of technical meetings in Beijing, one day of meetings in Chengdu and in Shanghai, a visit to the Southwest Research Laboratory, banquets in the 3 cities and a lot of sightseeing.

The Chinese Association for Science and Technology appears to be the national science and engineering agency. It has 106 constituent societies covering all areas of science and technology, education and public information on science. The Chinese Nuclear Society (CNS) is number 52 on the list. The major tasks of CNS are to promote cooperation, to popularize nuclear science and technology, to promote international exchanges, organize meetings and to publish technical articles. We were given several copies of Volume 1 and 2 of the Chinese Journal of Nuclear Science and Engineering.

The itinerary is given in Annex II. We saw a lot of sights and enterprises, under the guidance of Zhang Xias-Liu, a very pleasant, patient and well-informed young man. Most of the time we were also accompanied by Zhou Shanyuan, a nuclear metallurgist from the Beijing Institute of Atomic Energy, who had spent two years in the U.S. and frequently served as technical translator. Additional assistants were provided for each locale.

Each day's activities were recorded by members of the group and this account will be available later. Only the technical exchanges are reported here.

### Beijing

Our hosts arranged for all of the contributed papers to be presented in Beijing. In order to accomplish this, there were parallel sessions, morning and afternoon for 3 days, September 26-28. The parallel sessions were held at two different locations, so that some time was wasted getting to them, picking them up for lunch, etc. The papers that we presented are listed in Annex III. I attended the safeguards sessions, which are identified as A. It would have been useful to have rehearsed these presentations. Only two papers were presented in each session, but there was not enough time left for questions and discussion. Some of the papers could have been shortened with no loss of communication. Copies of the final papers were given out here and at the other places.

With precious little feed back, my impression of Chinese reactions are these:

1. They are somewhat puzzled by our great concern about subnational threats.

2. They were interested in Charlie Vaughan's description of the evolution of semi-automatic material accounting at G.E. Wilmington, in the dry conversion process, and in the instrumentation that has been developed for use there. Charlie emphasized that the primary reason for these developments was for effective fuel management, but I'm not sure they appreciated this. They were very interested in how well the materials could be measured. I feel that Charlie's four papers will be educational for the Chinese, even though he was not requested to present anything at Chengdu or Shanghai.

3. There was considerable interest in Keepin's paper on NDA instrumentation. Unfortunately he ran overtime, which cut time for questions.

4. There appears to have been interest in Cusabona's analytical paper, Bishop's description of BWR's in Japan and Mrs. Thorup's fuel cycle data system, since these three were requested to speak at the other places.

5. Little interest was expressed in IAEA safeguards. Several of the senior scientists told me, outside of the meetings, that China had applied for membership in the IAEA. As near as I could make out the technical people consider this to be a political move. I tried to explain, when given the opportunity, that technical people have an important role to play regarding the IAEA.

6. The Chinese specifically expressed interest in the following: Standard Reference Materials and sample exchanges such as SALE, training courses, etc. such as the LANL NDA and SSAC courses. We should find out how China may participate in these.

### *Southwest Research Facility*

It was a fascinating bus ride from the Emei resort, up one valley, across a divide, and down into another large valley with a river, the research institute and surrounding villages.

We assembled in a room to meet the local officials and to learn about the new research reactor. The institute has 3,000 employees, of whom 1,300 are scientists or engineers. The reactor went critical in 1979, achieved full power in December 1980, and has consumed 6 cores so far. Power is 125 MwTh. Neutron flexes are $6.2 \times 10^{14}$ and $1.5 \times 10^{15}$ for testing fuels and producing radioisotopes. There are 4 cooling loops flowing $5 \times 10^6$ kg water per hour; input 50° output 70°C. It is enclosed and pressurized. The fuel elements have several concentric, thin tubes with 25 w/o HEU in A1. We were also shown the control rods. As I recall, there is 700 g HEU per assembly and up to 30 may be employed. There appear to be 200 or more locations in the core for fuel, control, samples, reflectors, etc. The reactor was down, so that we could view from the top and look down on the core. It seems to be well designed for changing fuel, inserting test elements, etc. They also showed us the hot cells (15) which appear to be well designed and equipped. All of this is said to have been fabricated in China. Fuel assemblies are produced elsewhere (not identified). Except for this, all questions were freely answered.

Several of the personnel from this institute attended the technical session in Chengdu, October 6.

**Chengdu**

After supper October 5, the local leaders met with Ed Johnson to discuss what papers were to be presented. Obviously they knew what had transpired at Beijing. After this Ed explained the schedule. There were to be 6 papers in the morning, 5 in the afternoon, each of 20 minutes duration.

Ed gave the first paper on fuel cycle economics. Ralph Caudle then gave a synopsis of IAEA safeguards, which was drafted the night before to be more appropriate than the papers that Keepin and I had presented previously. The other papers were: NDA by Keepin, the NAC fuel cycle data base by Thorup, chemical analysis by Casabona, and GE's fabrication and experience in Japan by Bishop. Questions were directed mostly to Bishop, e.g. how many enrichments may be used in one rod, how well can these be measured, how much Gd in poisoned rods, what are advantages of the dry conversion process?

In the afternoon the talks were: Rod consolidation by Thorup, dry retrievable spent fuel storage alternatives by Fletcher, high level waste solidification by Carson, U.S. waste repository program by Hoffman, and in-situ mining by Thorup. I didn't note the questions in this case.

The morning selections seem reasonable to me. I don't know why the Chinese should be interested in rod consolidation or dry spent fuel storage. The PWR that they are designing will have, as I recall, 15-20 years storage capacity. I can understand their interest in high level waste solidification and deep burial because of their military nuclear program.

**Shanghai**

The program here was very similar to that at Chengdu. The local leaders made a similar selection. Bill Teer was requested to discuss transportation of radioactive materials, in place of something else. I neglected to list these papers.

The questioning here was more animated. Fuel fabricators asked questions of Bishop and Vaughan. Our delegation asked questions, e.g. about the Chinese PWR reactor schedule. At the end of each session, small groups formed around Bishop, Carson and Fletcher. It would have been constructive if these discussions had occurred more often and not been interrupted so soon to catch a bus.

**The Banquets**

The first was in Beijing the evening of our first day there. The welcoming speech was given by a very enthusiastic man from the Chinese Association for Science and Technology. Most members of the delegation were able to meet one or two of the officials with whom we would be associated later.

The second was on the last day of our visit to Chengdu. It was a reception following dinner, not a banquet. It was Joe Lieberman's birthday. Our hosts arranged for a caligrapher to paint a scroll for him and for a birthday cake. Music was played for dancing and eventually everyone got into the act.

The third was a formal banquet, the last evening of our visit to Shanghai. At least one of the Chinese at each table was fluent in English. We were relaxed and there was good conversation all around.

**Second Thoughts and Conclusions**

This was hardly what I expected. At first I felt that it had been badly arranged. Except for the SW Research Laboratory, the technical exchange was very one-sided.

I don't know much about the original invitation, or whether the Chinese intimated what subjects might be of interest to them. People to People sent John Luppert to China in mid-August to check on the arrangements for our odyssey (and possibly others). It would seem to have been more useful to have had Ed or an alternative visit Beijing six months before the visit to discuss how to make our visit more profitable.

It turned out, to my surprise, that there was some interest in almost every one of the papers submitted. Not so surprising, someone in the group was prepared to give reasonable answers to every question that was raised. Also, at each place, we volunteered to send additional papers, etc., after we returned. I will send copies of the Brookhaven computerized instrumentation catalogue which lists all of the NDA and containment/surveillance instruments that we know about with references, suppliers, etc. I will be happy to provide more specific information if requested. I also promised to send Zhan Ping a list of IAEA documents which should be of interest to the Chinese.

We should compare our impressions as to what the Chinese expected of us, how well we may have responded to this and as to where we go from here.

Dennis Bishop said that the Chinese invite foreigners for somewhat stilted exchanges in order to size them up. If one makes a good impression, one can expect more meaningful exchanges later. While this makes sense as regards commercial

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companies, it may also be true for professional societies, since it is clear that their view and ours regarding professional societies are not the same.

I judge that it was the Chinese who suggested the considerable amount of sightseeing, the limited and rather formal technical sessions and made very little provision for relaxed, personal technical exchanges, not to say fraternizing. We managed some of the latter anyway, but I was sorry that there was almost no opportunity for informal technical exchanges in small groups or individually.

There were of course, laudatory statements at our final banquet in Shanghai. This says nothing as to how useful our visit was to them. If everyone in the group will send letters of appreciation and reprints, etc., we may be able to open a mutually useful channel of communication on the subjects we presented and, quite possibly, some others.

I now know a little about the Chinese society and about its scientific/technical operations. I look forward to their active participation in and support of the IAEA.

**Annex I**
**Members of the Delegation**

Dennis M. Bishop: Manager Japan Fuel Project, G.E. Technical Services Co., Japan Branch

Arthur B. Carson: Consultant. 32 years with G.E. and EPRI, San Francisco, CA.

Lewis F. Casabona, 18 years as head of the Nuclear Fuels Analysis Group at Teledyne Isotopes, Westwood, N.J.

Ralph E. Caudle, Head Office of Safeguards and Security, DOE, Washington, D.C.

John F. Fletcher: Pacific Northwest Laboratory, Project Manager for Retrievable Storage Systems

William A. Higinbotham: Technical Support Organization (Safeguards), Brookhaven National Laboratory, Upton, N.Y.

Peter L. Hofmann: Manager Program Analysis Department, Battelle, Columbus.

John L. Jaech: Analyst, Exxon Nuclear Co., Richland and Chairman INMM.

E.R. Johnson: President E.R. Johnson Assoc., Reston, VA. and Leader of this Delegation.

Mrs. Jerry L. Johnson: E.R. Johnson Assoc., and Assistant Leader of this Delegation

G. Robert Keepin: Special Assistant to the Deputy Director General for Safeguards of the IAEA, Vienna.

Joseph A. Lieberman: President of OTHA Inc., Glen Echo, MD.

Bill R. Teer: Vice President of Transnuclear Inc., White Plains, N.Y.

Carol S. Thorup: Group Vice President, Nuclear Assurance Corp., Norcross, GA.

Charles M. Vaughan: Nuclear Materials Management and Licensing, G.E., Wilmington, NC.

Vivian A. Vaughan: Nuclear Manufacturing Document Coordinator, G.E., Wilmington, NC.

Mrs. Patricia Casabona; Mrs. Marion M. Caudle; Mrs. Jesie L. Fletcher; Mrs. Alyce S. Jaech; Mrs. Madge T. Keepin; Mrs. Tamar D. Lieberman; Mrs. Patricia M. Teer.

**Annex II**
**ITINERARY**

Sept. 21: Reception and dinner, 5:30-10:00 p.m., Four Seasons Hotel, Seattle.

Sept. 22: Depart Seattle 1:40 p.m., arrive Japan about 3:30 p.m., Sept. 23. Reception and dinner at the New Otani Hotel, sponsored by General Electric Co.

Sept. 24: Depart from Narita Airport, arrive Yan Jing Hotel, Beijing about midnight.

Sept. 25: Sightseeing. Welcoming banquet at Beijing Roast Duck Restaurant, 6:30 to 9:30 p.m.

Sept. 26-28: All American papers were presented in two parallel sessions, morning and afternoon.

Sept. 29: Sightseeing. Depart Beijing about 7 p.m. arrive Jin Jiang Hotel, Chengdu about midnight.

Sept. 30-Oct. 1: Sightseeing.

Oct. 2: By bus from Chengdu to Emei resort hotel.

Oct. 3: Sightseeing.

Oct. 4: Visit S.W. Research Laboratory.

Oct. 5: Return to Chengdu by bus.

Oct. 6: 6 papers presented in the morning and 5 in the afternoon to Chengdu and S.W. Laboratory personnel. Reception in the evening.

Oct. 7: Sightseeing. Fly to Shanghai. Arrive Jing Jiang Hotel in time for dinner.

Oct. 8: Presented 5 papers AM and 5 papers PM to Shanghai Nuclear Society personnel.

Oct. 9: Sightseeing. Banquet in the evening.

Oct. 10: Fly to Hong Kong. Hotel problems. Stayed at Miramar Hotel that night. Sunset boat ride, etc.

Oct. 11: Sightseeing. Transferred to Sheraton Hotel.

Oct. 12: Return to Seattle via Narita Airport Japan.

**Annex III**
**Sessions A/1-6, Safeguards and Material Management**

A-1: Ralph Caudle: U.S. Physical Protection
W. Higinbotham: Comparison of U.S. and IAEA Safeguards, U.S. Material Control and Accounting

A-2: C. Vaughan: Elements of a Nuclear Materials Management System
C. Vaughan: Development of the GE Wilmington System, 1971 to the present

A-3: C. Vaughan: The G.E. Manufacturing Information Control System
C. Vaughan: Instrument development for the above
V. Vaughan: Document Control for the G.E. Hardware Facility

A-4: G. R. Keepin: NDA Instrumentation
G. R. Keepin: IAEA Goals, etc.

A-5: L. Casabona: Analytical Techniques and QC
J. Jaech: Statistical Analysis

A-6: D. Bishop: G.E. Facilities and Experience in Japan
C. Thorup: The Nuclear Assurance Co. fuel cycle data system

**Sessions B/1-6**

E. R. Johnson: Nuclear Fuel Cycle Economics

Carol Thorup: Disassembly of LWR Spent Fuel to Increase Reactor Pool Capacity

J. F. Fletcher: Monitored Retrievable Spent Fuel Storage Alternatives

Peter Hofmann: Economic Analysis of Permanent Disposal of High Level Wastes

Arthur Carson: High-level Waste Solidification

J. A. Lieberman: U.S. Regulations on Radioactive Waste Disposal, *Alternative Methods for High Level Waste Depositories*

Bill Teer: U.S. Regulations on Transportation of Radioactive Materials Package Design and Testing for Radioactive Shipments

Dennis Bishop: Experience of General Electric in the Fabrication of LEU Fuels and in Supporting Japanese Power Plants

Carol Thorup: In-situ Uranium Minning

# JOURNAL ARTICLE DEADLINES

Deadlines for technical manuscripts (requiring review) and news articles, etc. (not requiring technical review) are given in the annual schedule noted below. As a convenient reminder to colleagues in your organization, you may wish to post this schedule.

| Issue | Technical* Manuscripts Due | News** Articles, etc. Due | Publication Mailing Date |
|---|---|---|---|
| Spring | January 1 | March 1 | April 1 |
| Summer | July 1 | September 1 | October 1 |
| Winter | October 1 | December 1 | January 1 |

*To submit a technical article (requiring review), send three copies to Dr. William A. Higinbotham, TSO, Building 197, Brookhaven National Laboratory, Upton, Long Island, New York 11973 (phone 516/345-2908, or FTS 666-2908). One copy should be sent to Editor, NUCLEAR MATERIALS MANAGEMENT, INMM Headquarters, 8600 West Bryn Mawr Avenue, Chicago, Illinois 60631 U.S.A. (phone: 312/693-0990).

**News articles, photos (with captions, of course), book reviews, summaries of technical presentations, guest editorials, technical notes, etc. should be submitted by the appropriate deadline to the Editor at INMM Headquarters.

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# A REMINISCENCE, 1944

**Chapter 2**

**R.D. SMITH**

On the first Sunday after my arrival in Oak Ridge, (to quote Casey Stengel, "You could look it up.") a friend and I decided to visit Norris Dam. Almost none of us G.I.'s had cars, but patriotism was so high at the time that almost anyone in a car would stop for your thumb and uniform. So we hitch-hiked to Norris Dam. It was the most impressive thing I had ever seen. At that time I hadn't seen Niagara Falls, but on this day Norris Lake was going over the dam. A huge flow. Of course it wasn't going over the road across the dam; it was flowing over the spillways about a foot and a half deep. We walked across the dam and asked one of the TVA employees if this occurred all the time. He told us it was the first time it had ever happened. Now I knew why there was so much mud in Oak Ridge. We were having a very wet spring; not very conducive to starting a war.

As a small aside, a few years ago it happened again. I took Evelyn and my mother and perhaps a few others to seet it. To my knowledge, those are the only two times that it's happened.

Now, back to the laboratory and my back bench. As usual I was a shade tipsy from the ether, but I had my three apparati set up and purring, and I had about three-quarters of an hour free. It was night-shift and I wandered into the laboratory office. I looked at the shelf of books there. I was reading the titles and suddenly was struck by one of them. It was something like "The Chemistry of the Rarer Elements." I pulled it down and noticed a slightly dirty streak down the closed pages. I got quite excited, sat down, and opened the book at the streak. It said, "The Chemistry of Uranium." I read the whole chapter in about ten minutes. Here was what we were doing! The mysterious "T" was uranium. I recognized all the reactions and compounds. Now, at least I knew what we were working with; I never did know why until Hiroshima.

When you know what you're working with you can do so more intelligently, and I read the book over and over. I observed what sometimes went wrong with my extractions. The principal, if not the only difficulty, was that sometimes they would emulsify and simply refuse to extract. The prescribed method for breaking the emulsion was to add more concentrated nitric acid. Once when I did this, the apparatus sort of exploded (not the glass which held nicely, but from the thistle tube into which I was pouring the acid). No one who has concentrated nitric acid sprayed all over him including his eyes can imagine what that is like. Much as I love laboratory work, it was awful. Fortunately there were about six people around who saw what had happened. They grabbed me, and put me under the safety shower. Here I was with all my clothes on, wet as hell, and somebody was saying, "How are your eyes?" Actually, they were okay although somewhat red for a few days. Those safety showers are the greatest.

So I asked Forrest Clark why they sometimes emulsified. He said that some guys out in the plant did not use just nitric acid, but also sulfuric and hydrochloric, and that that was the cause. After I thought that over for a while, I told him that he knew as well as I did that silver sulfate and silver chloride are almost insoluble. The very next day he brought me a five-pound bottle of silver nitrate. So I set up filter-stands and filters, procured lots of fine filter-paper, got some wash-bottles into which I put diluted nitric acid, and I was in business. I never had another emulsion. My method was adopted as procedure.

One other small comment on the back-bench experience: I asked what to do with the silver chloride and silver sulfate precipitates which I had collected. I was told to pour them down the drain! I probably poured twenty or twenty-five pounds of silver down the drain. In war time, one must do strange things. On the other hand, it is customary to pour used reagents down the drain. We would have probably spent more than the silver was worth at that time had we tried to recover it.

Then came penta-ether. It was billed as a better extractant. I used to know the formula, but I'm afraid I've forgotten it. I was selected to develop a laboratory procedure to use penta-ether instead of diethyl ether in our analyses. It was safer; it was surer; it didn't form emulsions; but, lamentably, it also didn't make anybody sing.

The new procedure involved putting the samples through three separatory funnel work-outs. I must have looked like the bartender at the Ritz because for that period I usually had one in each hand and was shaking them violently as one would do a Martini or something. I taught the new procedure to the girls and quite suddenly was promoted to assistant foreman.

Serious assistant foreman duties included trying to break in the new people who were assigned to us. This was no problem most of the time. They were mostly girls, about eighteen or so, who had a minimum education but were bright enough to pick up on everything quickly. I had two real problems though. The first was a very nice looking young man who had had some college chemistry and seemed to be an ideal hire. I talked to him at length several times and he was perfectly lucid—he knew his chemistry. Then all of a sudden—a most peculiar thing—he didn't know his name of anything else. I called the medical department and the guards and they took the poor boy somewhere. What a shame!

Then I had this guy who spoke well and had been a chemist for some years. He had references, he had the education; I couldn't understand why he wasn't employed. It was soon apparent. The poor man's memory was gone. I would explain a procedure to him and watch him perform it. The first time it would be almost right, but with repetition the procedure would disappear into meaningless gestures. He was completely non-functional; another sad case. Of course, that's why they were not in the army.

There are only two things better than working Oak Ridge in the Spring of 1944. One is Christmans—any Christmas—and the other is being with a friend, such as a wife you will always have. Toward the end of the summer, Evelyn had to go back to Boonville, New York (of all places) to assume a teaching position.

After about three months of being together, it was a wrenching experience for both of us. But that appeared to be the way it had to be. When you're as young as we were, you don't think as clearly as true adults. There were alternatives, such as just breaking the teaching contract, but we simply didn't quite understand.

Meanwhile back at the laboratory, I had become a chemist—I mean officially—and a foreman. (The Army still called me a Technician Fifth Grade which was and is an insult.) I was transferred to another laboratory where I was to be one of the four round-the-clock foremen. I have written before about concentrated nitric acid, but this place practically swam in it. We had huge bottles of sodium bicarbonate solution everywhere so we could dilute, perhaps neutralize, the acid if it got on us. And get on us it did. In warmer weather we had brown spots all over our skin. In colder weather our clothes were all in holes. Our quartermaster, who was really a pretty nice guy, would give me a terrible time every time I came in for a new suit of G.I.'s. He was pretty used to it though and I got my suits regularly.

This reminds me of an occurrence at the back bench (I'm sorry that I can't keep things in order). The girls a few benches up from me also put their residues in five-gallon bottles. When the bottles got full they were too much for the girls to handle, so they would call on me. Now the way one picks up a five-gallon bottle is by the neck, and I must have done this hundreds of times. I had only maybe ten feet to walk with the dumb thing, but the bottom gave way and soaked me about to my knees. This residue was oxalic and hydrochloric acid (fortunately little of the latter).

I went to the men's room, washed my socks and shoes as well as I could and tried to do something about the lower parts of my pants. But it seemed that nothing could be done. I can hardly believe it even today, but in all honesty the lower part of each of my olive drab pant legs had turned a robin's egg blue. I was somewhat embarrassed to go home in this condition, but I did. There was some snickering on the bus.

But back to my new laboratory; I had more than a dozen new girls that I didn't know. Unlike the girls in the other laboratory, they were not northerners—they were East Tennessee girls. Talk about a cultural divide! I couldn't understand them and they couldn't undertand me! I'm talking about language. Every time I asked one of them to do something she's say an absolutely noncomittal, "Well". So I would watch her, and she'd do it. To me that Tennessee "Well" is about the deepest well there is.

I found out what "hep yo' sef" meant, and "git yo' sef a cheer." I watched them and they were funny. Each and every one was working as hard as she could. They really believed they were winning the war, and in a crazy sort of way they were.

And sing! Back at the back bench we sang the nationally popular tunes of the day. In the new laboratory, there was a whole new flavor to the songs. I'm told that the songs of Appalachia are late Elizabethan. Be that as it may, I was subjected to all 152 or so verses of "In The Pines". Good Lord, it got so I was remembering them. There was one girl—her name was Lena—who would sit on a tall stool in the middle of the laboratory and cry uncontrollably because, as she said, "It was so beautiful".

I learned a great many Baptist hymns as well; and they are terrific. What an experience! I learned the bass part of "Have a Little Talk with Jesus", and you should have heard those girls. Everything from a beautiful soprano to the best contralto I've ever heard. How they could sing!

And work! Willingly! I've never seen anything quite like it. Every once in a while, one of them would drop out. Of course, I knew what was going on. In that day and age, one didn't talk about that sort of thing. When things calmed down, I would look at Mary, one of the older girls, and she would wink. She was a sly old fox and, I must say, an ally.

One night on night-shift the girls got to speculating about my age. We had our work done up pretty well so I didn't see any harm in it. Mary, who was maybe thirty-five, suggested that they have a sort of raffle. Mary had a dry humor. I readily agreed and the girls all made bets on my birthday. My birthday is October 25, 1922 which made me at that point about twenty-four years old, but not quite. They bet, and at the average, had me at about thirty-two.

The thing that put them off the track mainly was my bald head. I had begun to bald in high school, continued in college, and sort of finished it in the army. I'd been married for some years. They didn't know I was married at the age of twenty. It was a long-standing joke between me and the girls when they found out I was almost ten years younger than they thought.

By the way, Mary won the raffle.

NEXT: We buy a state park.

# BOOK REVIEW

**EUGENE V. WEINSTOCK**
Brookhaven National Laboratory

BEFORE IT'S TOO LATE:
A SCIENTIST'S CASE FOR NUCLEAR ENERGY, Bernard L. Cohen, Plenum Press, New York, 1983, 292 pages, $16.95

This is the best book on the nuclear-power controversy that I have read yet. Written by a professor of physics at the University of Pittsburgh and past Chairman of the Division of Nuclear Physics of the American Physical Society, its unique feature for a book on this subject written for a lay audience is its quantitative approach to virtually all the controversial issues of nuclear power. Although every effort is made to simplify the calculations (which appear as appendices to each chapter and use only arithmetic), this aspect will no doubt frighten some readers off. That would be unfortunate, since one of Prof. Cohen's main points is that the whole nuclear power debate has suffered grievously from a general public failure to appreciate the importance of a quantitative understanding of the risks of technology. As he points out, in the absence of quantitative comparisons any technology can be made to appear as dangerous as one chooses.

Another great virtue of the book is its extensive documentation. Almost every factual statement is backed up by a reference, with individual chapters having, typically, a list of forty or fifty references at the end. Prof. Cohen has performed a signal service by wading through this immense literature and summarizing it in understandable terms in a single document.

The main topics covered are the hazards of radiation, reactor safety, the nature of risk and its pervasive role in our society, high-level radioactive waste, plutonium and nuclear weapons, the costs of nuclear power, solar energy, and the role of the media in shaping public attitudes towards nuclear power. In some of these subjects—for example, the hazards of radioactive waste—Prof. Cohen has the expertise arising from extensive original research. In others, such as costs and reactor safety, he disclaims in a couple of refreshingly modest footnotes any special authority except for that resulting from an extensive reading of the technical literature and discussions with acknowledged experts.

There are so many good things about this book that it is hard to know which ones to single out for special mention. I thought that the discussion of the dangers of radiation was one of the clearest I have ever seen. To put these dangers in perspective the very effective device of comparing the risk of a given exposure to radiation with similar risks from everyday activities is adopted. Thus, 1 millirem turns out to present the same risk, in terms of shortening life expectancy, as 3 puffs on a cigarette, 10 extra calories to an overweight person, or driving an extra 3 miles.

The relationship between cancer induction and radiation dose is also simply explained. In all the calculations the linear hypothesis is used. According to this, the probability of causing cancer is proportional to the total dose over the entire range, no matter how small, and independent of dose rate. In a tartly-worded foreword Nobel laureate and medical physicist Rosalyn Yalow takes issue with this assumption, pointing out that it grossly exaggerates the health effects of low doses and is in conflict with much of the observational evidence. Even so, Cohen's estimates of the health effects of some of the most highly publicized actual radiation releases turn out to be minuscule. Then why all the public fuss, bordering on hysteria, about radiation? Cohen lays the blame directly at the door of the media and their anti-nuclear manipulators. More about this later.

The chapters on risk and on the hazards of high-level radioactive waste are also particularly well written. Risk is expressed in terms of the average loss of life expectancy (LLE) resulting from the particular activity under consideration. This provides a common basis for comparing the risks of different activities and, in particular, for different ways (e.g. nuclear, coal, oil, and solar) of generating the same amount of electrical energy. A most instructive and interesting table lists LLE's for 38 different risks. At the top of the list is the risk of being male rather than female (LLE = 2800 days, the difference in average life expectancy of male and female). At the bottom is the risk that would result from an all-nuclear U.S. electrical system (LLE = 0.03 days, according to NRC estimates). In between are such risks as being 15 pounds overweight (LLE = 450 days), of driving a small instead of a standard-size car (LLE = 50 days), and of having one diet drink every day of ones life (LLE = 50 days).

The anti-nukes frequently object to these comparisons on two grounds. First, the non-nuclear risks, such as those from motor vehicles, supposedly involved voluntary activities which one could avoid, whereas a nuclear plant is imposed on every member of the public, regardless of his wishes. Second, an activity which kills a certain number of people in one or a few spectacular accidents is somehow worse than one which kills the same number of people in the same time but more or less unnoticeably and only one or two at a time. Cohen effectively disposes of both arguments. With regard to the first, many of the non-nuclear risks are also involuntarily assumed by the public. For example, pedestrians account for roughly 10,000 of the 50,000 victims of automobile accidents per year, and the risks of coal-burning plants are assumed as involuntarily as those of nuclear. As to the second, Cohen points out that the argument can hold (if it does at all) only as long as the two types of activity kill precisely the same number of people each year. Thus, if technology A kills even one less person than technology B (both producing the same product and being in all other respects equal), most people would agree that it is preferable from a safety point of view to B. Precisely on these grounds, nuclear should be preferred to coal, oil, gas, or solar as a means of generating electricity.

With the LLE's as a framework, the risks of various kinds of electrical-generating systems are compared, assuming in each case that the system generates all the electricity in the U.S. For coal, oil, and gas the LLE's are 13, 4, and 2.5 days, respectively; for solar it is 0.4 days, arising mainly from the manufacture of the large amounts of materials like concrete, steel, and glass required to emplace the photovoltaic cells. Solar is thus more than 10 times as dangerous as nuclear, but the former is the darling of the media and the latter the whipping boy.

As might be expected from Prof. Cohen's professional activities in this area, the chapters on radioactive waste are especially good. Again, the quantitative approach is adopted. It shows that even if the high-level waste from one year's operation of a large nuclear power reactor were merely vitrified and dumped at random into the oceans the eventual number of deaths caused (over millions of years, that is) would be only 0.6. If, instead, this amount of waste were buried underground in such a form that it could be assumed to have the properties of average rock submerged in ground water, it would produce approximately 0.02 deaths, plant of comparable size would cause 70 eventual deaths, and that from a solar plant at least 2 and as many as 80 deaths, the latter figure applying to photovoltaic cells made of the highly toxic substance, cadmium.

In the discussion of plutonium and nuclear weapons, Cohen neatly skewers the common belief that almost anyone—and, in particular, terrorists—can easily make a nuclear bomb once they get their hands on some plutonium. After describing the difficulties and dangers, he points out that in neither of the two highly publicized cases of so-called student designs was anything even remotely resembling a workable design produced. For example, in the case of the Princeton student, John Aristotle Phillips (who later ran for Congress on the strength of the publicity he had received), the description did not even include dimensions but only crude sketches. It is clearly impossible to evaluate such a "design", yet that did not stop the media from labelling it "workable".

The treatment of plutonium toxicity and the use of plutonium dispersal as a terrorist weapon is also enlightening. Once again, quantitative reasoning leads to the conclusion that the dangers have been much exaggerated, and that there are far simpler and more effective ways of achieving the same end.

Cohen's anger and frustration at being unable to get his message through to the public come out again and again. He bitterly—and, in my view, justifiably—denounces the television news commentators as being primarily entertainers and totally uninterested in the truth if it is in the least complex, nonsensational, or disagrees with their preconceived notions. The most influential newspapers (e.g. the New York Times and the Washington Post) he accuses of bias, and buttresses his case by citing the polls of scientists and journalists conducted by the social scientists Stanley Rothman and Robert Lichter.

The book is not perfect. For example, I thought that the discussion of non-proliferation policy did not do justice to the views of the Carter advisors (with whom I hasten to add, I disagree). In the discussion of domestic safeguards it was sometimes not clear whether the practices being described were those of the private or the governmental (i.e. DOE) sector. Perhaps the most serious defect is an occasional tendency to exaggerate. For example, concerning the potential use of plutonium as a fuel, Cohen declares his conviction that one day it will come to be looked upon as "one of God's greatest gifts to humanity." Greater than antibiotics, anaesthesia, or agriculture? He also characterizes the public's misunderstanding of nuclear power as "probably the greatest tragedy in American history." Greater than slavery or the Civil War?

The trouble with this kind of hyperbole, harmless though it may seem (and understandable, perhaps, in view of the provocation), is that it provides critics with an easy target for attack and with a means for discrediting the substance of the arguments. Commissioner Gilinsky, for instance, recently dismissed as "puerile" an offer by Prof. Cohen to eat as much plutonium as any prominent nuclear critic will eat or drink caffeine. (The offer was made to counteract the recurrent exaggerations of plutonium toxicity).

But these faults are minor in comparison with the great virtues of the book. Prof. Cohen is to be congratulated for having written a book on a complex, controversial topic that is at the same time informative, authoritative, and eminently readable. If I were to buy only one book on this subject, this would be it.

# REPORT OF THE INMM LONG RANGE PLANNING COMMITTEE TO THE EXECUTIVE COMMITTEE

**SAMUEL C. T. McDOWELL**
Department of Energy
Washington, D.C. U.S.A.

The Long Range Planning Committee (LRPC) met on October 21, 1983, at DOE Headquarters, Germantown, to review the INMM's implementation plans for the Long Range Planning Committee report. Attending were: S. McDowell (Chairman), Y. Ferris, R. Lumb, E. Johnson, and V. DeVito.

The LRPC's comments and recommendations on the INMM's implementation plans were presented to the INMM Executive Committee at its meeting in Columbus, Ohio, November 14-15, 1983. These comments and recommendations are given below for each of the ten (I-X) topical areas of the implementation report, as well as the Executive Committee's action:

I. Expand Interest and Coverage of INMM to All Phases of Nuclear Materials Management

LRPC's Response:

"The LRPC fully agrees (see topics below)."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

II. Expand a Number of Topical Meetings to Service Membership

LRPC's Response:

"The technical chairman of the next annual meeting should be assigned responsibility, for action now, to include waste management, transportation and decommissioning sessions in the meeting, built around invited speakers, and the call for papers should include and highlight those topics. Special sessions should be held, possibly running concurrently with safeguards and security. Suggested names of points of contact and lead spokespersons for these areas were presented by the LRPC at the November 14-15, 1983, Executive Committee Meeting."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

III. Conduct Workshops

LRPC's Response:

"New NRC regulations will focus on utilizing process control as a major part of material control. Important to such a concept is control instrumentation which can measure and control the flow of materials in the process. Experience in the development and application of such instrumentation exists at LANL, AGNS, NFS, etc. The LRPC believes that sufficient operating experience has been demonstrated with these systems at these facilities to support a workshop in this area."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

IV. Continue Training Programs With Specific Objective of Qualifying Students to Become Certified Nuclear Materials Managers

LRPC's Response:

"A training program specifically oriented to certification is planned for February 20-24, 1984, at the Key Bridge Marriott, Washington, DC. Further, the Executive Committee should authorize discussions with NRC and DOE to seek encouragement for the certification program at both agencies. The Committee should delegate this responsibility to a specific individual."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

V. Increase Membership -- Particularly Through Those With Interest in Expanded Areas

LRPC's Response:

"Membership applications should be at every topical meeting and workshop. Registration lists from such meetings should go to the membership committee and the committee should write each non-member and invite him/her to become a member. Messervey is taking an active role; a list of over 500 potential candidates has been sent to him. Each Chapter should set membership goals. We should expand our interests to include waste management, decommissioning, transportation, utilities, consultants, etc. An article should appear in the Journal on 'what do you get for your membership.' Show what each gets for his dues."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

VI. Initiate Publication of Monographs in all Areas Set Forth in I. Above. To Enhance Member Education, Stature of INMM, and to Disseminate Information to the Scientific Community

LRPC's Response:

"Messervey should set up arrangements for publishing monographs, considering methods of compensation such as residual rights, etc. A plan is needed for development and publication of the monographs. Technical publication houses need to be approached and agreements reached. Budgets need to be developed for the monograph editors (there are expenses involved, and where financial commitments are made, it is easier to keep people to committed schedules). We should concentrate on one subject initially (waste management is certainly an excellent choice - of high current interest), get commitments from publishers, editors, contributors, then use that experience as a pattern for the other monographs."

EXECUTIVE COMMITTEE's ACTION --- RICHARD DUDA WILL FOLLOW-UP ON POSSIBILITIES FOR A MONOGRAPH IN THE INTERNATIONAL AREA.

VII. Initiate Publication and Dissemination of Information Regarding Nuclear Materials Management in the Areas Set Forth in I. Above -- To the General Public and Government Leaders

LRPC's Response:

"The LRPC recognizes the efforts of the Safeguards Committee to contact all of the oversight committees of Congress which impact nuclear energy, and to establish liaison with them, and the steps being taken by the Safeguards Committee to introduce factual information to those committees and Congress in general. These activities include those of the Government Liaison Subcommittee. Members should report to the Journal when presentations are given to various interested groups. These presentations will interest and initiate activities by others. Messervey should be contacted for speakers on subject areas."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

VIII. Expand Subscriptions of INMM Journal and Proceedings to Libraries

LRPC's Response:

"There are mailing lists for libraries available -- we have been offered the ANS library mailing list. It is many times our own and is an excellent starting point. We need action here -- not more planning. More material is needed for the Journal -- call individuals for articles. We need an expanded distribution of the Journal. Some of the papers of the China 'People to People' visit should be published; also papers on waste management, packaging, transportation, decommissioning, etc."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

IX. Continue to Strongly Support and Expand INMM Standards Activities in ANSI N14 and N15 Committees

LRPC's Response:

"We should review our continued involvement in ANSI which costs the INMM $2,500/yr. to be on the Board. Suggest we solicit industrial contributions to the INMM to support the programs. We should be in a position to set the tone and direction of regulations."

EXECUTIVE COMMITTEE's ACTION --- REVIEW IN A YEAR.

X. Maintain Sufficient Funds in Treasury to Support INMM Activities (Including Payment of Expenses of Executive Committee Members) and Executive Director at Least a Year in Advance. Pro Forma Budgets Should be Developed for Period 1983-1987 to Insure This Goal is Met

LRPC's Response:

"We need a five year budget, updated annually. A system needs to be established for accumulating routinely the needed information so that the Executive Committee can analyze and approve the budget plan. Our financial reports should include a comparison with the prior year, so that progress can be evaluated, and comparison made with the objectives defined in our budget so that we can see how close we are coming to our target."

EXECUTIVE COMMITTEE's ACTION --- APPROVED.

Chairman, Long Range Plans Committee

# SAFEGUARDS APPROACH FOR GAS CENTRIFUGE TYPE ENRICHMENT PLANTS

Authored by the Hexapartite Safeguards Project [HSP]*
Edited by Joerg H. Menzel

United States Arms Control and Disarmament Agency
Washington, D.C. U.S.A.

ABSTRACT

For many years, safeguards experts have wrestled with the problem of how to get effective and credible safeguards at uranium enrichment plants while protecting sensitive information and minimizing the operator's burden. In an effort dedicated to solving this problem for gas centrifuge uranium enrichment plants subject to INFCIRC/153-type safeguards agreements, six technology holders and the inspectorates of the IAEA and Euratom created the Hexapartite Safeguards Project (HSP) in November 1980. After 2 1/2 years of intensive study it was concluded that, for commercial gas centrifuge uranium enrichment plants in NPT states, the safeguards approach involving limited-frequency unannounced access (LFUA) by IAEA inspectors to cascade areas offers the best solution. This report, based on the text produced by the HSP, provides (1) the essential details of the project, (2) the "LFUA" safeguards approach, and (3) the possible inspection activities inside and outside the cascade areas.

## PART I: THE HEXAPARTITE SAFEGUARDS PROJECT (HSP)

### A. Introduction

Commercial exploitation of the gas centrifuge process for uranium enrichment began in earnest in the early 1970's. From the outset, attention was given to the need to apply an effective and an efficient international safeguards approach to plants of this type. The general principles for achieving this were easily and relatively quickly established since the physical characteristics of the gas centrifuge enrichment process readily lend themselves to the maintenance of accurate material accounts.

However, the elaboration of a basic safeguards approach proved very difficult because of the sensitivity of this novel process. Throughout the 1970's there were many efforts at resolving these difficulties, notably in the IAEA Advisory Group Meeting held in Tokyo in 1977. In each case agreement could not be reached on the point as to whether or not inspectors would need access to the cascade halls of gas centrifuge enrichment plants if an effective and efficient safeguards approach was to be implemented under NPT conditions. It was argued by several technology holders that access was unacceptable because information sensitive on both commercial and non-proliferation grounds would be at risk and that an effective and efficient safeguards approach could be implemented without access to the cascade halls.

This situation was clearly unsatisfactory, and and in the late 1970's the need to come to an agreed safeguards approach was given added impetus by the expansion of existing gas centrifuge enrichment programs and the initiation of new ones. Eventually in 1980, there was a series of *informal discussions* between the IAEA, Euratom and technology holders of the gas centrifuge process and the outcome was a concensus to collaborate to reexamine the situation and to solve the outstanding problems.

### B. Form and Purpose of the HSP

An initial ad hoc meeting was held at URENCO's offices in Marlow, England, in November 1980. The participants were the IAEA, Euratom, Australia, Japan, Troika (comprising the Federal Republic of Germany, the Netherlands and the UK) and the USA.

The participants all shared a common commitment to achieving rapid and real progress and to studying practical applications at real plants, not paper studies on model plants. The aim was to establish a sound technical basis for the development of effective and efficient safeguards strategies by the inspectorate(s), i.e., the IAEA and Euratom:

-- effective in the way that they met the objectives of the inspectorate(s);

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-- efficient in the way that they made good use of the resources applied.

With these aims in mind, the proposal for a Hexapartite Safeguards Project (HSP) was accepted and it was agreed that:

(1) The goal of the project would be to develop, within 2 years, an adequate basis of technical experience and information which could be used by the IAEA, Euratom and the State involved in their evaluation of the various safeguards approaches and the possible development of arrangements for the direct implementation of an effective and efficient safeguards approach to specific plants.

(2) The technical objective of the HSP was to facilitate the application of effective and efficient international safeguards at uranium enrichment plants of the gas centrifuge type.

This was to be achieved through the exchange of relevant information, thereby coordinating individual development efforts, and by the technical consideration of possible safeguards approaches. The case of non-access by inspectors to the cascade halls of the plants and other cases of varying degrees and frequency of access were to be treated in parallel.

The participants also agreed that they were not looking for a legal structure for the project but rather for practical and satisfactory cooperation towards a common objective.

## C. Discussion and Results

To carry out the basic information exercise four working teams were set up, each to study a specific aspect of the problem, namely (1) facility characteristics; (2) containment and surveillance; (3) nuclear materials accountancy; and (4) safeguards strategies including different degrees of access to cascade areas.

The groups met as required to accomplish their work and their progress was monitored by a series of HSP Plenary Meetings.

The four teams completed their work and their reports provided the basis for the work of a further sub-group, which was set up to define, assess and evaluate the advantages of the "non-access" and "limited-frequency unannounced access" models.

After detailed consideration, the assessment sub-group concluded that a safeguards approach based upon limited-frequency unannounced access (LFUA) to cascade areas was capable of meeting safeguards objectives, in particular those for material of high strategic value. Part II of this paper describes the LFUA safeguards approach.

It was agreed by the participants in the sub-group that for the application of this approach it would be necessary that the approach be accepted by all participants and equally applied to all technology holders participating in the HSP; that the nature and scope of inspectorate(s) verification activities be clearly and unambiguously defined and described; and that security concerns with regard to the protection of sensitive information be satisfactorily met.

A number of participants considered that non-access approaches were also capable of meeting the safeguards objectives. However, the group agreed that the limited-frequency unannounced access model exhibited three main advantages as compared to the non-access alternative:

(1) Less intrusion into plant operations and lower equipment and manpower costs, both for the operator and for the inspectorate(s).

(2) Simpler implementation of the model, especially in already existing facilities or facilities already under construction.

(3) Greater availability, within the timescale of HSP, of instrument measurement techniques associated with the access approach.

The principal disadvantage of the access model was that it implied a higher risk of revealing sensitive information.

The assessment sub-group recommended that a safeguards approach based upon limited-frequency unnanounced access to cascade areas should be studied in detail for each technology to see how the above conditions could be applied.

The fifth plenary session of the HSP held in Sydney, Australia, in March 1982 endorsed the conclusions and recommendations of the assessment sub-group.

The seventh plenary meeting of the HSP took place in Luxembourg in January 1983. The paper "Inspection Activities Associated with Limited-Frequency Unannounced Access Model Applied to Gas Centrifuge Type Enrichment Plants" was finalized. The Hexapartite Safeguards Project completed its tasks on the technical level at the Luxembourg meeting, two years and three months after its establishment.

The final plenary meeting of the HSP was held in Vienna in March 1983 and, as of July 1, all other aspects directly related to the HSP were completed.

## D. Conclusion

It has been agreed that, for commercial gas centrifuge uranium enrichment plants in NPT states, the safeguards approach involving limited-frequency unannounced access by IAEA inspectors to cascade areas together with inspection activities outside the cascade areas offers an effective and efficient safeguards measure capable of meeting the objectives of IAEA safeguards and also of minimizing the risk of revealing sensitive information in accordance with INFCIRC/153-type agreements. The experts participating in HSP thus arrived at a consensus that this safeguards approach would be appropriate for all commercial gas centrifuge uranium enrichment plants situated in states party to the NPT.

This safeguards approach clearly provides the clear and unambiguous definition and description of the nature and scope of the inspectorates' verification activities which was one of the requirements identified by the assessment sub-group.

As HSP was looking toward the common objective of an effective and efficient safeguards regime, it was necessary to formalize the acceptance of these findings by all participants and the assurance of their equal application to all technology holders. In order to meet related security concerns about the protection of sensitive information it will be necessary for each of the technology holders and the inspectorate(s) to make their own appropriate efforts as well as to cooperate to facilitate the implementation of the proposed safeguards approach.

PART II: THE "LFUA" SAFEGUARDS APPROACH

A. Scope

The participants in HSP consider that the safeguards approach described in this document is capable of meeting the objectives of IAEA safeguards in accordance with INFCIRC/153-type safeguards agreements and satisfies the relevant technical requirements. It should, however, be understood that nothing in this document shall be interpreted as altering rights and obligations of the parties concerned, as provided in the individual safeguards agreement.

Further, it is understood that, on acceptance of limited-frequency unannounced access, extended containment and surveillance (C/S) measures at the periphery of the cascade area will not be used.

The question of verification of gas phase nuclear material flows and inventories inside the cascades and associated piping is not considered relevant.

B. Objectives and Underlying Assumptions of Inspection Activities, Including Those Inside Cascade Halls

As with all investigations by HSP, only gas centrifuge enrichment plants subject to safeguards under an INFCIRC/153-type agreement (for non-nuclear weapon and for nuclear weapon states) and operating at a stated maximum enrichment level of 5 percent or less have been considered. Accordingly, the overall safeguards objective expressed in para. 28 of INFCIRC/153 has formed the basis for all considerations of safeguards capability in this report. As applied to centrifuge uranium enrichment plants, implementation of the objective of safeguards entails a set of safeguards measures whose application by the inspectorate(s) permits the detection, in a timely manner and with high confidence, of the diversion of a significant quantity of uranium, including the production of a significant quantity of uranium at an enrichment level higher than declared. In considering diversion strategies, special emphasis must be placed on meeting the relevant goals for strategies involving material of high strategic value.

It is assumed that in principle it is possible, but not necessarily easy, to produce higher enrichments than the declared design values by:

- -- rearrangement of the enrichment equipment or by
- -- modifying the operating mode, e.g., recycling of flows or parts of them by using alternative feed and take-off points.

Inspection activities may be categorized as (1) those needed to verify that the nuclear material flows and inventories are in accordance with declaration and (2) those needed to verify that material production is in the range of declared enrichment, i.e., to verify enrichment, to verify that all nuclear material is routed as described in the design information, and to verify that cascades are connected as declared.

It is assumed further that there are indications or anomalies which may be observed or detected by an inspector in the case that centrifuges are used for the production of high enriched uranium. The following indications might be associated with HEU diversion scenarios:

- -- significant variations in UF6 flow or concentration at feed and withdrawal stations (this includes significant MUF or systematic data falsification);
- -- changes in declared UF6 piping arrangement;
- -- existence of additional storage, feed and withdrawal stations/facilities;
- -- a radiation field indicating HEU.

The safeguards activities related to the detection of all except the first indication listed above require access of IAEA inspectors to the cascade hall.

Measures which might be used to implement the activities outside the cascade area would be the use of conventional material balance and C/S measures. Measures which might be used to implement those activities inside the cascade area may be broadly classified into direct visual observation by inspectors and technical measures, i.e., radiation monitoring and NDA measurements, sampling, and application and verification of seals. Wherever inside cascade area NDA enrichment measurement is referred to, it means quick NDA measurement (go/no go) to confirm only that the enrichment level is in the LEU range.

Possible inspection activities and associated measures are described in Part III of this paper. Appropriate combinations of such activities and measures will be adopted for each facility.

C. Comparability of Inspection Activities at Different Enrichment Facilities in NPT-States

Safeguards should be applied equally at similiar facilities under similar conditions. On the other hand, it must be recognized that there are safeguards-relevant differences in technology which need to be taken into account by the inspectorate(s) and which can result in some differences in the relative usefulness, frequency and time required for the inspection activity at the facility, including visual and instrumental inspection activities inside cascade areas. Therefore, it is assumed that for the various enrichment facilities the inspectorate(s):

-- utilize the same basic assumptions and safeguards approach;
-- derive the same benefit in meeting its safeguards objective from the deterrent value of unannounced access to cascade areas plus the random character of certain inspection activities, and from the detection value of inspection activities in regard to similar installed equipment, process configuration and plant features;
-- implement comparable frequency and duration of inspection activities at facilities of similar separative capacity, differentiating only on the basis of facility characteristics affecting the inspectorates' ability to draw requisite conclusions.

D. Frequency and Duration of Inspection Activities

1. Frequency and duration of routine inspection activities outside cascade areas

The mode of inspection would be intermittent. For facilities up to about 1,000,000 SWU/a, the average frequency of routine inspection visits for activities outside the cascade areas is expected to be in the range of 12-15 times per year. Since routine inspection activities outside the cascade halls and inspections within the cascade halls will not necessarily have to be carried out during the same visit, the total frequency of inspection visits may be higher. Additional routine inspection visits may be performed to service safeguards equipment or, as required due to plant operating conditions, in order to give the inspectorate(s) the opportunity to verify the feed, product and tails before they are fed to or shipped from the plant. An average duration for an inspection visit to perform a physical inventory verification would be 2 weeks and an average duration for an intermittent routine inspection visit would be 3 working days provided that the conditions at the plant allow the inspection activities to be carried out without delay or interruption. Usually it is IAEA practice to send at least 2 inspectors to perform the inspection activities. Under comparable conditions, it is expected that the total routine inspection effort for facilities with small separative capacities will be less than that for facilities with large separative capacities.

2. Frequency and duration of inspection access to cascade areas

Frequency of inspector access inside the cascade area will be determined, inter alia, by the separative capacity involved, the timescale and difficulty of modifying a facility for production of high enriched uranium (HEU), the time necessary for the production of 25 kg of U-235 in HEU and the time required to remove the resulting anomalies. In addition, the frequency and scope of inspection activities outside the cascade areas will influence the frequency of access. Under comparable conditions, the frequency of access should be higher for facilities with larger separative capacities than for those with smaller separative capacities. Important components of the timescale and difficulty of modification are the specific design features of the facility and cascade piping and valving arrangements. If the modifications require stopping the centrifuges, more time will be required than in situations where the modifications can be made without bringing the cascades to atomospheric pressure. The time required for the production of 25 kg of U-235 in HEU depends not only on the involved separative capacity but also on the production strategy applied and the flexibility of the cascades. The necessary number of inspections inside the cascade area will be plant specific. An average frequency for inspector access to cascade areas of 4 to 12 times per year for facilities up to about 1,000,000 SWU/a capacity would be appropriate.

As for facilities where use of visual observation is emphasized the duration of the inspections will be determined by the time required to carry out the visual observations and, if performed, sampling, NDA measurements and seal verifications. As for facilities where the use of installed instrumentation is emphasized the need for interrogation, maintenance and repair of the instrumentation will mainly determine the duration of the inspections. As for plants where the use of portable radiation instrumentation is emphasized the duration of access will be determined by the time necessary to make the required random measurements and visual observations. It is assumed that the time required to perform the inspection activities inside cascade areas would be in the range of 1 to 8 hours.

E. Protection of Information of Particular Sensitivity

It is recognized that there is certain information at centrifuge enrichment facilities which is of particular sensitivity.

Some of this information is required to be provided for the implementation of safeguards in pursuance of Article 8 of an INFCIRC/153-type agreement.

It is further recognized that the operator has the right to protect information which is not required to be provided in pursuance of Article 8 noted above.

The application of the relevant provisions of an INFCIRC/153-type agreement is expected to provide the necessary protection of information coming to the inspectors' knowledge.

F. Restrictions Suggested on Access Approaches

The following restrictions have been suggested for inspection activities in the cascade hall:

(1) The average frequency of inspection should be limited. (See Section D. In addition, it must be noted that the announcement of access inside the cascade hall will be made either on the occasion of routine inspection visits to the plant or as part of unannounced inspections provided in Article 84 of INFCIRC/153).

(2) The number of inspectors participating in each inspection should be restricted. (Usually, it is IAEA practice to send at least two inspectors for routine inspections at key facilities so as to maintain the necessary credibility to its safeguards system).

(3) The inspectors should be escorted. (The presence of at least one representative of the plant during the inspection is essential in order to clarify and explain anomalies).

(4) The inspectors may not depart from the predetermined and agreed paths. (However, the inspectors must have sufficient access in order to be able to perform the inspection activities properly).

(5) The instruments and equipment to be used and the modalities of their use by inspectors are to be limited to those agreed upon. (If the plant operator requests that the inspectors use his equipment, the inspectors must be in a position to verify that the equipment is functioning properly and that it is properly calibrated. It should be noted that if photographs are taken by the operator for the inspector during the inspection, these may be developed by the operator but only in the presence of the inspector. Photographs taken for verification purposes and kept in the custody of the operator must be under inspectors' seal).

(6) The duration of the inspection activities may be limited to an agreed maximum time. (However, the duration of the inspection must provide sufficient time to perform the planned activities. If any anomalies are detected, deviation from the agreed schedule may become necessary).

(7) Access may be delayed by up to 2 hours. (It is understood that from one to a maximum of two hours delay between the request for access to a cascade hall and the actual inspectors' access is required by the operator to protect certain information).

PART III: POSSIBLE INSPECTION ACTIVITIES

Possible inspection activities and associated measures are described below. Appropriate combinations thereof will be adopted for each facility.

A. Verification of Nuclear Material Flows and Inventories

Inspection activities to verify the nuclear material flows and inventories have been studied by the HSP. The findings are that conventional material accountancy and its verification is in principle adequate to meet low enriched uranium detection criteria for plants with separative capacities up to about 2,000,000 SWU/a. Some facilities in states having participated in the HSP presently lie well within this range. One facility would exceed this limit, if the full design capacity were to be built.

For plants with separative capacity up to about 2,000,000 SWU/a, except in exceptional circumstances, inspection activities associated with conventional material accountancy (and related C/S measures) would take place exclusively outside cascade areas. Other nuclear materials in the cascade area (e.g., in the chemical traps) might need to be verified.

Inspection activities outside cascade areas will include examination of operator's records and comparison of their records with reports submitted to the IAEA. In addition, the inspectors will make independent measurements for evaluation of the operator's measurement system and verification of flow and inventory of nuclear material, including the application of appropriate C/S measures.

Statistical techniques and random sampling will be used in the verification activities. Attribute and variable sampling plans should be applied to the whole population of UF6 cylinders to be verified. Provisions should be made to give the inspectors the opportunity to verify the feed, product and tails before they are fed to, or shipped from, the plant.

1. Routine inspection activites outside cascade areas

The inspectors may perform the following activities on the occasion of any routine inspection:

(1) Examination of records

-- examination of the book inventory using facility data (e.g., for the purpose of updating);
-- examination of records;
-- reconciliation of reports with records.

(2) Evaluation of operator's measurement system

-- verification of the functioning and calibration of instruments and other measuring and control equipment, and requestting recalibrations as necessary;
-- verification that the operator's analytical performance conforms to the latest international standards;
-- if necessary, standards of the inspectors may be submitted to the plant operator for measurement.

(3) Verification of nuclear material flow

-- identification and counting of UF6-cylinders and other items containing nuclear material;
-- verification of "empty," gross and net weights of feed-, product-, and tails-cylinders and other items containing nuclear material on the plant operator's scale or an inspectors' scale;
-- observation of taking representative samples for the inspectors from UF6-cylinders, UF6-streams or other UF6-containers;
-- attributes measurements by portable NDA equipment of U-235 enrichment of randomly selected feed-, product- and tails- cylinders and other items containing uranium;
-- attributes measurements by in-line monitors, if available, of U-235 enrichment in gaseous or liquid UF6-streams;
-- application, verification, removal and replacement of inspectors' seals on UF6-cylinders, safeguards equipment, records left at the plant between inspections including any design information kept on the premises of the state, and on agreed valves or flanges or UF6 pipings;
-- verification of the integrity of sealed containers or other sealed items;
-- use of temporary C/S techniques at the feed and withdrawal stations and at the UF6 cylinder storage as well as during LFUA inspections at the boundary of the cascade area, where agreed;
-- Quick Inventory Examination (QIE), if the required instrumentation is available and where agreed;
-- installation and servicing of safeguards equipment. (However, if such safeguards equipment interfaces directly with process operation, and is not removed, the operator will be requested by the inspector to perform such tasks in the presence of the inspector).

2. Physical inventory verification

The physical inventory of nuclear materials (LEU, natural U and depleted U) in gas centrifuge type enrichment plants will be taken simultaneously in accordance with agreed methods in all MBA's and at least once a year. This operation implies switching over the feed flows in the cascades to measured containers and simultaneous switching over of relevant product- and tails-flows to emptied desublimers or to measured containers. All nuclear material, except that in the cascades or where applicable and agreed in the cascade halls, will be itemized and a list of the inventory items will be prepared by the operator to be presented to the inspectors.

In this context the inspectors may perform the following activities, in addition to the activities listed under section 1 above, on the occasion of any physical inventory verification:

-- every item on the list of the inventory items is checked for its existence and for compatibility with the tag value where applicable;
-- the nuclear material in sealed and unsealed containers is verified as described in section 1.3. Verified unsealed containers should be sealed if appropriate;
-- temporary C/S measures may be taken during physical inventory verification, where agreed.

B. Verification of Material Production in the Range of Declared Enrichment

In order to produce HEU, the plant operator would need to:

-- provide the required separative capacity,
-- alter the operational configuration,
-- provide the required withdrawal station,
-- provide the required uranium feed,
-- perform the enrichment operation,
-- restore the operational configuration, and
-- remove or conceal the produced material.

Commercial gas centrifuge plants are composed of a number of identical cascades. A small number of these cascades could be used as building blocks from which cascades designed signed for production of HEU could be constructed. Alternatively, single cascade(s) could be used in a batch recycle mode to produce HEU. In either case, the rearrangement of the cascades could be accomplished by modification at the feed, tails or product headers, but without any or with only a few alterations of the interconnections between the many machines from which the individual cascades are constructed. In this fashion, sufficient separative capacity to produce a significant quantity of HEU could be made available in a centrifuge enrichment plant.

For their facilities, some technology holders have pointed to a degree of transparency for the separation equipment located within the cascade halls. It is claimed to be possible to survey readily and easily the repetitive design of the cascade connecting pipework with feed, product and tails headers. Each cascade has its own connection with valves to the main header pipes. For facilities of this type, it is assumed that the inspectors would rely primarily on visual observations. The use as necessary of installed or portable instrumentation would be a supplementary measure. However, demonstration of this transparency has been performed only for the Capenhurst facility. One of these technology holders further pointed out that the traceability of the UF6 pipes inside and outside the cascade area may assist in the verification that all nuclear material passes through declared Key Measurement Points (KMP). It must be emphasized that visual observation inside the cascade hall alone does not confirm the enrichment level. On the other hand, the access approach proposed for the other facilities would emphasize instrumental measures and verification of process equipment operation. In the latter case, the IAEA would be expected to rely on the use of instrumentation as the primary safeguards technique, and the use of visual observation would be a supplementary technique.

1. Visual observation inside cascade areas

Direct physical access allows inspectors visual observation of safeguards-relevant plant features. Visual observation of cascades assists the inspectors in performing inspections.

Visual observation can help in verification that the nuclear material contained in the cascade area is as declared and thus aid the establishment of the inventory. In addition, visual observation of cascades and associated pipework assists the inspectors in verifying the design information. Such verifications could fall into two categories:

-- the as-designed installation of process equipment, and
-- the as-designed operation of process equipment.

The verification of installed equipment would require inspectors to compare design drawings with, e.g., installed pipes, valves, conduits, pumps, traps, etc. (Some valves and flanges which are normally kept open or closed could be identified in the course of this verification and be agreed to be sealed.) This should also confirm the absence of any equipment or sampling points (as appropriate) other than those declared, which might be used to feed UF6 into or remove UF6 from the cascade.

Visual verification of process configuration can be performed by checking against the design drawings or photographic records supplied by the plant operator (or made in the presence of the Inspectorate(s)). This reference material could, for the sake of protection of information of particular sensitivity, be kept at the plant under inspectors' seal.

2. Technical measures inside cascade areas

Permanently installed radiation monitoring equipment, such as area monitors or pipe monitors, may be used to detect HEU. The inspector could also use portable NDA equipment on pipework, equipment and traps to verify that the nuclear material is as declared.

Other technical measures inside the cascade area would include sampling where safe operation allows and application/verification of seals if so agreed and specified in the Subsidiary Arrangements. In conditions of good traceability of piping it might be possible to perform such activities, and in addition QIEs (where relevant), outside the cascade area.

2.1 Radiation monitoring and NDA measurements

For those plants with greater "transparency" characteristics, any necessary enrichment measurements by portable NDA equipment may be made on the cascade connection to headers located inside the cascade hall. NDA measurements may also be performed on vessels or pipelines, including headers, outside the cascade hall, provided these are directly connected to and traceable from the cascade(s).

Some test results of gamma-ray monitoring with a Ge detector have been reported by the Netherlands, with regard to the Almelo plant. Their measurements indicate that if the plant were to produce uranium of enrichments of 20% or higher, this can be detected by gamma-ray measurements on "top" centrifuges or header pipes. The very preliminary results of neutron measurements with a He-3 neutron detector indicate that large amounts of UF6 (not quantified) are quite traceable by their neutron field. A method of determinng the enrichment of uranium in plant pipework has been demonstrated at Capenhurst. A full technical assessment of the technique has still to be made but it was possible to demonstrate that the measurement could be made with equal validity either inside or outside the cascade hall.

The following radiation monitoring and NDA measurement techniques have been proposed for plants with lesser "transparency" characteristics:

-- individual centrifuge and/or header gamma-ray measurements using a portable, high-purity Germanium (HP Ge) detector;
-- cascade area gamma-ray measurements using a portable HP Ge detector, for example, from the process building bridge-cranes;
-- cascade area neutron measurements using a large number of stationary neutron detectors mounted on cascade service modules;
-- collimated centrifuge gamma-ray measurements taken with an automated HP Ge detector system at the floor level by the operator.

Descriptions and state of the art of relevant monitors in various stages of development were reported to HSP. Monitors tested in the U.S. with promising results are a neutron monitor with four shielded detectors, an unshielded area neutron detector, a gamma-ray area monitor with four NaI detectors, and an intrinsic Ge gamma-ray detector for axial measurements. In all cases, near-field measurement techniques (neutron and gamma-ray) exhibited a greater sensitivity for the detection of HEU production in U.S. centrifuges than far-field measurement techniques. Near-field gamma-ray techniques proved to be more sensitive in detecting HEU production in short time intervals than neutron techniques. More detailed information should be obtained before selection of appropriate monitors can be made and measurement time/configurations can be determined.

### 2.2 Sampling

Samples may be taken from cascades or from groups of cascades where safe operation allows. The latter may be more acceptable to some plant operators. For the time being, the inspectors do not envisage taking samples inside cascade halls as a routine inspection measure. However, sampling might be considered for clarification of anomalies. Sampling may also be performed on vessels or pipelines outside the cascade hall, provided that these are directly connected to and traceable from the cascade(s).

### 2.3 Application and verification of seals

Seals would be applied and verified in the cascade area to maintain continuity of knowledge with respect to the status of valves and flanges, if so agreed and specified in the Subsidiary Arrangements. This could be specially useful during plant commissioning and decommissioning phases, e.g., when a new section of cascade piping is being added, or an old section is being retired, taking particular account of the protection of information of particular sensitivity.

Seals are also applied (and verified) to permanently installed safeguards equipment, if applicable.

## POSTSCRIPT

Pursuant to Article 34 of the Agreement between the IAEA and the U.S.A. for the application of safeguards in the U.S.A., the United States has notified the IAEA of the addition, effective 1 July 1983, of the Gas Centrifuge Enrichment Plant (GCEP) to the license-exempt portion of the list provided for in Article 1(b) of the Agreement.

Pursuant to Article 2(b) of the Agreement, the IAEA has designated the Portsmouth Gas Centrifuge Enrichment Plant for the application of safeguards under the terms of the Agreement as of 1 August 1983.

The IAEA carried out the first Ad Hoc inspection at GCEP pursuant to Article 69 of the Agreement on 3 August 1983.

Since GCEP is under construction, the U.S. will provide the IAEA with the information needed for Subsidiary Arrangements by about 1 January 1984.

## ACKNOWLEDGEMENT

The Hexapartite Safeguards Project (HSP) has received praise as an example of international cooperation at its best. The success of the project can be traced directly to the close working relationship of the technical and policy-making communities and their firm determination to solve collectively a problem which heretofore had escaped solution. In the U.S., the success of the HSP was principally due to the dedication and hard work of a group of people ranging from the scientists at several DOE contractors to senior officials at the Department of State, the Arms Control and Disarmament Agency and the Department of Energy. The list of names of all who contributed to the HSP is long. However, without the support and sound advice provided by Len Brenner (DOE/OSS) and Dave Thomas (DOE/OUE), and the technical writings by Dave Swindle (UCC-ND), Dave Gordon (BNL) and Mike Rosenthal (ACDA), the United States would not have been able to achieve its objective in this important area.

# OPERATIONS AND SUPPORT UNITS COOPERATION IN THE DEPARTMENT OF SAFEGUARDS*

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ABSTRACT

With the tremendous growth of the Department of Safeguards, from a small beginning as a Section in the late 1950's to its present huge departmental size consisting of several divisions, the importance of cooperation by its component units cannot be overemphasized. The basis for cooperation lies in the realisation that all the units are working for the attainment of a common safeguards objective, and the progress in this direction in the past few years has been very encouraging. Thus there is more to unite than to divide the Operations and Support Units of the Department, and the cooperation between the various units will be further enhanced when team-work in achieving effective safeguards becomes the order of the day.

## INTRODUCTION

The big annual conferences of the Institute are, unfortunately, out of the reach of all but a few of us, so this home-grown conference has provided the opportunity to share in home-grown truths. The conference title is apposite, in that most of us who are participants in the drama never seem to have the opportunity to ponder how we cooperatively achieve the important objectives assigned to Agency Safeguards, namely, to provide assurance to the international community that States are complying with their international obligations regarding nuclear materials and nuclear facilities placed under safeguards. [1] To appreciate the magnitude of the task and the amount of the cooperative teamwork involved, let us consider how the various units, that today make up the Department of Safeguards, evolved.

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## EVOLUTION OF THE DEPARTMENT OF SAFEGUARDS.

In the beginning, all safeguards was in one section! Then in the early 1960's it became a division. The first inspections were carried out in 1962 at NORA in Norway and at the Brookhaven Graphite reactor in the USA. In 1964 the Department of Safeguards and Inspections was created with the Division of Development being added to the existing division. In the late 1960's, the Section for Standardisation and Administrative Support was added to the two Divisions. By these moves, the need for a strong support to the Safeguards Operations was given a concrete expression.

The next stage came in 1977 when the SGDE was organised into its present form. The Operations was split in two divisions (A and B) and the Division of Safeguards Information Treatment (SGIT) was created.

Apart from these divisions, several other important units in the Department of Safeguards were called into being to provide needed support. The Safeguards Evaluation Section came into being in 1977. The Safeguards Training Section first began as a unit in the System Studies Section in 1977. It became a separate unit in 1978 and an independent section in 1981. Thus by the time that the 1982 reorganisation of the Department of Safeguards began, it became evident that the coordination of the interaction between the various units of the Department should be done in a systematic way.

The Safeguards Department Reorganisation Plan [2] of 1982 provides the latest departmental structure in which the Department will have 7 divisions, three in operations and four in the supporting role. This document detailing the various divisions of the Department of Safeguards, the sections within them and their respective assignments has recently been prepared at the behest of the Director General. In the document, the need for a close cooperation between the various units of the Department, as well as the dependence of the Department of Safeguards on the support of the other departments of the Agency, were well illustrated.

SUPPORT TO OPERATIONS.

For the International Symposium on Recent Advances in Nuclear Materials Safeguards, organised by the Agency and held in Vienna from 8 - 12 November 1982, a joint paper [3] on "Recent Advances in Safeguards Operations" was presented by the directors of the two operations divisions. An important theme of that paper was the support to the Operations which contributed to the recent advances in safeguards implementation. Here the support of the Member States through their various Technical Support Programmes was merely acknowledged, while the details and the magnitude of this support were provided by the Director-SGDE in his paper [4] on the "Research and Development Programmes in Support of IAEA Safeguards" at the same symposium.

The main emphasis was on the support given to the Operations by the Support Units and which contributed to the recent advances in IAEA safeguards operations. By acknowledging that the effectivenes of Agency Safeguards depends, not only on the availability of a sufficient number of qualified inspectors, but also on their proper training, the existence of a good system for data acquisition and treatment and the availability of appropriate equipment for in-field verification of nuclear material, containment and surveillance, we are paying tribute to our colleagues in the Support Units of the Department.

For example, one of the major contributions to operations by the Safeguards Training Section is that now newly recruited inspectors, who join the Agency in between normal Introductory Training Courses, no longer have to wait for several weeks or months to get some basic training. With the excellent training system and material available to them, such recruits can now quickly cover some course programmes in the interim, with self-instruction aids, and thus be equipped to carry out inspections within a relatively short time.

The Safeguards Information Treatment Division provides invaluable support to Operations by its well developed system of sorting, storing, analysing and comparing data received from the Member States and providing the inspectors with accounting and other essential data for safeguards implementation.

The role of the Safeguards Evaluation Section in support of the Operations in effective safeguards implementation has not been so well publicised. However, the impact of the EEV on the work of the Operations divisions has been steadily increasing since its formation in 1977. There is nobody in Operations who does not know of EEV, from the directors down to the newest recruits, who may be called upon to assist in assembling data for the SIR questionnaires! The EEV not only supports the Operations to achieve effective safeguards, but also presents anually the achievements, the problems and the limitations of safeguards operations to the Member States via the Safeguards Implementation Report (SIR).

The oldest division created in the support of Operations is the Division of Development and Technical Support (SGDE), which has steadily expanded its primary role. It not only develops procedures, techniques,equipment and provides technical serves, but also coordinates the support programmmes provided by the Member States. From these activities have emerged a variety of equipment, methods and techniques which are the cornerstones of safeguards implementation!

COOPERATIVE ACHIEVEMENTS.

Those of us who have been in the Department of Safeguards for the past ten years, and have witnessed the tremendous growth in the Department and its responsibilities, are very conscious of the achievements in cooperation between the various units. In these last ten years, international safeguards has gone through significant evolutionary changes. Gone are the days when most inspections consisted of a team of one or two inspectors with a simple radiation detector. Today the inventories of large important facilities may require a team consisting of many regular inspectors and their colleagues from the SGDE, SGIT and EEV, and these who have to plan and work together in handling a large amount of data and sophisticated equipment in the field. The logistics of the dispatch of the equipment and sample containers to the facilities, the receipt and follow-up of the samples as well as their analysis by SAL, also involve units other than those in the Department of Safeguards. The successful accomplishment of the work of such teams bears testimony to the cooperative spirit existing between operations and the various support units of the Department of Safeguards.

In addition to this type of contact and cooperation between the various members of a department in the same organisation, several coordination meetings have been set up to further enhance the cooperation between operations and the support units. To name a few, we have the ISIS, NDA and C/S coordination meetings.

(a) The IAEA Safeguards Information System (ISIS) Coordination Meetings have as their purpose the facilitating of improved utilisation of ISIS under the SGIT Division.

The principal activities of the ISIS Coordination Meetings are to bring to the Department of Safeguards and, in particular to the operations sections, a better understanding of the ISIS, its current status and how it can assist them in their duties. The meetings serve to bring to the attention of SGIT any problems encountered in the use of ISIS and any recommendations for its improvement.

(b) The NDA Coordination Meetings were instituted in 1981 to improve communications and cooperation between SGDE and the SG Operations Divisions. The Inspectors acquire first-hand knowledge of newly developed NDA instrumentation, methods and techniques, and also provide the SGDE staff with feedback for possible corrective actions with equipment developers or for initiation of new development projects.

(c) The C/S Coordination Meetings were instituted in 1981 on the same basis as the NDA Coordinatin Meetings, but the principal concern was the development, utilisation and feedcback for improvements in the C/S equipment.

(d) The various coordination meetings for dealing with the Support Programmes of the Member States represent a good example of the cooperative venture undertaken by the Operations and SGDE. Substantial financial resources of the Member States and the man-power resources of both the Agency and the Member States are involved in this very productive venture. All who have participated in the JASPAS, POTAS, and similar support programme meetings know the feeling of comradeship which the Agency participants from the various divisions share on such occasions.

FUTURE TREND IN COOPERATION.

The various units of the Department have come a long way together in cooperative effort, and the recent Departmental reorganisation will make further demand on our cooperative resources. In addition to the close integration between the sections in each division of operations brought about by the recent functional structure of these divisions, the importance of involving a large proportion of members of the support units in safeguards inspections has recently been emphasised. This will involve a great deal of coordination and cooperative work, the type that can only be found in a team. Thus the future trend should be teamwork by all the units of the Department if we are to achieve the safeguards objectives effectively.

An area in which the spirit of teamwork will be tested in the near future is the planned demonstration exercises in various types of nuclear facilities in the Member States . Up to now, the Training Section arranged training courses, the SGDE developed instruments, the SGIT processed data and the Operations carried out inspections to be evaluated by EEV. In these planned exercises, most of the resources of the Department will be brought to bear on the same issue simultaneously, and hence teamwork is very essential. There is no doubt whatever that we shall rise to the occasion!

CONCLUSION.

In conclusion, I would record that our experience in the last few years has been one of a steady improvement in the cooperation between operations and the support units. Our cooperative endeavour will reach its zenith when it is realised by everyone, that all the units of the Department of Safeguards are there to work for a common objective, and that for effective achievement of our objective, we must all work together as a team.

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# IAEA SAFEGUARDS EQUIPMENT SURVEY AND ASSESSMENT: AN EXAMPLE OF FRUITFUL OPERATIONS/SUPPORT CO-OPERATION

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ABSTRACT

Safeguards equipment and instrumental techniques are essential components of the International Atomic Energy Agency (IAEA) safeguards inspection and verification activities. Owing to the increasing quantities of nuclear material under IAEA safeguards, to the more complicated forms and composition in which nuclear material is being increasingly used and to expanding fuel cycle activities resulting in new safeguards requirements and a need to increase the effectiveness of IAEA safeguards, substantial budgetary resources for the procurement, maintenance and replacement of safeguards equipment will be required during the coming years. New and better safeguards equipment developed with the support of Member States is becoming available commercially. Taking into account these factors and the growing number of inspectors, a comprehensive survey and assessment of IAEA safeguards equipment requirements for 1983 to 1988 was recently carried out in the IAEA Department of Safeguards. A preliminary overview of the survey and assessment was presented in the Board of Governors document GOV/INF/429 (February 1983) and a somewhat more detailed summary is presented here.

Safeguards equipment requirements as indicated by the comprehensive survey have been summarized in two ways: 1) by Safeguards Operations Region and 2) by facility type. The survey clearly shows a strong field requirement for reliable, simple-to operate instrumentation that provides the inspector with direct in-situ measurement and verification results (e.g., assay results in grams, and direct reading of enrichment or isotopic fractions). Instruments having such automated measurement capability are now becoming commercially available and the anticipated growing use of microprocessor-based gamma ray and neutron coincidence counting nondestructive assay (NDA) instruments, as well as advanced C&S equipment, is readily apparent from the survey projections. Throughout the survey, the entire process of input data gathering, collation and assessment involved extensive discussion and interactions with all IAEA Safeguards Operations Divisions/Regions as well as those concerned in the Division of Development and elsewhere throughout the Department of Safeguards. The periodic review and assessment of equipment usage, effectiveness and requirements in the future will continue to provide an excellent opportunity for exchange of new knowledge and field experience among the various Safeguards Operations Divisions, as well as technical consultation, cross-fertilization of ideas and fruitful co-operation between operations and support staff at all levels.

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SURVEY DESCRIPTION AND RESULTS

The survey and assessment of IAEA safeguards equipment requirements was organized as follows: First, a selective listing of the major safeguards equipment items that are already in use or that can reasonably be expected to become available for field use in the general time-frame under consideration was established (near term, 1983-85; extended term, 1986-88). The resulting "master list" of NDA and C&S equipment, together with a standardized equipment identification code, is presented in Tables 1 and 2, which show equipment items in two general categories: "presently in use" and "under development". This equipment "master list" will be periodically modified and updated in order to reflect new developments and experience gained in the field. Based on the safeguards equipment "master list" and the projected growth in the number of nuclear installations for each major facility type (see summary Table 3), a standardized "IAEA Safeguards Equipment Forecast Table" was developed which provides one common format for the tabulation of current and estimated future equipment requirements by facility type for each of the Operations Regions in the Department of Safeguards. The data for 1982 in the forecast tables summarize the equipment items currently being used by each Operations Region. For the projection of needs in the years 1983, 1984 and 1985 each Operations Region was requested to estimate its equipment requirements; by mutual agreement, the estimates were made on the assumption (not realized at present) that PLARIE (Planned Actual Routine Inspection Effort) could be fully carried out. These estimates were then evaluated and discussed in detail with each of the Operations Regions, so as to ensure a common basis for all estimates. The shared use of a given equipment item (e.g., in inspections at different facility types) had to be factored into equipment need projections. Accordingly, an "equipment usage code" was employed to indicate the approximate fraction of time that a particular equipment item is needed for use in a particular facility type. In addition, plant-owned and -operated in-situ equipment that may be made available for use by IAEA inspectors is included in the survey and separately identified by the letter P. (Such plant-owned equipment items are, of course, not included in the projections of IAEA equipment needs.)

Results of the comprehensive survey have been summarized in two ways:

1. by Operations Region and
2. by facility type.

As an example of equipment requirements by Operations Region, Tables 4A and B show the completed equipment forecast tables (NDA and C&S respectively) for the Far East Region Facilities (OA1 and OA2) for 1984. As one example of equipment requirements by facility type, Table 5 summarizes survey results (both NDA and C&S equipment) for light water reactors from 1982 to 1985 for all Operations Regions. The "Summary of IAEA Safeguards Equipment Projections" shown in Tables 6A and B presents the total safeguards equipment requirements of each Operations Region for each indicated year (subject to certain manpower, budget and equipment limitations as discussed below). The resulting total annual equipment needs are summarized in the four columns labelled $\Sigma$ in Tables 6A and B.

It is important to note that the numbers in the facility type columns in Tables 4, 5 and 6 cannot be simply added up across the rows to obtain overall IAEA needs for each equipment item. Economies resulting from shared use of equipment, as well as the impact of different facility-specific characteristics, geographical considerations, etc., had to be carefully taken into account by each Operations Region in estimating actual equipment needs. At a later stage in the assessment of survey results, the effects of inspection manpower (budget) limitations and of delays in equipment development, acquisition, test, evaluation and field implementation also had to be factored into actual equipment requirements. The first (manpower) limitation is factored in by the introduction of a "resource limitation factor"(1), while an attempt is made to account for the second (equipment) limitation by introduction of an "equipment limitation factor".(2)

The projection of equipment needs on the basis of facility type (e.g., as shown for one facility type--LWRs--in Table 5) is summarized in Tables 7A and B, which show in each facility column the total number of units of each safeguards equipment item required independently for each facility type by the year 1985, the last year for which detailed projections have been made. The resulting projections of operations needs, together with estimated equipment requirements for the SGDE Technical Services Section (DTS), are given for 1985 in the column headed "Equipment requirements in 1985 (with equipment sharing and 100% PLARIE)". Application of the appropriate resource limitation factor and equipment limitation factor (taken as 74% and 80%, respectively, for 1985(1,2) then leads to the estimated overall equipment requirements for 1985 given in the final column in Tables 7A and B.

The present survey and assessment results clearly show a strong requirement for reliable, simple-to-operate instrumentation that provides the inspector with direct in-situ measurement and verification results (e.g., assay results in grams, and direct reading of enrichment or isotopic fractions). Instruments having such automated measurement capability are now becoming commercially available and the anticipated growing use of microprocessor based gamma ray and neutron coincidence counting NDA instruments (e.g., PMCA and UNCL; see Figures 1 and 2) is readily apparent from the survey projections. There is similarly a clear requirement for advanced C&S equipment (e.g., advanced photosurveillance units, TV surveillance units, improved Cerenkov devices, CANDU spent fuel counters) and new types of seals (e.g., fibre optic, VACOSS electronic, ultrasonic)--see for example Figures 3, 4 and 5).

There is no question that the overall efficiency and effectiveness of IAEA

(1) Assumed manpower (inspector) "resource limitation factors" (expressed as percentage of full PLARIE--Planned Actual Routine Inspection Effort) are taken as follows: ~60% in 1983; 65% in 1984; 74% in 1985; 83% in 1986; 91% in 1987; and ~100% of full PLARIE in 1988. (See IAEA Document GOV/2107, part B (1983))

(2) "Equipment limitation factors" of 70% for 1984 and 80% for 1985 and subsequent years are assumed in order to allow for, inter alia, delays in equipment availability and delivery.

safeguards can be appreciably enhanced if increases in inspector manpower are coupled with commensurate increases in the basic inspection tools (e.g., NDA and C&S equipment) that the inspector requires to perform his difficult task. However, the full potential and cost effectiveness of modern safeguards equipment, properly implemented in the field, can be realized only when effective field operations are fully backed by equally effective support activities.

In the future, as the inventory of safeguards equipment grows from its present level of ~$5 million to a projected total of some $20-30 million by 1988, the demands on technical support functions of all kinds will increase rapidly and will of necessity require a steadily greater proportion of the total equipment budget (and commensurate manpower as well). Although the annual costs of technical services are only ~10% of the total safeguards equipment inventory at any given time, over the years the resulting cumulative costs become considerable. Thus, *over the six-year period 1983-88 the projected* total cost of equipment and supplies for technical services amounts to nearly one-third of the projected total cost of all safeguards equipment. In the future, consideration might be given to the possibility of Member State support programmes, in addition to developing new instrumentation, also helping to provide the necessary diagnostic and maintenance equipment (and associated training), replacement units and spare parts, and possibly even making available some maintenance expertise under appropriate contractual arrangements with the IAEA.

In any case, it is abundantly clear that in coming years it will be of vital importance (and indeed a major challenge) to ensure adequate technical support within the IAEA for the Agency's expanding safeguards field operations.

Throughout the recent IAEA safeguards equipment survey, the entire process of input data gathering, collation and assessment involved extensive discussion and interactions with all Safeguards Operations Divisions/Regions as well as those concerned in the Division of Development and elsewhere throughout the Department of Safeguards. Such periodic review and assessment affords an excellent opportunity for exchange of new knowledge and field experience among Safeguards Operations Regions, as well as technical consultation, cross-fertilization of ideas and increased co-operation between operations and support staff at all levels. One particularly valuable benefit of such technical interactions and co-operation is the accompanying positive, promotional impact on the development of broadly-based policies, guidelines, and procedures for the practical use of NDA and C&S equipment in safeguarding specific types of nuclear facilities. Such standardized policies and measurement procedures, properly implemented, will greatly enhance the IAEA's capability and effectiveness in carrying out its overall safeguards inspection and verification responsibilities.

ACKNOWLEDGEMENT

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Figure 1. PORTABLE MINI-MCA (PMCA)

The PMCA is an "intelligent" portable battery-operated multichannel analyzer (2048-4096 channels) that can display and record gamma-ray spectra obtained from NaI or high resolution gamma-ray detectors (e.g., intrinsic Ge or Ge(Li)). The system provides measurement procedure prompting for specific measurements, internal calculations and diagnostics and provides data and instrument-status logging on a built-in tape drive. Other features include cathode ray tube spectrum display with cursor, region-of-interest assignment with area or integral readout, a live-time clock timer, adjustable upper and lower level discriminators, magnetic tape storage and serial output data dump. With appropriate standards and calibration procedures the PMCA can be used to measure U enrichment as well as $^{235}U$ content in various physical and chemical forms. For well characterized feed and product materials, an enrichment measurement together with weighing (verified, as appropriate, by standard weights) can be used to verify total $^{235}U$ content of materials to within 1% or 2% on the assumption that the sample is homogeneous.

Used in conjunction with small intrinsic Germanium detectors (e.g., $< 1$ cc) the PMCA can also provide rapid, positive identification (a very effective attribute measurement, based on $\gamma$-spectrum signatures) for various uranium and plutonium samples, coupons, foils, pellets, etc. Under appropriate circumstances, and with the requisite software, the PMCA promises to be a most useful tool for verification of Pu content in different types of feed, product, scrap and waste materials. The PMCA has recently been authorized for use by IAEA inspectors in the field and is projected to have widespread utility throughout the Agency inspectorate in the future.

Figure 2. URANIUM NEUTRON COINCIDENCE COLLAR (UNCL)

The UNCL is a neutron coincidence counter system that is based on the same design and operation principles as the High Level Neutron

Coincidence Counter (HLNC). The UNCL can be operated in both the active and the passive mode to measure the $^{235}U$ and the $^{238}U$ content, respectively, of LWR fuel assemblies. In the active mode a low intensity ($5 \times 10^4$ n/s) AmLi neutron source interrogates the fuel assembly, and the induced activity (from $^{235}U$ fission) is counted using the coincidence method. When no interrogation source is present, the passive neutron coincidence rate gives a measure of the $^{238}U$ by the spontaneous fission reactions.

Experimental tests on PWR and BWR assemblies at facilities in Belgium, Sweden and the U.S.A. have demonstrated that, for measurements of similar fuel assemblies in a facility, the overall accuracy ($1\sigma$) for assay of $^{235}U$ content is 1-2 percent. For absolute measurements using calibration parameters from other facilities and fuel assemblies, the accuracy should be in the range of 2-4 percent depending on how closely the standards correspond to the unknown and how carefully the calibration has been performed. When operated in the passive mode, the UNCL can be used to confirm $^{238}U$ content to within $\sim$10%. The $^{235}U$ response sensitivity enables detection of the removal or substitution of 3-4 rods in a PWR assembly and one rod in a BWR assembly. The UNCL has been authorized for routine use by IAEA inspectors in the field.

Figure 3. ADVANCED CCTV SURVEILLANCE SYSTEM (STAR)

The STAR advanced CCTV surveillance system is a microprocessor controlled system using solid state TV cameras with provision for backup and slave cassette video recorders. Recording can be initiated by a motion detector, as well as at timed intervals. Time and date information is recorded on each frame. Images are stored temporarily on video discs before being copied to a cassette video recorder. The STAR system has undergone extended field tests in Austria, Canada, the U.K. and the U.S.A. and is now considered ready for field use by the Agency inspectorate. It has recently been authorized for limited use in safeguards inspections.

Figure 4. VACOSS III ELECTRONIC SEAL (VCOS) (Upper photograph)

The VACOSS III Electronic Seal employs electronic encoding techniques for identification and to generate and store information about the transmission of light pulses through a fibre optic loop. The VACOSS III control/readout unit is seen in the foreground of Figure 4 (upper photograph) and the fibre optic loop plus seal/sensor unit is in the background. Application of VCOS (or FBOS, as soon as they become available for routine use) would permit verification of the seals on the spot, without any delay for verification of the seals (e.g., at IAEA Headquarters or at field offices). The VCOS seal would also enable confirmation of the date and time that the seal had been attached, e.g., by the reactor- or plant-operator.

Figure 5. FIBRE OPTIC SEAL (FBOS) (Lower photograph)

Fibre optic seals employ a multi-strand plastic fibre-optic loop whose ends are enclosed in a seal. The seal unit is configured so that a unique random pattern of fibres is formed. The unique pattern of fibre ends for a given seal is established by illuminating one end of loop and observing, or photo- graphing, the magnified pattern of the optical fibres at the other end of the loop. This unique pattern can then be verified by com- paring the observed pattern of fibres with the original pattern established at the time of applying the seal. Shown in Figure 5 (lower photograph) is the COBRA seal, with the plas- tic fibre-optic loop and hand-operated sealing tool seen at left, and the readout/verifier unit on the right. The COBRA fibre optic seal is undergoing continued field test and evaluation; it has not as yet been authorized for safeguards use.

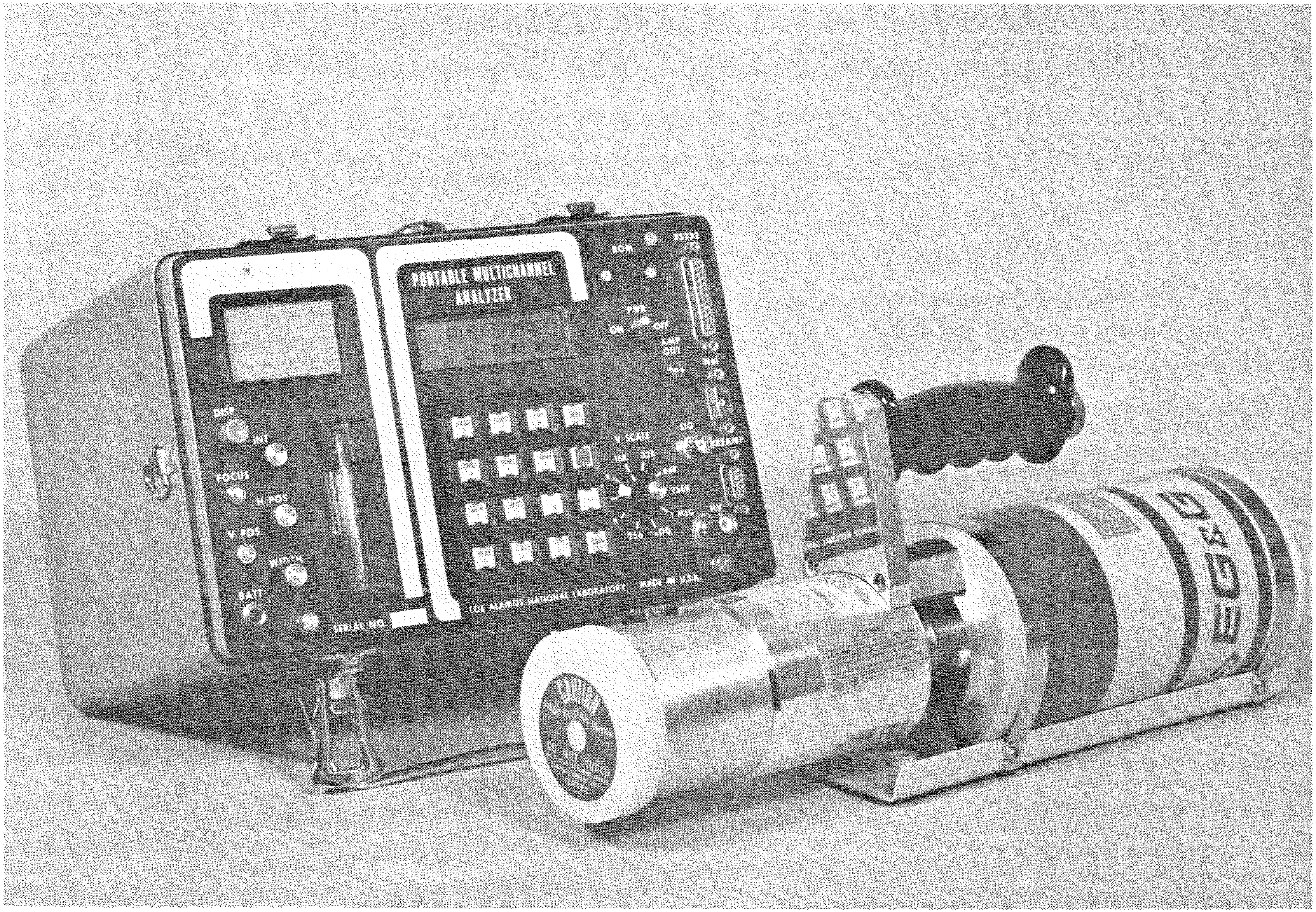


FIGURE 1. PORTABLE MINI-MCA (PMCA)

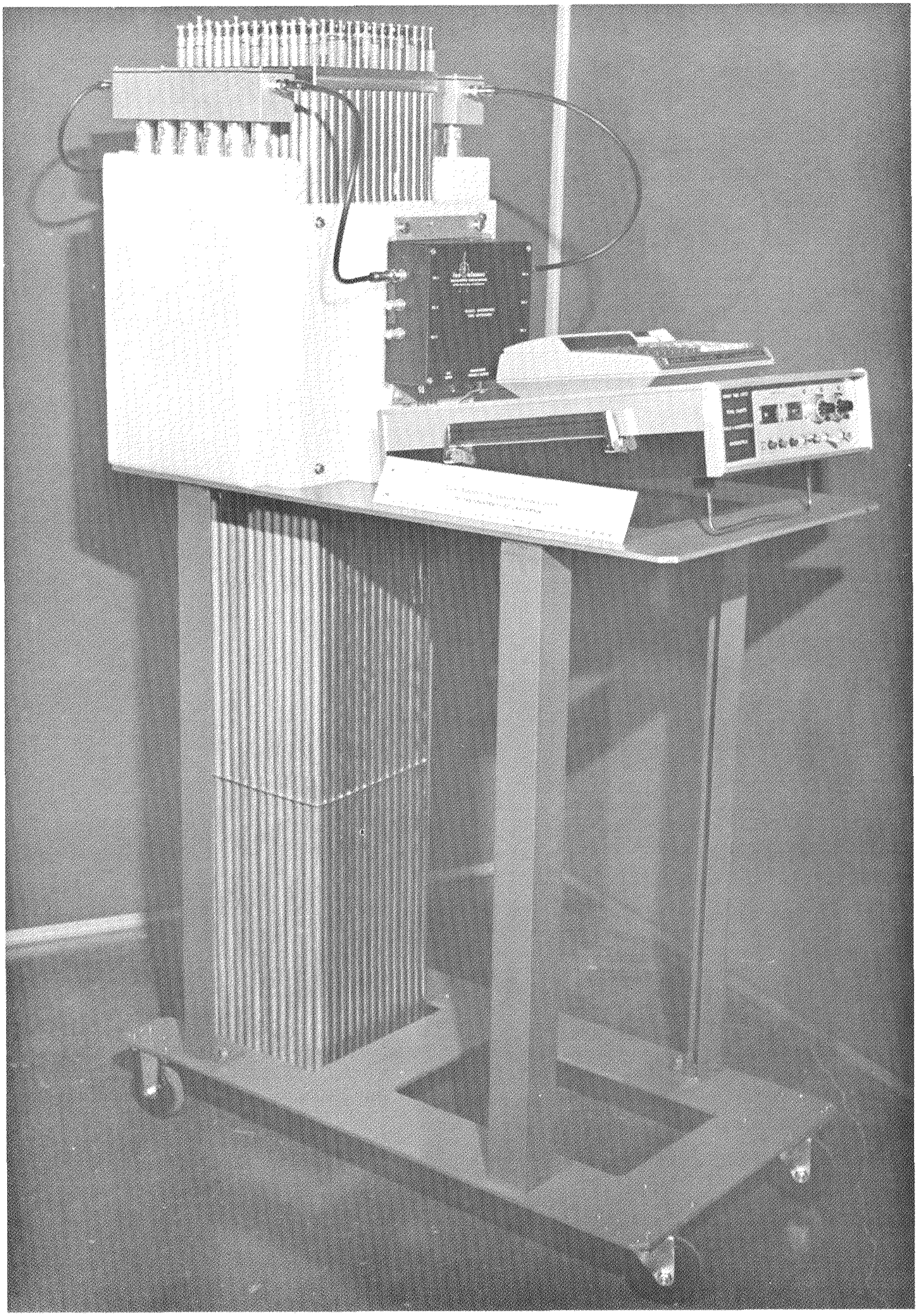

FIGURE 2. URANIUM NEUTRON COINCIDENCE COLLAR (UNCL)

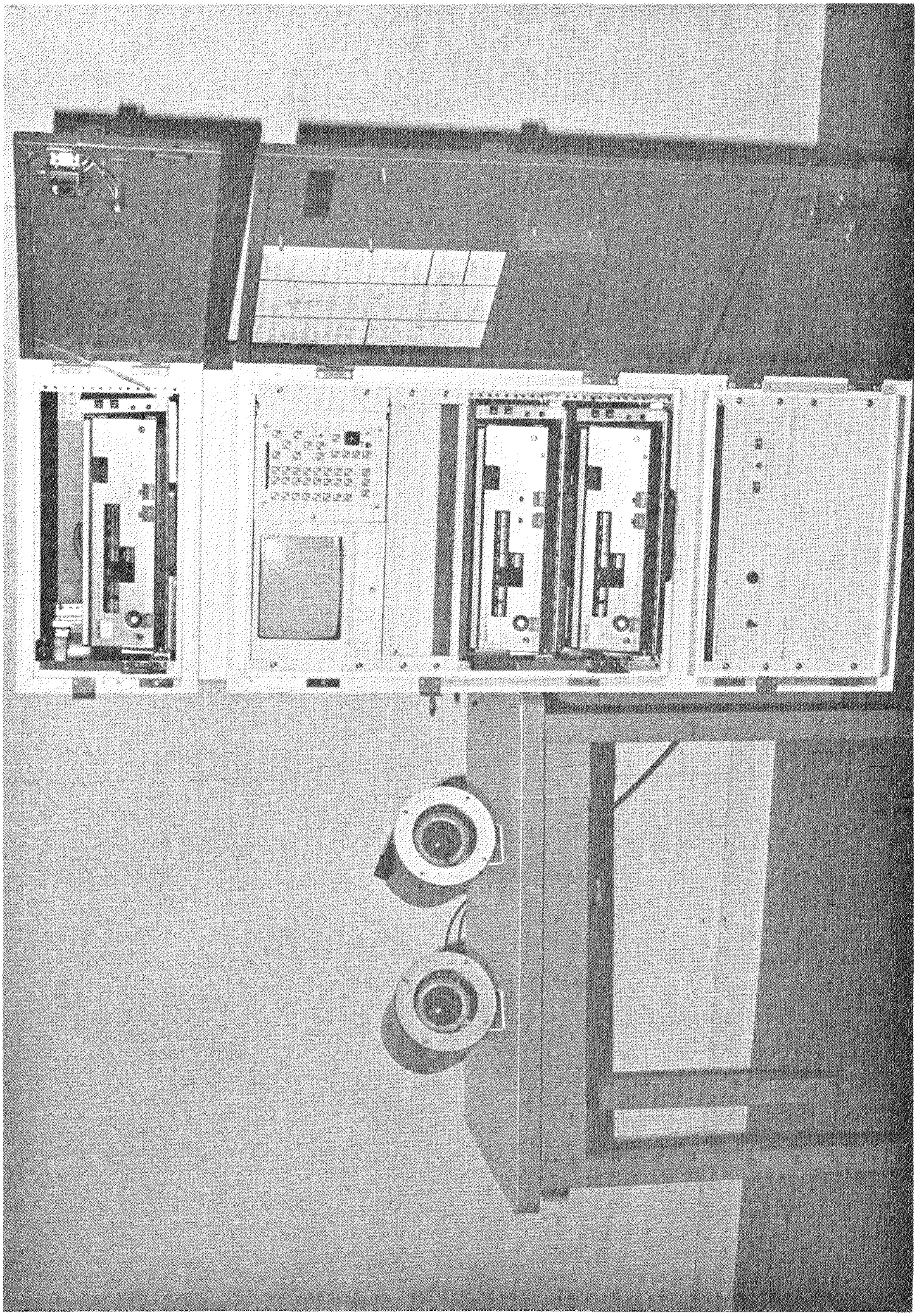

FIGURE 3. ADVANCED CCTV SURVEILLANCE SYSTEM (STAR)


FIGURE 4. VACOSS III ELECTRONIC SEAL (VCOS)

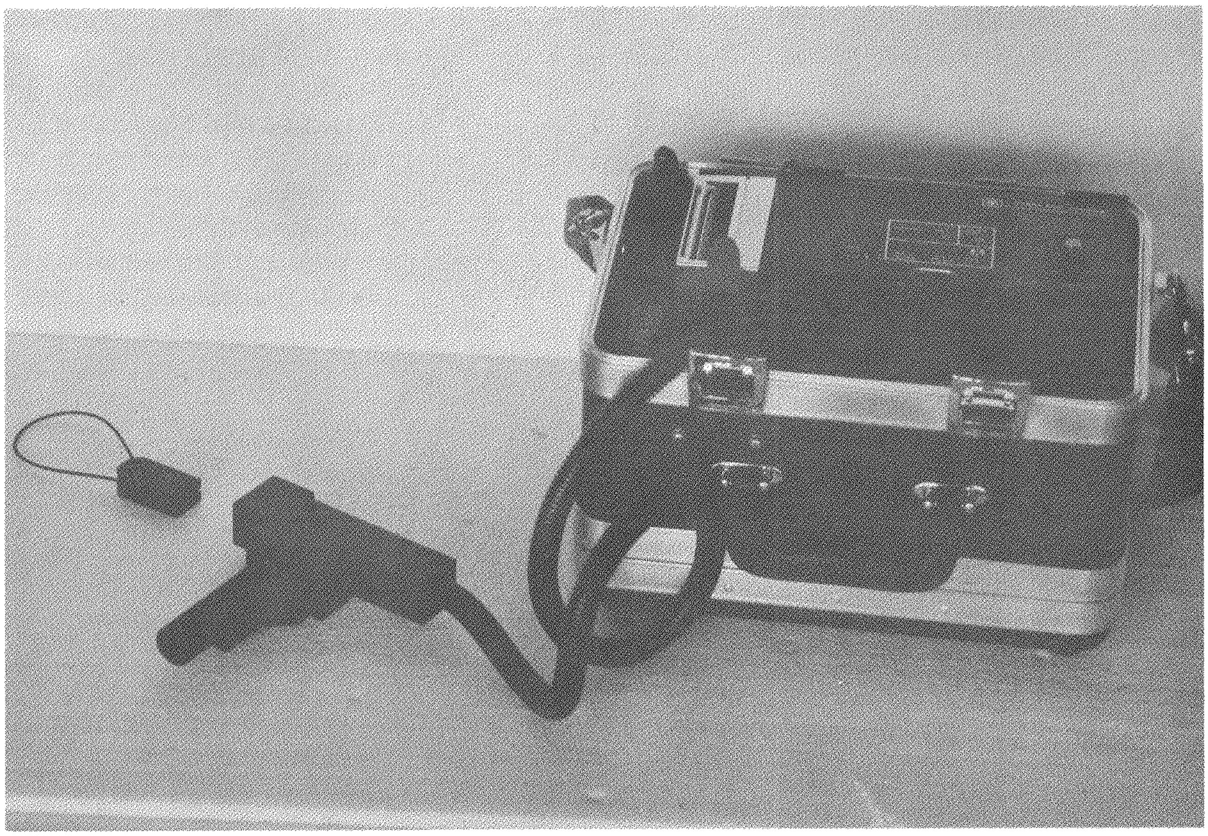

FIGURE 5. FIBRE OPTIC SEAL (FBOS)

TABLE 1.

## NDA EQUIPMENT FOR IAEA SAFEGUARDS

| CODE | NAME OF INSTRUMENT | EST.UNIT COST (U.S. $) | EQUIPMENT STATUS/Comments |
|---|---|---|---|
| A – Equipment presently in Use (** Routine Use; * Limited Use) | | | |
| SAM2 | SAM-II Stabilized Assay Meter** | 3 K | 37 units, in use |
| BSAM | BNL Stabilized Assay Meter** | 10 K | 8 units total (3 not operational) |
| PITT | Pittman 322C** | 1.8 K | 9 units, in use |
| HM-4 | HM-4 Hand-Held Assay Probe** | ~ 8 K | 7 units, in use; 3 on order |
| SLNA | Silena Multi-Channel Analyser (4 K/1 K)** | 10–15 K | 18 units (1 K); 7 units (4 K) |
| SLNC | Silena Cicero MCA (8 K)** | 17 K | 3 units at HQ; 4 more on order (12/82) |
| PIAU | Pu Isotopic Analysis Unit (LLNL)* | 10 K | Evaluation nearing completion; 3 ordered |
| PMCA | Portable Mini-MCA* | 12 K | Prototype eval. complete; 2 commercial units ordered for evaluation |
| GDET | Germanium Detectors** | 10–20 K | 28 units available and in use |
| SNAP | Hand-Held Neutron Detector** | 3 K | 4 units, in limited use |
| HLNC | High-Level Neutron Coinc. Counter** | 45 K | 11 units in field use |
| Specialized Coincidence Counter Heads (5): | | | |
| CNCC | Channel Neutron Coinc. Counter** | 50 K | 1 unit in field use |
| BCNC | Bird Cage Neutron Coinc. Counter** | 50 K | 1 unit in field use |
| INVS | Inventory Sample Counter** | 50 K | 1 unit in field use |
| FPTC | FBR Pin-Tray Counter** | 50 K | 1 unit in field use |
| FBAC | FBR Assembly Counter** | 50 K | 1 unit in field use |
| AWCC | Active Well Coincidence Counter* | 75 K | 3 units: 1 in use; 2 under T & E |
| UNCL | Uranium Neutron Coincidence Collar** | 55 K | Field Operational for PWR, BWR; T & E on WWER. 5 units delivered to IAEA 12/82 |
| KEDG | K-Edge Densitometer* | 120 K | 1 unit in field use |
| PRGC | Programmable Calculators (e.g. HP-97 & 41 C)** | 1–2 K | ~ 20 in use (in field and at Headquarters) |
| PRTC | Portable Computers (e.g. HP-85)** | 5 K | 5 in field; 1 at HQ; 3 ordered |
| STRG | Strain Gauge, Hoist & Electronics Unit* | 9 K | 1 unit demonstrated; 1 calibrated; 4 ordered |
| ULTG | Ultrasonic Thickness Gauge ($UF_6$ cyl.)** | 5 K | 6 units, in use |
| ELTM | Electromanometers* | 70 K | 2 in-plant units in use |
| EBAL | Electronic Balances | 5 K | 14 plant-owned units (used by inspectors) |
| STDW | Standard Weights (mass range as appropriate) | 1–2 K | ~ 25 sets; various mass ranges, 1 g–20 kg |
| FRSC | Fuel Rod Scanner | ~ 100 K | 3 plant-owned units (used by inspectors) |
| B – Equipment under Development, Test and Evaluation | | | |
| ION 1 | ION-1 γ, n Detector & Electronics for Spent Fuel NDA (PWR, BWR, WWER) | 25 K | 3 units available; standard procedures being developed and documented |
| UFBC | Universal FBR Assembly Counter (also useable for Pu nitrate bottles) | 50 K | FBR Assembly Counter prototype in experimental use at Pu Facility |
| PNCL | Plutonium Neutron Coincidence Collar | 60 K | Tested on MOX fuel; T & E continuing |
| SGSC | Segmented Gamma Scanner | 100 K | 2 units: 1 at HQ; 1 at SAL (Seibersdorf) |
| XRFD | X-Ray Fluorescence Detector | 150 K | Needs further development, test & evaluation |
| CALR | Calorimeter (bulk or small sample) | 50–80 K | Problems with sample packaging/size req'mts |
| D2OM | $D_2O$ Meas. System/Sample Containers | ~ 200 K | Early stage of development |

TABLE 2.

## CONTAINMENT/SURVEILLANCE EQUIPMENT FOR IAEA SAFEGUARDS

| CODE | NAME OF INSTRUMENT | EST. UNIT COST (U.S. $) | EQUIPMENT STATUS/Comments |
|---|---|---|---|
| A – Equipment presently in Use (** Routine Use; * Limited Use) | | | |
| PHSR | Photo Surveillance Unit (Twin Minolta)** | 1.5 K | Approx. 200 units, in use in the field |
| TVSR | TV Surveillance (Cameras, Recorders, etc.)** | 25 K | 20 units in field use; 2 plant-owned units |
| PRTV | Portable TV (Cameras & Recorders)* | ~ 20 K | System specifications being prepared |
| CKVD | Cerenkov Viewing Device* | 6 K | 7 JAVELIN units; 10 VARO units avail. |
| UWTV | Underwater TV Camera* | 20 K | 3 IAEA units avail.; 20 plant-owned units |
| UWVD | Underwater Viewing Devices* | 12 K | 1 IAEA unit avail.; 25 plant-owned units |
| ADPS | Adhesive/Paper Seals** | 0.75 | Widespread use by SG inspectors |
| CAPS | Cap Seals (Metallic type E & type X)** | ~ 15 | Double cap seal is standard IAEA seal |
| TLDS | TLD Dosimeters* | ~ 10 | Yes/no monitor for CANDU reactors |
| RPLG | RPL-Glass Dosimeters** | ~ 6 | In use as yes/no monitor |
| TEPM | Track Etch Reactor Power Monitor** | ~ 25 | 1 unit in field use |
| REPM | Reactor Power Monitor ($^3$He Detector)* | ~ 10 K | One unit available for use |
| B – Equipment under Development, Test and Evaluation | | | |
| APSU | Advanced Photo Surveillance Unit | ~ 7 K | 9 units undergoing T & E |
| ICVD | Improved Cerenkov Viewing Device | ~ 20 K | 1 unit demonstrated; 1 going to IAEA |
| CSFC | CANDU Spent Fuel Bundle Counter | ~ 90 K | Under final test (cost ~ 90 K per port.) |
| CSFV | CANDU Spent Fuel Gamma Verifier | ~ 4 K | Test & evaluation nearing completion |
| CATV | CANDU CCTV System (8 cameras) | ~ 250 K | 3 units installed; 1 to be installed |
| CFCS | CANDU Film Camera System | ~ 10 K | T & E at 3 stations |
| SHRT | Shrink Tube Seals | ~ 5 | Ongoing field tests |
| FBOS | Fibre Optic Seal (e.g. Cobra) | 15 | More field tests required |
| FBOV | Fibre Optic Seal Verifier | ~ 20 K | Continuing field test and evaluation |
| USBA | Ultrasonic Seal for BWR Assemblies | 350 | Continued Devel./T & E |
| USBV | Ultrasonic Seal (for BWR) Verifier | ~ 30 K | Continued Devel./T & E |
| ULCS | Ultrasonic Cap Seal (CANDU Spent Fuel) | 350 | Devel./T & E, completion expected in '83 |
| UCSV | Ultrasonic Cap Seal Verifier (CANDU) | ~ 10 K | Devel./T & E, completion expected in '83 |
| VCOS | V A C O S S III Electronic Seal | 300–600 | 10 units avail. for ongoing field test |
| VCSV | V A C O S S III Seal Verifier | ~ 3 K | 3 units avail. for ongoing field test |
| CFFC | CANDU Fresh Fuel Bundle Counter | ~ 4 K | Prototype under field test |
| PMAS | Portal Monitors & Advanced C/S system | – | Under development, T & E |
| AUVD | Advanced Underwater Viewing Devices | – | Under development, T & E |
| SHPC | Shipping Containers (e.g. PAT-2, Type B) | ~ 15 K | PAT-2 & type B containers avail. for use |
| STAR | STAR Advanced CCTV Surveillance System | ~ 70 K | 6 units avail. More testing still required |
| MSTR | Mini Star CCTV Surveillance System | ~ 8 K | Prototype under development |

TABLE 3.

PROJECTED GROWTH OF MAJOR NUCLEAR ACTIVITIES UNDER SAFEGUARDS, 1982–85*

| FACILITY TYPE | NUMBER OF INSTALLATIONS+ BY TYPE 1982 (as of 12/31) | 1983 | 1984 | 1985 |
|---|---|---|---|---|
| **Power Reactors:** | | | | |
| LWR REACTORS | 110 | 118 | 134 | 143 |
| CANDU (600 MW Stations) | 4 | 4 | 4 | 5 |
| CANDU (Multi-unit Stations) | 16 | 16 | 16 | 16 |
| CANDU (< 300 MWe) and other OLRs | 14 | 14 | 16 | 16 |
| Pu FUELLED REACTORS (FBR & ATR; excluding thermal recycling in LWRs) | 2++ | 1 | 1 | 2 |
| TOTALS | 146 | 153 | 171 | 182 |
| **Conversion and Fuel Fabrication:** | | | | |
| NATURAL U CONV./FUEL FAB. | 13 | 14 | 14 | 14 |
| LEU CONV./FUEL FAB. | 21 | 23 | 23 | 23 |
| HEU CONV./FUEL FAB. | 8 | 8 | 8 | 8 |
| MOX FUEL FAB./(incl. Pu conv.) | 4 | 5 | 6 | 6 |
| TOTALS | 46 | 50 | 51 | 51 |
| **Research Reactors & Critical Assemblies:** | | | | |
| RESEARCH REACTORS (≥ 25 MWt) | 13 | 13 | 14 | 16 |
| LARGE SCALE CRITICAL ASSEMBLIES (≥ 1 S.Q.) | 3 | 3 | 3 | 3 |
| RESEARCH REACTORS (< 25 MWt) & CRITICAL ASSEMBLIES (< 1 S.Q.) | 161 | 161 | 163 | 163 |
| TOTALS | 177 | 177 | 180 | 182 |
| **Reprocessing Plants:** | 7++ | 7 | 7 | 8 |
| **Uranium Enrichment Plants:** | 4 | 6 | 7 | 7 |

* For NW states, only facilities under INFCIRC/66/Rev.2 agreements or facilities that were formally designated by IAEA for application of full safeguards in 1982 under voluntary offer agreements are included.

\+ As used here and in recent IAEA Annual Reports, the term "installation" refers to an individual unit, such as a reactor, fuel fabrication plant or critical assembly. Thus, there is often more than one installation under one facility code assigned by a facility attachment, and each such installation is counted separately.

++ The PFR Reactor and the PFR Reprocessing Plant at Dounreay were under safeguards for nearly all of 1982, and have been included in the present listing for 1982.

# IAEA SAFEGUARDS EQUIPMENT FORECAST TABLE 4A OPERATIONS SECTION FAR EAST YEAR 1984

**EQUIPMENT ITEM**

EQUIPMENT USAGE CODE:
A 100-80% R Resides in Plant, IAEA-Owned
B 80-60% P Plant-Owned/Operated Eqp't
C 60-40%
D 40-20%
E 20->0%

| Code | Equipment Item | LIGHT WATER REACTORS | CANDU 600MW and 4-Unit Sta. | CANDU <300 MW & Other OLRs | Pu Fuelled Reactors | Natural U Conversion & Fuel Fab. | LEU Conversion & Fuel Fab. | HEU Conversion & Fuel Fab. | MOX Conversion & Fuel Fab. | Research Reactors (>25 MW) | Large Scale Critical Assemblies | Small Res. Reactors & Crit. Assy's | Reprocessing Plants | Enrichment Plants | All Other Facilities (Storages etc.) | SECTION NEEDS, ALL FACILITIES: Section Σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FACILITIES: | 41 | 1 | 1 | 1 | 4 | 8 | 1 | 3 | 3 | 2 | 26 | 1 | 2 | 9 | 103 |
| | ARIE (MD): | | | | | | | | | | | | | | | |
| SAM2 | SAM-II STABILIZED ASSAY METER (with NaI) | | | | | | 5E | | | | | | | | | 2D |
| BSAM | BNL STABILIZED ASSAY METER (with NaI) | | | | | | | | | | | | | | | |
| PITT | PITTMAN 322C (with NaI) | 1E | | | | | 4E | | 1E | 1E | | 1E | | | | 2C |
| HM-4 | HM-4 HAND-HELD ASSAY PROBE (with NaI) | | | | 1C | | 7R | | 2R | 1E | 1E | 1E | | | | 1B9R |
| SLNA | SILENA MCA (4K, & older 1K) | | | | | 2E | 1D | | 2C | | 2C1R | | 1E | 1D | | 3B1R |
| SLNC | SILENA CICERO MCA (8K) | | | | | | | | 1E3R | 1E | 2R | | | | | 1E5R |
| PIAU | PU ISOTOPIC ANALYSIS UNIT (LLNL) | | | | | | | | 2R | | 1R | | | | | 3R |
| PMCA | PORTABLE MINI-MCA | | | | 1C | 1R | 1C2R | 1R | 2R | 1C1R | 1B | 2D | 1R | 1D1R | | 7C9R |
| GDET | GERMANIUM DETECTORS | | | | 1C | | 1C3R | 1B | 2R | 1C1R | 1C2R | 2D | | 1D2R | | 6B10R |
| SNAP | HAND HELD NEUTRON DETECTOR | | | | | | | | | | | | | | | |
| HLNC | HIGH LEVEL NEUTRON COINC. COUNTER | | | | 1C | | | | 3C4R | 1E | 1R | | | | | 3B5R |
| AWCC | ACTIVE WELL COINCIDENCE COUNTER | | | | | | | 1D | | | 1D | | | | | 1B |
| CNCC | CHANNEL NEUTRON COINC. COUNTER | | | | | | | | | | 1R | | | | | 1R |
| BCNC | BIRD CAGE COINCIDENCE COUNTER | | | | | | | | | | 1R | | | | | 1R |
| INVS | INVENTORY SAMPLE COUNTER | | | | | | | | 2C3R | | | | 1R | | | 1B4R |
| FPTC | FBR PIN-TRAY COUNTER | | | | | | | | 2R | | | | | | | 2R |
| FRSC | FUEL ROD SCANNER | | | | | | | | | | | | | | | |
| UNCL | URANIUM NEUTRON COINCIDENCE COLLAR | 2E | | | | | 7D7R | | | | 1D | | | | | 4C7R |
| PNCL | PLUTONIUM NEUTRON COINCIDENCE COLLAR | 1E | | | | | | | | | | | | | | 1E |
| UFBC | UNIVERSAL FBR ASSEMBLY COUNTER | | | | | | | | 2R | | | | | | | 2R |
| ION1 | ION-1 DETECTOR FOR SPENT FUEL NDA | 3E | | | | | | | | 1E | | | 1R | | | 2D1R |
| KEDG | K-EDGE DENSITOMETER | | | | | | | | 1R | | | | 1P | | | 1R1P |
| PRGC | PROGRAMMABLE CALCULATORS (eg HP-97; 41C) | | | | | | | | 2R | | 2R | | | | | 4R |
| PRTC | PORTABLE COMPUTERS (eg HP-85) | | | | 1C | | 2C7R | | 6R | 1E | 2R | | 1R | | | 2C16R |
| STRG | STRAIN GAUGE, HOIST & ELECTRONICS UNIT | | | | | 2R | 1D2R | | | | | | | 2R | | 1D6R |
| ULTG | ULTRASONIC THICKNESS GAUGE ($UF_6$ CYL.) | | | | | | 2R | | | | | | | 4R | | 6R |
| EBAL | ELECTRONIC BALANCE | | | | | | | | | | | | | | | |
| STDW | STANDARD WEIGHTS (Sets of various masses) | | | | | 2R | 13R | 2R | 2R | | | | 1R | 3R | | 23R |
| SGSC | SEGMENTED GAMMA SCANNER | | | | | | | | | | | | | | | |
| XRFD | X-RAY FLUORESCENCE DETECTOR | | | | | | | | | | | | | | | |
| CALR | CALORIMETERS (Indicate bulk/small sample) | | | | | | | | | | | | | | | |
| ELTM | ELECTROMANOMETERS | | | | | | | | 1P | | | | 1P1R | | | 1R2P |
| D2OM | $D_2O$ MEASUREMENT DEVICES/SAMPLE CONTAINERS | | | | | | | | | | | | | | | |

# IAEA SAFEGUARDS EQUIPMENT FORECAST TABLE 4B OPERATIONS SECTION FAR EAST YEAR 1984

**EQUIPMENT ITEM**

EQUIPMENT USAGE CODE:
A 100-80% R Resides in Plant, IAEA-Owned
B 80-60% P Plant-Owned/Operated Eqp't
C 60-40%
D 40-20%
E 20->0%

| Code | Equipment Item | LIGHT WATER REACTORS | CANDU 600MW and 4-Unit Sta. | CANDU <300 MW & Other OLRs | Pu Fuelled Reactors | Natural U Conversion & Fuel Fab. | LEU Conversion & Fuel Fab. | HEU Conversion & Fuel Fab. | MOX Conversion & Fuel Fab. | Research Reactors (>25 MW) | Large Scale Critical Assemblies | Small Res. Reactors & Crit. Assy's | Reprocessing Plants | Enrichment Plants | All Other Facilities (Storages etc.) | SECTION NEEDS, ALL FACILITIES: Section Σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FACILITIES: | 41 | 1 | 1 | 1 | 4 | 8 | 1 | 3 | 3 | 2 | 26 | 1 | 2 | 9 | 103 |
| | ARIE (MD): | | | | | | | | | | | | | | | |
| PHSR | PHOTO SURVEILLANCE UNIT (Twin Minolta) | 24R | | 1R | | | | | | 4R | | | 1R | | | 30R |
| ELPS | ELMO PHS UNIT (Orig./FRG/Japan,Unit) | 14R | | 1R | 3R | | | | | 3R | | | 1R | | | 22R |
| TVSR | TV SURVEILLANCE (Cameras, Recorders etc.) | 2R | | 1R | | | | | | 2R | | | | | | 5R |
| PRTV | PORTABLE TV (Cameras & Recorders) | 10D | | | | | 1D | | 1D | | | | | | | 10C |
| CKVD | CERENKOV VIEWING DEVICE | 4D | | | | | | | | | | | | | | 4B |
| ICVD | IMPROVED CERENKOV VIEWING DEVICE | 6D | | | | | | | | | | | | | | 6B |
| UWTV | UNDERWATER TV CAMERA | 29P | | | | | | | | | | | | | | 29P |
| UWVD | UNDERWATER VIEWING DEVICES | | | | | | | | | | | | | | | |
| CFCS | CANDU FILM CAMERA SYSTEM | | 4R | | | | | | | | | | | | | 4R |
| CATV | CANDU CCTV SYSTEM (8 Cameras) | | 1R | | | | | | | | | | | | | 1R |
| CFFC | CANDU FRESH FUEL BUNDLE COUNTER | | 2R | | | | | | | | | | | | | 2R |
| CSFC | CANDU SPENT FUEL BUNDLE COUNTER | | 2R | | | | | | | | | | | | | 2R |
| CSFV | CANDU SPENT FUEL GAMMA VERIFIER | | | | | | | | | | | | | | | |
| ADPS | ADHESIVE/PAPER SEALS | | 100 | | 200 | 20 | 40 | 40 | 40 | 100 | 200 | 100 | 120 | 40 | | 1000 |
| CAPS | CAP SEALS (Metallic type E & type X) | 700 | 100 | | 300 | 25 | 60 | 200 | 450 | 100 | 420 | 25 | 550 | 70 | | 3000 |
| SHRT | SHRINK TUBE SEALS | | | | | | 8 | | | | | | | 52 | | 60 |
| FBOS | FIBRE OPTIC SEAL (Eg. Cobra) | | | | | | | | 2 | | 18 | | | | | 20 |
| FBOV | FIBRE OPTIC SEAL VERIFIER | | | | | | | | 1C | | 1C | | | | | 1 |
| USBA | ULTRASONIC SEAL for BWR ASSEMBLIES | | | | | | | | | | | | | | | |
| USBV | ULTRASONIC SEAL (for BWR) VERIFIER | | | | | | | | | | | | | | | |
| ULCS | ULTRASONIC CAP SEAL (CANDU spent fuel) | | 30 | | | | | | | | | | | | | 30 |
| UCSV | ULTRASONIC CAP SEAL VERIFIER (CANDU) | | 1R | | | | | | | | | | | | | 1R |
| VCOS | VACOSS III ELECTRONIC SEAL | | | | | | | | | | 20 | | | 6 | | 26 |
| VCSV | VACOSS III SEAL VERIFIER | | | | | | | | | | 1 | | | 1 | | 2 |
| TLDS | TLD DOSIMETERS | 39R | 4 | 2R | | | | | | 7R | | | 2R | | | 54 |
| RPLG | RPL GLASS DOSIMETERS | | | | | | | | | | | | | | | |
| TEPM | TRACK ETCH REACTOR POWER MONITOR | | | | | | | | | 1R | | | | | | 1R |
| REPM | REACTOR POWER MONITOR ($^3$He Detector) | 10R | | 1R | 1R | | | | | 2R | | | | | | 14R |
| PMAS | PORTAL MONITORS & ADVANCED C/S SYSTEM | | | | | | | | | | | | | | | |
| AUVD | ADVANCED UNDERWATER VIEWING DEVICES | | | | | | | | | | | | | | | |
| SHPC | SHIPPING CONTAINERS (e.g. PAT-2; TYPE B) | | | | | | | | 2C | | | | 2C | | | 4C |
| STAR | STAR ADVANCED CCTV SURVEILLANCE SYSTEM | | | | | | | | | | | | 1R | | | 1R |
| MSTR | MINI STAR CCTV SURVEILLANCE SYSTEM | 1B | | | | | | | | | | | | | | 1B |

# IAEA SAFEGUARDS EQUIPMENT PROJECTIONS BY FACILITY TYPE (BY OPERATIONS SECTIONS., 1982-1985) TABLE 5

| FACILITY TYPE: LIGHT WATER REACTORS | | 1982 (In Use) | | | | | | | 1983 | | | | | | | 1984 | | | | | | | 1985 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FE | NA | SSE | A+L | CNE | EUR | FAC. Σ | FE | NA | SSE | A+L | CNE | EUR | FAC. Σ | FE | NA | SSE | A+L | CNE | EUR | FAC. Σ | FE | NA | SSE | A+L | CNE | EUR | FAC Σ |
| EQUIPMENT ITEM | FACILITIES: | 34 | 2 | 3 | 14 | 31 | 26 | 110 | 37 | 2 | 4 | 14 | 34 | 27 | 118 | 41 | 2 | 4 | 16 | 39 | ·32 | 134 | 45 | 2 | 4 | 16 | 42 | 34 | 143 |
| | ARIE (MD): | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SAM2 | SAM-II STABILIZED ASSAY METER (with NaI) | | | 1D | | 3D | | 4 | | | 1E | | 2D | | 3 | | | | | 1C | | 1 | | | | | | | 0 |
| PITT | PITTMAN 322C (with NaI) | 1E | | | | | | 1 | 1E | | | | | | 1 | 1E | | | | | | 1 | 1E | | | | | | 1 |
| HM-4 | HM-4 HAND-HELD ASSAY PROBE (with NaI) | | | 1E | 2E | 1E | | 4 | | | | 2E | | | 2 | | | | 2E | | | 2 | | | | 2E | | | 2 |
| SLNA | SILENA MCA (4K, & older 1K) | | | | | | | 0 | | | | | | 1E | 1 | | | | | | 1D | 1 | | | | | | 1B | 1 |
| PMCA | PORTABLE MINI-MCA | | | | | | | 0 | | | 1D | | 3D | 1C | 5 | | | 1D | | 4D | 1A | 6 | | | 1D | | 5D | 2A | 8 |
| GDET | GERMANIUM DETECTORS | | | | | | | 0 | | | | | | 1E | 1 | | | | | | 1D | 1 | | | | | | 1B | 1 |
| UNCL | URANIUM NEUTRON COINCIDENCE COLLAR | | 1E | | | | | 1 | 2E | 1C | 1E | | | | 4 | 2E | 1C | 1D | | 1E | 1A | 6 | 2E | 1C | 1D | | 3E | 1A | 8 |
| PNCL | PLUTONIUM NEUTRON COINCIDENCE COLLAR | | | | | | | 0 | | | | | | 1E | 1 | 1E | | | | | 1D | 2 | 1E | | | | | 1B | 2 |
| ION1 | ION-1 DETECTOR FOR SPENT FUEL NDA | | 1E | | | 1E | | 2 | 2D | 1A | | | 1E | | 4 | 3E | 1A | | | 2E | 5D | 11 | 3E | 1A | | | 3E | 8C | 15 |
| PRGC | PROGRAMMABLE CALCULATORS (eg HP-97; 41C) | | | | | | | 0 | | 1C | | | | | 1 | | 1C | | 1E | | 2B | 4 | | 1C | | 1E | | 2A | 4 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PHSR | PHOTO SURVEILLANCE UNIT (Twin Minolta) | 25R | 3R | | 14R | 36R | 25R | 103 | 33R | 4R | | 4R | 40R | 25R | 106 | 24R | 4R | | 2R | 44R | 15R | 89 | | 4R | | | 45R | 7R | 56 |
| ELPS | ELMO PHS UNIT (Orig./FRG/Japan,Unit) | | | | | | | 0 | | | | 15R | | 5R | 20 | 14R | | | 19R | | 20R | 53 | 42R | | | 26R | | 25R | 93 |
| TVSR | TV SURVEILLANCE (Cameras, Recorders etc.) | 2R | 2P | 3R | | | | 7 | 2R | 2P | 5R | | | | 9 | 2R | 2P | 5R | | | 2R | 11 | 2R | 2P | 5R | | | 5R | 14 |
| PRTV | PORTABLE TV (Cameras & Recorders) | | | | | | | 0 | 6D | | | | | | 6 | 10D | | | | | | 10 | 12D | | | | | | 12 |
| CKVD | CERENKOV VIEWING DEVICE | 2E | 2A | 2D | 3E | 3D | | 12 | 4B | | 2D | 3E | 3D | 1B | 13 | 4D | | 2D | 4E | | 1A | 11 | 7D | | 2D | 4E | | 1A | 14 |
| ICVD | IMPROVED CERENKOV VIEWING DEVICE | | | | | | | 0 | 4B | 2R | | | | 1B | 7 | 6D | 2R | | | 3C | 1A | 12 | 14D | 2R | | | 3C | 1A | 20 |
| UWTV | UNDERWATER TV CAMERA | 20P | | | | | | 20 | 25P | 1A | | | | | 26 | 29P | 1A | | | | | 30 | 33P | 1A | | | | | 34 |
| UWVD | UNDERWATER VIEWING DEVICES | | | | | 1R24P | | 25 | | 1A | | | 1R27P | | 29 | | 1A | | | 1R32P | | 34 | | 1A | | | 1R33P | | 2/33P |
| ADPS | ADHESIVE/PAPER SEALS | | | 10 | | | 100 | 110 | | | 30 | | | 100 | 130 | | | 30 | | | 100 | 130 | | | 30 | | | 100 | 130 |
| CAPS | CAP SEALS (Metallic type E & type X) | 400 | 20 | 15A | 160 | 310 | 160 | 1005 | 600 | 20 | 20 | 250 | 333 | 100 | 1323 | 700 | 20 | 20 | 300 | 440 | 200 | 1680 | 800 | 20 | 20 | 300 | 448 | 200 | 1788 |
| FBOS | FIBRE OPTIC SEAL (Eg. Cobra) | | | | | | | 0 | | | | | | | 0 | | | | 30 | | | 30 | | | | 30 | | | 30 |
| FBOV | FIBRE OPTIC SEAL VERIFIER | | | | | | | 0 | | | | | | | 0 | | | | 1B | | | 1 | | | | 1B | | | 1 |
| USBA | ULTRASONIC SEAL for BWR ASSEMBLIES | | | | | | | 0 | | | | | | | 0 | | | | | | | 0 | 360 | | | 400 | | | 760 |
| USBV | ULTRASONIC SEAL (for BWR) VERIFIER | | | | | | | 0 | | | | | | | 0 | | | | | | | 0 | 2 | | | 2D | | | 4 |
| VCOS | VACOSS III ELECTRONIC SEAL | | | | | | | 0 | | | | 4R | | | 4 | | | | 4R | | | 4 | | | | 4R | | | 4 |
| VCSV | VACOSS III SEAL VERIFIER | | | | | | | 0 | | | | 1E | | | 1 | | | | 1E | | | 1 | | | | 1E | | | 1 |
| TLDS | TLD DOSIMETERS | | | | | | 25 | 25 | | | | | | 30 | 30 | 39R | | | | | 35 | 74 | 42R | | | 20 | | 32 | 94 |
| REPM | REACTOR POWER MONITOR ($^3He$ Detector) | | | | | | | 0 | | 1A | | 3R | | | 4 | 10R | 1A | | 6R | | | 17 | 29R | 1A | | 15R | | | 45 |
| MSTR | MINI STAR CCTV SURVEILLANCE SYSTEM | | | | | | | 0 | | | | | | | 0 | 1B | 1A | 1D | | | | 3 | 2B | 1A | 1D | | | | 4 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## TABLE 6A

## SUMMARY OF IAEA SAFEGUARDS EQUIPMENT PROJECTIONS

| EQUIPMENT ITEM (NDA) | | 1982 (In Use) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | $\sum$ |
| SAM2 | SAM-II STABILIZED ASSAY METER (with NaI) | 10 | 4 | 5 | 4 | 1 | 3 | 27 |
| BSAM | BNL STABILIZED ASSAY METER (with NaI) | | | 1 | | | | 1 |
| PITT | PITTMAN 322C (with NaI) | 2 | | 2 | | | | 4 |
| HM-4 | HM-4 HAND-HELD ASSAY PROBE (with NaI) | | 2 | | | 2 | 1 | 5 |
| SLNA | SILENA MCA (4K, & older 1K) | 5 | 3 | 3 | 4 | | 1 | 16 |
| SLNC | SILENA CICERO MCA (8K) | | | | | | | 0 |
| PIAU | PU ISOTOPIC ANALYSIS UNIT (LLNL) | | | | 1 | | | 1 |
| PMCA | PORTABLE MINI-MCA | | | | | | | 0 |
| GDET | GERMANIUM DETECTORS | 5 | 3 | 4 | 4 | | 1 | 17 |
| SNAP | HAND-HELD NEUTRON DETECTOR | | | | | | 1 | 1 |
| HLNC | HIGH-LEVEL NEUTRON COINCIDENCE COUNTER | 4 | 2 | | 4 | | | 10 |
| AWCC | ACTIVE WELL COINCIDENCE COUNTER | | | 1 | | | | 1 |
| CNCC | CHANNEL NEUTRON COINCIDENCE COUNTER | 1 | | | | | | 1 |
| BCNC | BIRD CAGE COINCIDENCE COUNTER | 1 | | | | | | 1 |
| INVS | INVENTORY SAMPLE COUNTER | 1 | | | | | | 1 |
| FPTC | FBR PIN-TRAY COUNTER | 1 | | | | | | 1 |
| FRSC | FUEL ROD SCANNER | | | 1P | 2P | | | 3P |
| UNCL | URANIUM NEUTRON COINCIDENCE COLLAR | | | 1 | | | | 1 |
| PNCL | PLUTONIUM NEUTRON COINCIDENCE COLLAR | | | | | | | 0 |
| UFBC | UNIVERSAL FBR ASSEMBLY COUNTER | 1 | | | | | | 1 |
| ION1 | ION-1 DETECTOR FOR SPENT FUEL NDA | | | 1P | | | 1 | 1/1P |
| KEDG | K-EDGE DENSITOMETER | 1P | | | | | | 1P |
| PRGC | PROGRAMMABLE CALCULATORS (e.g. HP-97; 41C) | 5 | 3 | 6 | 6 | | | 20 |
| PRTC | PORTABLE COMPUTERS (e.g. HP-85) | 3 | | | | | | 3 |
| LCBS | LOAD-CELL-BASED WEIGHING SYSTEM | | | 2 | | | | 2 |
| ULTG | ULTRASONIC THICKNESS GAUGE ($UF_6$ CYL.) | 1 | | 2 | 1 | | 1 | 5 |
| EBAL | ELECTRONIC BALANCE | | | 9P | 27P | | 5P | 41P |
| STDW | STANDARD WEIGHTS (Sets of various masses) | 1 | 3 | 2 | 2 | | | 8 |
| SGSC | SEGMENTED GAMMA SCANNER | | | | | | | 0 |
| XRFD | X-RAY FLUORESCENCE DETECTOR | | | | | | | 0 |
| CALR | CALORIMETERS (Indicate bulk or small sample) | | | | | | | 0 |
| ELTM | ELECTROMANOMETERS | 2P | | | | | | 2P |
| D2OM | $D_2O$ MEAS. SYSTEM/SAMPLE CONTAINERS | | | | | | | 0 |

(BY OPERATIONS REGIONS, ALL FACILITY TYPES)

| 1983 | | | | | | | 1984 | | | | | | | 1985 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | Σ | OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | Σ | OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | Σ |
| 8 | 2 | 2 | 6 | 1 | 2 | 21 | 2 | | 1 | | 1 | 2 | 6 | 2 | | 1 | | 1 | | 4 |
| | | 1 | | | | 1 | | | 1 | | | | 1 | | | 1 | | | | 1 |
| 2 | | 2 | | | | 4 | 2 | | 2 | | | | 4 | 2 | | 2 | | | | 4 |
| 7 | 1 | | | 3 | 1 | 12 | 10 | 1 | | | 3 | 1 | 15 | 10 | 1 | | | 3 | 1 | 15 |
| 4 | 2 | 4 | 5 | | 1 | 16 | 4 | 1 | 4 | 6 | | 1 | 16 | 4 | 1 | 4 | 7 | | 1 | 17 |
| 2 | | | | | | 2 | 6 | 2 | | | | | 8 | 6 | 2 | | | | | 8 |
| 2 | 1 | | 2 | | | 5 | 3 | 2 | | 2 | | | 7 | 3 | 2 | | 1 | | | 6 |
| 6 | 3 | 5 | 5 | 1 | 2 | 22 | 16 | 4 | 5 | 7 | 4 | 3 | 39 | 28 | 4 | 5 | 12 | 4 | 5 | 58 |
| 13 | 3 | 13 | 5 | 1 | 1 | 36 | 16 | 3 | 13 | 7 | 4 | 1 | 44 | 17 | 3 | 13 | 8 | 4 | 1 | 46 |
| | | | | | | 0 | | | | | | | 0 | | | | | | | 0 |
| 5 | 2 | | 5 | | | 12 | 8 | 2 | | 6 | | | 16 | 10 | 2 | | 6 | | | 18 |
| 1 | | 1 | 1 | | | 3 | 1 | | 1 | 2 | 1 | | 5 | 1 | | 1 | 4 | 1 | | 7 |
| 1 | | | | | | 1 | 1 | | | | | | 1 | 1 | | | | | | 1 |
| 1 | | | | | | 1 | 1 | | | | | | 1 | 1 | | | | | | 1 |
| 3 | | | 2 | | | 5 | 5 | | | 3 | 1 | | 9 | 5 | | | 3 | 1 | | 9 |
| 2 | | | | | | 2 | 2 | | | | | | 2 | 2 | | | | | | 2 |
| | | 1P | 2P | | 1P | 4P | | | 1P | 2P | | 1P | 4P | | | 1P | 2P | | 1P | 4P |
| 3 | 1 | 1 | 2 | 1 | 1 | 9 | 11 | 1 | 1 | 4 | 2 | 2 | 21 | 11 | 1 | 1 | 6 | 2 | 2 | 23 |
| | | | 2 | | | 2 | 1 | | | 2 | | | 3 | 1 | | | 3 | | | 4 |
| 2 | | | 2 | | | 4 | 2 | | | 4 | | | 6 | 3 | | | 4 | | | 7 |
| 2 | | 1P | | | 1 | 3/1P | 3 | | 1P | 5 | 2 | 1 | 11/1P | 3 | 1 | 1P | 7 | 2 | 1 | 14/1P |
| 1P | | | | | | 1P | 1/1P | | | 1 | | | 2/1P | 1/1P | | | 2 | | | 3/1P |
| 5 | 4 | 5 | 7 | | | 21 | 4 | 4 | 5 | 11 | 2 | | 26 | 4 | 4 | 5 | 12 | 2 | | 27 |
| 7 | 2 | 2 | 4 | | 1 | 16 | 18 | 2 | 2 | 5 | 1 | 1 | 29 | 18 | 2 | 2 | 6 | 1 | 1 | 30 |
| 3 | | 2 | 2 | | | 7 | 7 | | 2 | 4 | 1 | 1 | 15 | 7 | | 2 | 5 | 1 | 1 | 16 |
| 2 | | 2 | 3 | | 1 | 8 | 6 | | 2 | 4 | 1 | 1 | 14 | 6 | | 2 | 5 | 1 | 1 | 15 |
| | | 9P | 30P | | 5P | 44P | | | 9P | 30P | | 5P | 44P | | | 9P | 31P | | 5P | 45P |
| 19 | 3 | 2 | 10 | 2 | | 36 | 23 | 3 | 2 | 11 | 3 | | 42 | 23 | 3 | 2 | 11 | 3 | | 42 |
| | | | | | | 0 | | | | | | | 0 | | | | | | | 0 |
| | | | | | | 0 | | | | | | | 0 | | | | | | | 0 |
| | | | | | | 0 | | | | | | | 0 | | | | | | | 0 |
| 2P | | | | | | 2P | 1/2P | | | 1P | | | 1/3P | 1/2P | | | 2P | | | 1/4P |
| | | | | | | 0 | | | | | | | 0 | | | | | (1R)* | | (1R)* |

* May be delayed to 1986.

TABLE 6B.

SUMMARY OF IAEA SAFEGUARDS EQUIPMENT PROJECTIONS

| EQUIPMENT ITEM (C & S) | | 1982 (In Use) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | Σ |
| PHSR | PHOTO SURVEILLANCE UNIT (Twin Minolta) | 40 | 5 | 18 | 37 | 20 | 44 | 164 |
| APSU | ADVANCED PHOTO SURVEILLANCE UNIT | | | | | | | 0 |
| TVSR | TV SURVEILLANCE (Cameras, Recorders, etc.) | 4 | 11 | 2P | 3 | | 2 | 20/2P |
| PRTV | PORTABLE TV (Cameras & Recorders) | | | | | | | 0 |
| CKVD | CERENKOV VIEWING DEVICE | 2 | 3 | 2 | | 2 | 2 | 11 |
| ICVD | IMPROVED CERENKOV VIEWING DEVICE | | | | | | | 0 |
| UWTV | UNDERWATER TV CAMERA | 20P | | | | 1 | | 1/20P |
| UWVD | UNDERWATER VIEWING DEVICES | | | | | | 1/25P | 1/25P |
| CFCS | CANDU FILM CAMERA SYSTEM | 4 | | 7 | | | | 11 |
| CATV | CANDU CCTV SYSTEM (8 Cameras) | 1 | | 2 | | | | 3 |
| CFFC | CANDU FRESH FUEL BUNDLE COUNTER | | | | | | | 0 |
| CSFC | CANDU SPENT FUEL BUNDLE COUNTER | 2 | | 5 | | | | 7 |
| CSFV | CANDU SPENT FUEL GAMMA VERIFIER | | | 1 | | | | 1 |
| ADPS | ADHESIVE/PAPER SEALS | 1K | 160 | 40 | 1.3K | | | 2.5K |
| CAPS | CAP SEALS (Metallic type E & type X) | 1.9K | 220 | 340 | 8.5K | 400 | 940 | 12.3K |
| SHRT | SHRINK TUBE SEALS | | | 2 | | | | 2 |
| FBOS | FIBRE OPTIC SEAL (e.g. Cobra) | | | | | | | 0 |
| FBOV | FIBRE OPTIC SEAL VERIFIER | | | | | | | 0 |
| USBA | ULTRASONIC SEAL for BWR ASSEMBLIES | | | | | | | 0 |
| USBV | ULTRASONIC SEAL (for BWR) VERIFIER | | | | | | | 0 |
| ULCS | ULTRASONIC CAP SEAL (CANDU spent fuel) | | | | | | | 0 |
| UCSV | ULTRASONIC CAP SEAL VERIFIER (CANDU) | | | | | | | 0 |
| VCOS | VACOSS III ELECTRONIC SEAL | | | | | | | 0 |
| VCSV | VACOSS III SEAL VERIFIER | | | | | | | 0 |
| TLDS | TLD DOSIMETERS | | | 36 | 37 | | | 73 |
| RPLG | RPL GLASS DOSIMETERS | | 150 | | | | | 150 |
| TEPM | TRACK ETCH REACTOR POWER MONITOR | 1 | | | | | | 1 |
| REPM | REACTOR POWER MONITOR ($^3$He Detector) | | | | | | | 0 |
| PMAS | PORTAL MONITORS & ADVANCED C/S SYSTEM | | | | | | | 0 |
| AUVD | ADVANCED UNDERWATER VIEWING DEVICES | | | | | | | 0 |
| SHPC | SHIPPING CONTAINERS (e.g. PAT-2; TYPE B) | | 2 | | 8 | | | 10 |
| STAR | STAR ADVANCED CCTV SURVEILLANCE SYSTEM | | | | | | | 0 |
| MSTR | MINI STAR CCTV SURVEILLANCE SYSTEM | | | | | | | 0 |

(BY OPERATIONS REGIONS, ALL FACILITY TYPES)

| 1983 | | | | | | | 1984 | | | | | | | 1985 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | ∑ | OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | ∑ | OA1 + OA2 | OA3 | OA4 | OC1 + OC2 | OC3 | OC4 | ∑ |
| 47 | 6 | 60 | 36 | 6 | 50 | 205 | 30 | 6 | 82 | 19 | 4 | 54 | 195 | | 6 | 104 | 11 | | 56 | 177 |
| | | | 11 | 19 | | 30 | 22 | | | 30 | 27 | | 79 | 56 | | | 38 | 34 | | 128 |
| 5 | 10 | 2P | 5 | | 2 | 22/2P | 5 | 10 | 2P | 13 | | 2 | 30/2P | 5 | 10 | 2P | 16 | | 2 | 33/2P |
| 6 | | | | | | 6 | 10 | | | | | | 10 | 12 | | | | | | 12 |
| 4 | 3 | | 3 | 2 | 2 | 14 | 4 | 3 | | 3 | 3 | | 13 | 4 | 3 | | 3 | 3 | | 13 |
| 4 | | 8 | 3 | | | 15 | 6 | | 8 | 3 | | 2 | 19 | 8 | | 8 | 4 | | 2 | 22 |
| 25P | | 1 | | 1 | | 2/25P | 29P | | 1 | | 1 | | 2/29P | 33P | | 1 | | 1 | | 2/33P |
| | | 2 | | | 1/28P | 3/28P | | | 2 | | | 1/33P | 3/33P | | | 2 | | | 1/34P | 3/34P |
| 4 | | 7 | | 3 | | 14 | 4 | | 7 | | 3 | | 14 | 4 | | 7 | | 3 | 1 | 15 |
| 1 | | 2 | | 1 | | 4 | 1 | | 2 | | 1 | | 4 | 1 | | 2 | | 1 | 1 | 5 |
| 2 | | 8 | | | | 10 | 2 | | 28 | | | | 30 | 2 | | 28 | | | 1 | 31 |
| 2 | 5 | 20 | | 2 | | 29 | 2 | 5 | 22 | | 2 | | 31 | 2 | 5 | 22 | | 2 | 1 | 32 |
| | | 4 | | 1 | | 5 | | | 4 | | 1 | | 5 | | | 4 | | 1 | 6 | 11 |
| 1K | 230 | 40 | 1.3K | 100 | | 2.7K | 1K | 230 | 40 | 1.3K | 100 | | 2.7K | 1K | 230 | 40 | 1.3K | 200 | | 2.8K |
| 2.5K | 290 | 325 | 8.5K | 600 | 735 | 13K | 3K | 330 | 325 | 8.5K | 700 | 845 | 13.7K | 3.5K | 370 | 330 | 8.7K | 800 | 900 | 14.6K |
| 15 | | 10 | 250 | | 225 | 500 | 60 | | 10 | 500 | 100 | 210 | 900 | 70 | | 10 | 900 | 100 | 200 | 1.3K |
| | | | | 100 | | 100 | 20 | | | 300 | 100 | | 420 | 40 | | | 300 | 100 | | 440 |
| | | | | 1 | | 1 | 1 | | | 2 | 2 | | 5 | 2 | | | 2 | 2 | | 6 |
| | | | | | | 0 | | | | | | | 0 | 360 | | | | 400 | | 760 |
| | | | | | | 0 | | | | | | | 0 | 2 | | | | 2 | | 4 |
| | | 86 | | 12 | | 98 | 30 | 8 | 86 | | 26 | | 150 | 42 | 8 | 86 | | 42 | 5 | 183 |
| | | 7 | | 1 | | 8 | 1 | 1 | 7 | | 1 | | 10 | 1 | 1 | 7 | | 1 | 1 | 11 |
| | | | | 4 | | 4 | 26 | | | | 4 | | 30 | 40 | | | | 4 | | 44 |
| | | | | 1 | | 1 | 2 | | | | 1 | | 3 | 2 | | | | 1 | | 3 |
| 4 | | 36 | 47 | 20 | | 107 | 54 | | 36 | 48 | 20 | | 158 | 60 | | 36 | 46 | 20 | | 162 |
| | 150 | | | | | 150 | | 150 | | | | | 150 | | 150 | | | | | 150 |
| 1 | | | | | | 1 | 1 | | | | | | 1 | 1 | | | | | | 1 |
| | | 3 | | 3 | | 6 | 14 | | 3 | | 8 | | 25 | 34 | | 3 | | 18 | | 55 |
| | | | | | | 0 | | | | | | | 0 | (1)* | | | | | | (1)* |
| | | | | | | 0 | | | | | | | 0 | | | | | | | 0 |
| 2 | 2 | | 15 | | | 19 | 4 | 2 | | 20 | 1 | | 27 | 4 | 2 | | 20 | 1 | | 27 |
| 1 | | | | | | 1 | 1 | | 1 | 4 | | | 6 | 1 | | 1 | 4 | | | 6 |
| | | | | | | 0 | 1 | 1 | 1 | 5 | | | 8 | 2 | 1 | 1 | 6 | | | 10 |

* Rescheduled to 1986.

## TABLE 7A.

## IAEA SAFEGUARDS EQUIPMENT PROJECTIONS BY FACILITY TYPE

**EQUIPMENT ITEM (NDA)**

EQUIPMENT USAGE CODE:
A 100–80% R Resides in Plant, IAEA-Owned
B 80–60% P Plant-Owned/Operated Equipment
C 60–40%
D 40–20%
E 20–>0%

| | | Light Water Reactors | CANDU 600 MW and Multi-unit Sta. | CANDU <300 MW & Other OLRs | Pu Fuelled Reactors |
|---|---|---|---|---|---|
| | FACILITIES: | 143 | 21 | 15 | 3 |
| | ARIE (MD): | | | | |
| SAM2 | SAM-II STABILIZED ASSAY METER (with NaI) | | | | |
| BSAM | BNL STABILIZED ASSAY METER (with NaI) | | | | |
| PITT | PITTMAN 322C (with NaI) | 1 | 1 | 1 | |
| HM-4 | HM-4 HAND-HELD ASSAY PROBE (with NaI) | 2 | 1 | 2 | 1 |
| SLNA | SILENA MCA (4K, & older 1K) | 1 | 4 | | 1 |
| SLNC | SILENA CICERO MCA (8K) | | | | |
| PIAU | PU ISOTOPIC ANALYSIS UNIT (LLNL) | | | | |
| PMCA | PORTABLE MINI-MCA | 8 | 2 | 4 | 2 |
| GDET | GERMANIUM DETECTORS | 1 | 8 | | 3 |
| SNAP | HAND-HELD NEUTRON DETECTOR | | | | |
| HLNC | HIGH-LEVEL NEUTRON COINCIDENCE COUNTER | | | | 1 |
| AWCC | ACTIVE WELL COINCIDENCE COUNTER | | | | |
| CNCC | CHANNEL NEUTRON COINCIDENCE COUNTER | | | | |
| BCNC | BIRD CAGE COINCIDENCE COUNTER | | | | |
| INVS | INVENTORY SAMPLE COUNTER | | | | |
| FPTC | FBR PIN-TRAY COUNTER | | | | |
| FRSC | FUEL ROD SCANNER | | | | |
| UNCL | URANIUM NEUTRON COINCIDENCE COLLAR | 8 | | 2 | |
| PNCL | PLUTONIUM NEUTRON COINCIDENCE COLLAR | 2 | | | 1 |
| UFBC | UNIVERSAL FBR ASSEMBLY COUNTER | | | | 1 |
| ION1 | ION-1 DETECTOR FOR SPENT FUEL NDA | 15 | | 2 | |
| KEDG | K-EDGE DENSITOMETER | | | | |
| PRGC | PROGRAMMABLE CALCULATORS (e.g. HP-97; 41C) | 4 | 1 | 3 | 1 |
| PRTC | PORTABLE COMPUTERS (e.g. HP-85) | | 1 | | 2 |
| LCBS | LOAD-CELL-BASED WEIGHING SYSTEM | | | | |
| ULTG | ULTRASONIC THICKNESS GAUGE ($UF_6$ CYL.) | | | | |
| EBAL | ELECTRONIC BALANCE | | | | |
| STDW | STANDARD WEIGHTS (Sets of various masses) | | | | |
| SGSC | SEGMENTED GAMMA SCANNER | | | | |
| XRFD | X-RAY FLUORESCENCE DETECTOR | | | | |
| CALR | CALORIMETERS (Indicate bulk or small sample) | | | | |
| ELTM | ELECTROMANOMETERS | | | | |
| D2OM | $D_2O$ MEAS. SYSTEM/SAMPLE CONTAINERS | | | | |

| Natural U Conversion & Fuel Fab. | LEU Conversion & Fuel Fab. | HEU Conversion & Fuel Fab. | MOX Conversion & Fuel Fab. | Research Reactors (≥ 25 MW) | Large Scale Critical Assemblies (≥ 1 S.Q.) | Small Research Reactors & Crit. Assy's | Reprocessing Plants | Enrichment Plants | All Other Facilities (Storages, etc.) | Eqp't. Req'mts for Technical Services ('85) | Total Eqp't Presently in Use (Dec. 1982) | Eqp't Req'mts ('85), sharing & 100% PLARIE | Eqp't Req'mts in 1985; 74% PLARIE; 80% Eqp't Lim. Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 23 | 8 | 6 | 16 | 3 | 163 | 8 | 7 | 71 | | | | |
| | | | | | | | | | | | | | |
| 2 | 3 | 1 | | | | 3 | | | | 2 | 36 | 6 | 3 |
| | | | 1 | | | | | | | 0 | 6 | 1 | 1 |
| 1 | 4 | | 2 | 1 | | 2 | | | | 2 | 8 | 6 | 4 |
| 2 | 10 | | 2 | | 1 | 4 | 2 | | 5 | 5 | 9 | 20 | 13 |
| 2 | 2 | | 4 | | 4 | 1 | 6 | 2 | 1 | 2 | 24 | 15 | 9 |
| | | | 4 | 1 | 2 | | 2 | | | 6 | 7 | 15 | 9 |
| | | | 2 | | 1 | | 3 | | | 2 | 1 | 8 | 5 |
| 4 | 31 | 4 | 6 | 13 | 2 | 20 | 6 | 11 | 7 | 15 | 3 | 73 | 45 |
| 1 | 13 | 3 | 8 | 3 | 2 | 5 | 6 | 9 | 1 | 12 | 26 | 58 | 38 |
| | | | | | | | | | | 0 | 1 | 0 | 0 |
| | | | 10 | 1 | 2 | | 4 | | 1 | 6 | 12 | 24 | 16 |
| | 1 | 4 | 1 | | 2 | | | | | 2 | 3 | 9 | 5 |
| | | | | | 1 | | | | | 0 | 1 | 1 | 1 |
| | | | | | 1 | | | | | 0 | 1 | 1 | 1 |
| | | | 7 | | 1 | | 5 | | | 1 | 1 | 10 | 7 |
| | | | 2 | | | | | | | 0 | 1 | 2 | 1 |
| | 4P | | | | | | | | | 0 | 0 | 4P | 4P |
| | 22 | 1 | | 1 | 1 | | | | | 5 | 8 | 28 | 17 |
| | | | 2 | | | | | | | 2 | 1 | 6 | 4 |
| | | | 5 | | | | 1 | | | 2 | 1 | 9 | 6 |
| | | | | 3 | | 2 | 5 | | 1 | 6 | 2 | 20/1P | 13 |
| | | | 2 | | | | 1/1P | | | 1 | 0 | 4/1P | 2/1P |
| 1 | 10 | 2 | 5 | 6 | 4 | 8 | 5 | 3 | 1 | 0 | 20 | 27 | 22 |
| | 10 | 2 | 8 | 3 | 3 | | 6 | 4 | | 4 | 16 | 34 | 22 |
| 2 | 8 | | | | | | | 5 | 2 | 5 | 5 | 21 | 13 |
| | 7 | | | | | | | 7 | 1 | 5 | 9 | 20 | 13 |
| 2P | 17P | 4P | 3P | | | | 4P | 4P | 10P | 0 | 14P | 14P | 14P |
| 4 | 20 | 7 | 5 | | | | 6 | 3 | | 5 | 8 | 47 | 28 |
| | | | | | | | | | | 1 | 1 | 1 | – |
| | | | | | | | | | | 0 | 0 | 0 | – |
| | | | | | | | | | | 0 | 0 | 0 | – |
| | | | 1P | | | | 1/3P | | | 0 | 0 | 1/4P | 1/4P |
| | | | | | | | | | (1R)* | 0 | 0 | (1R)* | (1R)* |

* May be delayed to 1986.

## TABLE 7 B.

## IAEA SAFEGUARDS EQUIPMENT PROJECTIONS BY FACILITY TYPE

**EQUIPMENT ITEM (C & S)**

EQUIPMENT USAGE CODE:

- A 100–80% — R Resides in Plant, IAEA-Owned
- B 80–60% — P Plant-Owned/Operated Equipment
- C 60–40%
- D 40–20%
- E 20–>0%
- —

| | | Light Water Reactors | CANDU 600 MW and Multi-unit Sta. | CANDU < 300 MW & Other OLRs | Pu Fuelled Reactors |
|---|---|---|---|---|---|
| | FACILITIES: | 143 | 21 | 15 | 3 |
| | ARIE (MD): | | | | |
| PHSR | PHOTO SURVEILLANCE UNIT (Twin Minolta) | 56 | 84 | 12 | |
| APSU | ADVANCED PHOTO SURVEILLANCE UNIT | 93 | | 11 | 4 |
| TVSR | TV SURVEILLANCE (Cameras, Recorders, etc.) | 14 | | 7 | 2 |
| PRTV | PORTABLE TV (Cameras & Recorders) | 12 | | | |
| CKVD | CERENKOV VIEWING DEVICE | 14 | 1 | 4 | |
| ICVD | IMPROVED CERENKOV VIEWING DEVICE | 20 | 7 | 2 | 1 |
| UWTV | UNDERWATER TV CAMERA | 1/33P | | 1 | |
| UWVD | UNDERWATER VIEWING DEVICES | 2/33P | | | |
| CFCS | CANDU FILM CAMERA SYSTEM | | 18 | | |
| CATV | CANDU CCTV SYSTEM (8 Cameras) | | 5 | | |
| CFFC | CANDU FRESH FUEL BUNDLE COUNTER | | 31 | | |
| CSFC | CANDU SPENT FUEL BUNDLE COUNTER | | 25 | 7 | |
| CSFV | CANDU SPENT FUEL GAMMA VERIFIER | | 11 | | |
| ADPS | ADHESIVE/PAPER SEALS | 130 | 100 | 120 | 300 |
| CAPS | CAP SEALS (Metallic type E & type X) | 1800 | 320 | 210 | 750 |
| SHRT | SHRINK TUBE SEALS | | | | |
| FBOS | FIBRE OPTIC SEAL (e.g. Cobra) | 30 | | | |
| FBOV | FIBRE OPTIC SEAL VERIFIER | 1 | | | |
| USBA | ULTRASONIC SEAL for BWR ASSEMBLIES | 760 | | | |
| USBV | ULTRASONIC SEAL (for BWR) VERIFIER | 4 | | | |
| ULCS | ULTRASONIC CAP SEAL (CANDU spent fuel) | | 167 | 16 | |
| UCSV | ULTRASONIC CAP SEAL VERIFIER (CANDU) | | 9 | 2 | |
| VCOS | VACOSS III ELECTRONIC SEAL | 4 | | | |
| VCSV | VACOSS III SEAL VERIFIER | 1 | | | |
| TLDS | TLD DOSIMETERS | 94 | 40 | 7 | 4 |
| RPLG | RPL GLASS DOSIMETERS | | | 150 | |
| TEPM | TRACK ETCH REACTOR POWER MONITOR | | | | |
| REPM | REACTOR POWER MONITOR ($^3$He Detector) | 45 | 1 | 2 | 1 |
| PMAS | PORTAL MONITORS & ADVANCED C/S SYSTEM | | | | |
| AUVD | ADVANCED UNDERWATER VIEWING DEVICES | | | | |
| SHPC | SHIPPING CONTAINERS (e.g. PAT-2; TYPE B) | | | | |
| STAR | STAR ADVANCED CCTV SURVEILLANCE SYSTEM | | | 1 | |
| MSTR | MINI STAR CCTV SURVEILLANCE SYSTEM | 4 | | | |

| Natural U Conversion & Fuel Fab. | LEU Conversion & Fuel Fab. | HEU Conversion & Fuel Fab. | MOX Conversion & Fuel Fab. | Research Reactors (≥ 25 MW) | Large Scale Critical Assemblies (≥ 1 S.Q.) | Small Research Reactors & Crit. Assy's | Reprocessing Plants | Enrichment Plants | All Other Facilities (Storages, etc.) | Eqp't Req'mts for Technical Services ('85) | Total Eqp't Presently in Use (Dec. 1982) | Eqp't Req'mts ('85), sharing & 100% PLARIE | Eqp't Req'mts in 1985; 74% PLARIE; 80% Eqp't Lim. Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 23 | 8 | 6 | 16 | 3 | 163 | 8 | 7 | 71 | | | | |
| | | | | | | | | | | | | | |
| | | | | 15 | | | 1 | | 1 | 25 | 260 | 194 | 110 |
| | | | 3 | 8 | | | 6 | | | 40 | 0 | 165 | 100 |
| | | | 1 | 5 | | | 6 | | | 10 | 29 | 45 | 30 |
| | 1 | | 1 | | | | | | | 4 | 0 | 16 | 10 |
| | | | | 1 | | 2 | 3 | | | 3 | 19 | 16 | 10 |
| | | | | 1 | | 1 | 2 | | 1 | 8 | 0 | 43 | 25 |
| | | | | | | | | | | 1 | 1/20P | 3/33P | 2/33P |
| | | | | 1 | | 1P | | | | 1 | 1/25P | 4/34P | 2/34P |
| | | | | | | | | | | 3 | 11 | 18 | 13 |
| | | | | | | | | | | 1/3 | 3 | 5 1/3 | 3 |
| | | | | | | | | | | 2 | 0 | 33 | 20 |
| | | | | | | | | | | 1/3 | 8 | 32 1/3 | 21 |
| | | | | | | | | | | 0 | 1 | 11 | 7 |
| 140 | 260 | 140 | 240 | 150 | 220 | 110 | 300 | 140 | 220 | – | – | 2.8K | 1.7K* |
| 186 | 2130 | 1320 | 2500 | 480 | 1300 | 370 | 1090 | 680 | 1176 | – | – | 14.6K | 8.6K* |
| | 418 | | | | | | | 362 | 500 | – | – | 1.3K | 0.8K* |
| | | 50 | 200 | | 130 | 20 | | 10 | | 20 | 0 | 460 | 274* |
| | | 1 | 1 | | 2 | 1 | | 1 | | 1 | 0 | 7 | 4 |
| | 760 | | | | | | | | | 5 | 0 | 765 | 450* |
| | 4 | | | | | | | | | 1 | 0 | 5 | 3 |
| | | | | | | | | | | 8 | 0 | 191 | 113* |
| | | | | | | | | | | 1 | 0 | 12 | 7 |
| | | | | | 30 | | | 10 | | 1 | 0 | 45 | 27 |
| | | | | | 1 | | | 1 | | 1 | 0 | 4 | 2 |
| | | | 3 | 8 | | | 4 | | | 14 | 73 | 174 | 100* |
| | | | | | | | | | | 10 | 150 | 160 | 100* |
| | | | | 1 | | | | | | 0 | 1 | 1 | 0 |
| | | | | 4 | | 4 | | | | 5 | 0 | 60 | 36 |
| | | | | | (1R) | | | | | 0 | 0 | (1) | (1) |
| | | | | | | | | | | 0 | 0 | 0 | 0 |
| | | | 12 | | | | 15 | | | 1 | 10 | 28 | 16 |
| | | | 1 | | 1 | | 2 | | | 1 | 0 | 6 | 4 |
| | | | 1 | 1 | 1 | | 2 | | | 2 | 0 | 11 | 7 |

* EXPENDABLE SUPPLIES.

# CHARACTERISTICS OF PLANT SPECIFIC REFERENCE MATERIALS

**G. BUSCA**
Safeguards Directorate, Luxembourg

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## 1. INTRODUCTION

For the verification of nuclear materials, especially for quantitative methods, the need for a proper calibration and normalization procedure is evident and hardly needs to be stressed. The calibration is established by measuring items considered to be reference standards. These reference values must be traceable to a primary standard. In practice, the reference materials for a non-destructive assay (NDA) technique are carefully selected to be as representative as possible of the materials to be measured and are characterized by proper weighing and sampling for destructive analysis. The choice of suitable reference materials for calibration of an instrument is an important factor contributing to the reliability and capability of that instrument for verification purposes. In view of the diversity of materials, conditions of measurement, plant characteristics and operational constraints, the Euratom Inspectorate and the IAEA initiated a joint programme for the procurement and preparation of joint plant specific reference materials (PSRM) for NDA. As well as the two inspectorates, the Joint Research Centre of the CEC is participating actively in this programme, together with the Divisions of Development and Technical Support and Safeguards Information Treatment and the Safeguards Analytical Laboratory.

As already reported 1, 2 and 3/, the following basic criteria have been generally adopted for the procurement and preparation of PSRM:

- It must be similar to the production population.
- It must be well characterized and identified.
- The introduced error component into the measurements by the PSRM must be small and as low as reasonably achievable.
- The preparation must be justifiable by cost effectiveness analysis.

There are some general requirements which the PSRMs must fulfill. They are, in fact, used for verification of production of particular materials and serve as references for the measurements carried out with a specific instrument.

It is the object of this paper to describe, as an example, the procedures and measurements carried out to prepare a reference MOX pin and the methodology and evaluation methods used for characterization. The close coordination, cooperation and joint work of experts from different fields, such as inspectors, NDA experts, statisticians and analysts, is discussed.

## 2. REFERENCE MOX PIN

For the preparation of a reference MOX Pin, a procurement scheme, based on limitations and provisions in the facility, measurement capabilities as well as the conditions and desired characteristics were prepared in advance and consisted of the following steps 1/:

- Random selection of two pins from the same production batch and use of NDA techniques to quantify the correlation between the two pins.
- Dismantling of one of the two pins, establishing total MOX and blanket weight and sampling of the pellets for destructive analysis.
- Evaluation of the uncertainties of the assigned values from the NDA and DA results.

As reported 2/, the NDA measurements performed were:

- A longitudinal scan with a rod scanning device, equipped with a Ge-Li detector, to check the longitudinal homogeneity of the pin. The Pu distribution (at differeent spectrum thresholds) was verified to be homogeneous along the pin within the limit of experimental uncertainty. This limit was evaluated to be 0.8%2/.

- A comparison of Pu isotopic ratios in the two pins was carried out using an intrinsic germanium detector. The measurement was repeated at different points along the pins. The average uncertainty in the results evaluated by internal error propagation was in agreement with the standard deviation evaluated from point to point variability.
- The total plutonium content ratio between the two rods and the Pu-240 equivalent ratio were monitored using a pin calorimeter and a coffin type variable dead time counter (VDC). Again, within the limit of experimental error (evaluated at a few tenths of a per cent for calorimetry and of the order of 1% for VDC), the measured ratios were in agreement with the declared ones.
- A sample of MOX pellets was selected for destructive analysis (DA). A detailed scheme for the analysis of samples was prepared to provide for distribution of samples to different laboratories, with consequent estimates of systematic and random errors.

It should be emphasized that all the relevant operations were carried out under continuous surveillance of the inspectors or, in their absence, appropriate containment was used to assure continuity of knowledge of the nuclear materials involved.

The selected MOX and blanket pellets were distributed to 4 laboratories for characterization measurement. The analytical schemes that were followed by the laboratories and normalized results to the overall mean is presented in 3/.

The methodology used for characterization was based on a standard nested analysis of variance for the plutonium, uranium and different isotopic concentratons. The model was:

$$I_{nij} = \mu + \lambda_n + \delta_{ni} + \varepsilon_{nij}$$

where $I_{nij}$ is the concentration result for the jth aliquot from the ith sample by laboratory n and

$\mu$ is the general mean
$\lambda_n$ is random laboratory effect
$\delta_{ni}$ is random sample dissolution effect
$\varepsilon_{nij}$ is random aliquot effect

The individual variance components for the different variables were estimated by analysis of variance techniques and are summarized in Tables 1 and 2. These are preliminary estimates. The analysis of variance calculations partition the total variability among the data into the three sources of variability allowed for in the experimental design. The degrees of freedom (df) indicate the number of independent deviations used in the calculation for each source. For example, there are 3 independent deviations of laboratory means from the overall mean since the fourth deviation is dependent on those 3 in that it is the negative of their sum.

Upon the completion of the above mentioned procedure, a detailed protocol was issued which describes the steps followed and the estimated uncertainty. The protocol guarantees the recording the traceability of all the certified data pertinent to the reference material from raw data to the final results and uncertainties. In addition, a certificate containing all relevant data was issued.

Table 1

Relative "Variance Components" ($\sqrt{\text{comp.}}$/C) 100%

| Source | df | PU | df | 238 | df | 239 | 240 | 241 | 242 |
|---|---|---|---|---|---|---|---|---|---|
| Laboratories | 3 | 0.11 | 1 | 0.72 | 3 | 0.05 | 0.06 | 0.35 | 0.54 |
| Pellets | 8 | 0.04 | 4 | 0.26 | 8 | 0.05 | 0.17 | - | 0.27 |
| Aliquots | 24 | 0.12 | 6 | 0.63 | 12 | 0.03 | 0.05 | 0.23 | 0.31 |

\- indicates a negative estimate

Table 2

Relative "Variance Components" ( $\sqrt{comp.}$/C) 100%

| | df | U | df | 235 | df | Am241 |
|---|---|---|---|---|---|---|
| Laboratories | 1 | 0.03 | 3 | 0.31 | 2 | 1.09 |
| Pellets | 4 | – | 8 | – | 6 | 0.66 |
| Aliquots | 12 | 0.07 | 12 | 0.50 | 9 | 0.69 |

– indicates a negative estimate

## 3. SUMMARY

From the joint IAEA/Euratom Inspectorate Programme on preparation of plant specific reference materials, an example describing the criteria, procedures and steps taken has been presented. The example consisted of preparation of a reference MOX Pin to be used for the calibration of an NDA instrument (Euratom VDC) for routine verification of the production in one facility.

The active participation of the operator in the preparation indicates, not only the interest of the plant in showing higher transparency of the measuring system, but also the contribution of the facility to the common goal for increasing the efficiency of safeguards.

As reported in 3/ with the available reference pin, it is possible for both safeguards authorities to improve effectiveness by verifying with an accurate quantitative method. The existence of this reference pin enables the inspectors to authenticate the instrument and minimize the measuring time to the optimized level based on the expected uncertainty and therefore requires less effort by the plant operator. In general, one can conclude that preparation of PSRMs improves safeguards effectiveness and reduces the time and effort required by operators and inspectors.

The preparation and characterization of such a reference material required close cooperation and support of experts from different fields of expertise. The contribution of the NDA experts in carrying out different measurements is just as important as the statistician's effort to analyze the data. Without the contribution of the inspector who provides information on the need and possibilities and describes the operation provisions, the preparation of such a reference material could not be performed (as in the case of the chemical analyst who has prepared the analytical scheme and evaluated the data). In summary, preparation of PSRM requires several experts. In the above mentioned example on the preparation of a MOX reference pin, the close cooperation between Euratom and IAEA Inspectorates and their supporting organizations can be restated. Within the IAEA and Euratom Inspectorate, experts from the operations divisions and support divisions have now cooperated in the characterization of several different PSRMs.

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# NDA IN THE IAEA SAFEGUARDS DURING THE NEXT FIVE YEARS: AN OUTLINE OF TWO POSSIBLE DEVELOPMENT AND IMPLEMENTATION SCENARIOS

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ABSTRACT

After a brief introduction about the role of NDA in the Agency Safeguards, two different scenarios are described. These show how the utilization and the usefulness of NDA can develop if the lowest and highest expectable priority, respectively, will be given to this sub--area of safeguards. For each case, an outline is given of what would be required from instrument development, computerization, acquisition of reference materials, standardization, inspector efforts, training and data collection and evaluation in order to achieve the described level of implementation. This paper is an extrapolation of four years' experience of NDA cooperation between the operational divisions and the supporting divisions and units. A couple of practically encountered cases of NDA data collection and evaluation are mentioned as examples supporting the conclusions about the future.

Acknowledgements.

The author wishes to gratefully acknowledge the cooperation, data input and discussions provided by several Agency Safeguards Inspectors. Although it might not be feasible to list here all individuals by name, some of those who have officially presented NDA results and plans, serving as input to my conclusions, are R. Abedin-Zadeh, W. Bahm, B. Barnes, T. Beetle, M. Krick, A. Lumetti, A. Ramalho and D. Rundquist, not to mention former staff members who have now left the Agency.

## 1. Introduction

In the overall IAEA Safeguards approach, including agreements between the Agency and the Member States, inspections, and statements regarding independent verification and safeguards implementation, a procedure is taking place in which the member state relaxes part of its sovereignty and the Agency, based on its findings, can act as a sort of international witness regarding the compliance of the member state with the NPT. The Safeguards Implementation Report (SIR) and other documents show the extent of this Agency "testimony" in terms of material amounts verified, detection probabilities, etc.

For about the last 10 years, it has been realized that various applications of NDA have a potential to contribute to this procedure by enhancing the physical verification and thus provide a higher degree of safeguards implementation. This is of benefit to each inspected country, because the Agency findings allow more substantial statements about its compliance with the NPT, and of benefit to the whole community of Member States because an effective safeguards implementation increases the general confidence in the non-proliferation purposes of the other Member States.

In the implementation of NDA for these purposes, studies have been made for various facility types, material flows and possible diversion strategies in order to assess where NDA verification could be used in the most efficient way, thus giving a high detection probability and a low false alarm rate.

In this paper, the NDA implementation forecast will be studied from only two extreme application types. These are gross defect testing in the sense of checking individual items for complete falsification or diversion of a conspicuous amount of fissile material from that item, and, on the other hand, variables testing, where a number of items from a material stratum are measured in order to check if there are small differences in the average material amounts. These small differences, after inferring to the whole stratum and addition of the estimated differences for all strata, might reveal a total deficiency significantly exceeding the acceptable limit amounts.

## 2. Low Implementation Level Scenario.

At this lowest expectable implementation level for the next five years, I simply choose today's level, assuming that the Agency does not want to reduce its ambitions on NDA.

To be straightforward, I do not think any secrecy is disclosed by the statement that the inspector's possibilities to draw firm conclusions from NDA in field applications today are rather limited. To pick up some practical examples, it has happened that a highly significant U-235 gross defect has been obtained in NDA using a calibration curve based on measurement of characterized reference materials up to a size of a third of the items being inspected. If the proper calibration standards had been available, the calibration curve would have been different and the problem might not have occurred.

Another example is a case where an old calibration curve was used, which covered the size range of the items to be inspected. When the random measurement error was estimated from the inspection measurement results and the error due to the uncertainty in the calibration parameters was added to this, some operator - inspector differences occurred. These could not be probabilistically explained from the "total" error variance calculated in the described way-

In this case, like in the first example, no conclusion could be reported. This time it was noticed that the items measured in field had a cladding which was different from that of the calibration standards and there was not enough information available to assess the influence of this error source. Moreover, because the calibration curve was old, a study was needed in order to quantify the influence of the NDA instrument drift and of the change of components, which sometimes is necessary in case of a malfunction disovered in the field. Such a study was planned, but until its results were available, the measured "discrepancies" should, of course, not be reported.

As a third and last example, I mention a case where the total NDA procedure was beset by so large uncertainties, when the available instrumentation was used for the material in question, that the total error variances to be used in field measurements evaluation were large enough to cover a theoretically possible diversion of significant quantities of fissile material. In this case, a certain improvement could be reached by using better NDA instruments and a more careful and time-consuming assay procedure in the field.

In addition to these three types of cases, you are probably aware of numerous inspection situations where NDA application is precluded by the complete lack of calibration standards that are similar enough to the field material.

<u>3. Highest Expectable NDA Implementation Scenario</u>

From the typical problems I have tried to briefly describe for the low-level alternative, the experienced reader can probably conclude that five years is not a very long time for improving the situation up to field measurement accuracy comparable to laboratory performance for a majority of the materials under safeguards. Even if that is achieved, some system study results show that detection probabilities against optimized diversion strategies for certain strategic facility types would still not be as high as the 95% that has been a sort of a standard goal temporarily used in the past. Some of the references have given very good outlines of what is needed to optimize NDA, and I will here just mention a few examples of actions that could be taken in a department-wide cooperation the next few years.

a. <u>Instrument Development and Computerization</u>. Instrument development in relation to accuracy, reliability and applicability to materials under safeguards, seems to be going on quite well. Recent reports show that gamma spectrometry for Pu isotopes is not very far from the accuracy where it can be used for independent NDA of Pu mass. As to computerzation, many good projects are underway, and their continuation is needed for reaching an improved NDA implementation level. Furthermore, it has to be remembered that computerization cannot replace training and physical understanding, although it can help to facilitate these things. It only serves as a "prompter handbook", evaluator and data storage. In order to make use of other experiences, error sources and routine updating necessary for a total on-the-spot evaluation including "all error sources" of an NDA field result, a computerized NDA instrument has to communicate with other computers by magnetic media.

b. <u>Standardization</u>. The question of standardization becomes relevant, both for data transfer and evaluation algorithms. Another question that has been raised in this context is that an "ideally" computerized NDA instrument could, in case of real diversion or a case of error sources difficult to trace, provoke a discussion on the floor level between the inspector and the facility operator, on a matter that should actually be treated on the top level, between the Agency and the country's representatives. If that is true, it is true also for many other inspection activities, such as item counting etc., so it should not have any discouraging impact on the development of an integrated computerized data evaluation and retention system.

c. Procurement and Characterization of Standards. This area is definitely one of the most urgent ones. It should be enough to mention here that one of the recent monthly NDA liaison meetings at the Agency expressed the highest priority to this area when a list of "wishes" to be submitted to the U.S.A. support program was discussed.

d. Inspector efforts. Expressed in man-days, this is a crucial item for NDA implementation. If kept constant, they might, with a well-planned increased use of computerized instruments, provide for quantitatively or qualitatively improved NDA implementation. However, because most NDA still is anticipated for the larger amounts of material in the future, more complex material flows and expanding fuel cycle activities, the inspector efforts in man-days seems to be a matter for the safeguards negotiation team, which has to find the best trade-off between the possible and the desirable. It seems logical that input is provided to that team in the form of man-day requirements realistically estimated from Instruction Manuals for Instrumentation (IMI), and preferably IMI's according to the format proposed in reference [1].

e. Training. The importance of training has already been mentioned in relation to computerization. The Agency should, if the extreme case is considered, make sure that the inspector is so well trained in measurement performance and understanding, that the Agency can trust its own inspector in case of a discussion with experts from a facility or member country. The NDA training at the Agency actually has increased considerably during the last few years. However, in comparison with field measurement experts in areas other than safeguards, who frequently have 6 - 12 months training before starting the actual field experience, it seems like most of the inspector NDA training has to take place in field, even after several weeks of NDA training during Agency courses or member country sponsored courses.

f. Data collection and evaluation. Centrally, or in operational divisions, this matter is related to the overall Measurement Quality Assurance (MQA) responsibility. In most organizations where quality control is systematically carried out, there is a special officer nominated to be responsible for this area. There is reason to believe that the Agency NDA needs the same if MQA is going to be taken seriously. An MQA officer has to be appointed on department or division level.

To return to the data collection and evaluation matter, it is important that the central resources in this area actually concentrate on the projects that are of highest priority and expand into depth only in those areas really requiring it. A promising concept that could help to keep track of error sources is the Measurement Error Data Bank (MEDB). The detailed development of a MEDB requires both a data element list and a usage algorithm agreement in order to prevent erroneous use of the stored data. Other data files need to be built up centrally, such as instrument performance files for the technical maintenance. Files containing data on operator - inspector comparisons must be centrally available for the study of trends and for retrieval of information necessary for the SIR.

As a guess about the five year prospect for the data collection and storage area, I would say it would be a good achievement if an MEDB would be built up, fed with NDA results and routinely give feedback in the form of error variances usefully delineated according to error sources. This feedback could be provided on magnetic media to field computers for inspection planning and in-field result assessment.

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# NUCLEAR FUEL CYCLE ECONOMICS

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ABSTRACT

Annual fuel cycle costs are presented for a typical 1,000 MWe pressurized water reactor operating in the United States under prevailing economic conditions. Based on the costs presented, it was concluded that reprocessing of spent fuel and recycle of recovered uranium and plutonium is not economical at the present time. However, a number of possible cost changes in the fuel cycle are identified which would make spent fuel reprocessing economical in future years. Other non-economic advantages of reprocessing are also identified.

Over the past several years there has been considerable discussion of comparative economics of the "once-through" nuclear fuel cycle and the "closed" fuel cycle as such apply to light water reactors. The "once-through" fuel cycle is illustrated in Figure 1, and is uniquely characterized by the disposal of spent nuclear fuel and its contained uranium and plutonium values. The "closed" fuel cycle is illustrated in Figure 2, and is uniquely characterized by the recovery and recycle of the unburned uranium and by-product plutonium contained in the spent fuel. A variation to the "closed" fuel cycle involves the reprocessing of spent fuel, recycle of recovered uranium, and use of recovered plutonium in breeder reactor development and demonstration programs. This paper will briefly discuss the current comparative economics of these fuel cycles and the sensitivity of the economics to prospective future changes in costs for individual steps in the nuclear fuel cycle.

The annual fuel cycle costs of a typical 1,000 MWe pressurized water reactor were estimated (assuming reloads are made annually) for the "once-through" fuel cycle, for a fuel cycle involving reprocessing and recycle of recovered uranium and plutonium, and for a fuel cycle involving reprocessing and recycle of recovered uranium and sale of recovered plutonium. In making these estimates the assumptions described in Table 1 were used. A comparison of the annual fuel cycle costs for the "once-through" fuel cycle, and for reprocessing and recycle of recovered uranium and plutonium, is set forth in Table 2; a comparison of the annual fuel cycle costs for the "once-through" fuel cycle, and for reprocessing and recycle of recovered uranium and sale of plutonium is set forth in Table 3.

From the cost data shown in Table 2 it can be seen that, based on the assumptions used, reprocessing and recycle of recovered uranium and plutonium is about \$1.7-million/year more expensive than the "once-through" fuel cycle. However, it should be noted that a breakeven situation would result if:

(1) the price of uranium concentrates increased to about \$89/kgU (\$34/lb $U_3O_8$) -- significantly less than the \$42/lb $U_3O_8$ price it attained a few years ago in a growing market, or

(2) the price for enrichment increased to about \$202/kgSWU, or

(3) the price of MOX fabrication was reduced to about \$620/kgHM -- which represents a factor of about 3.7 over the cost of fabrication of $UO_2$ fuel (as opposed to a factor of about 5.2 as represented by the escalated INFCE values), or

(4) the cost of waste disposal was reduced by about \$60/kgU -- or such that the cost of disposal of reprocessing wastes was about \$165/kgU or about 60 percent of that estimated for the cost of disposal of spent fuel, or

(5) the capital cost of the reprocessing facility was reduced by about \$395-million, or

(6) combinations of lesser cost changes in the above-listed elements of fuel cycle costs were experienced which have equivalent economic impact.

All of the above situations represent clear possibilities. The price of uranium concentrates

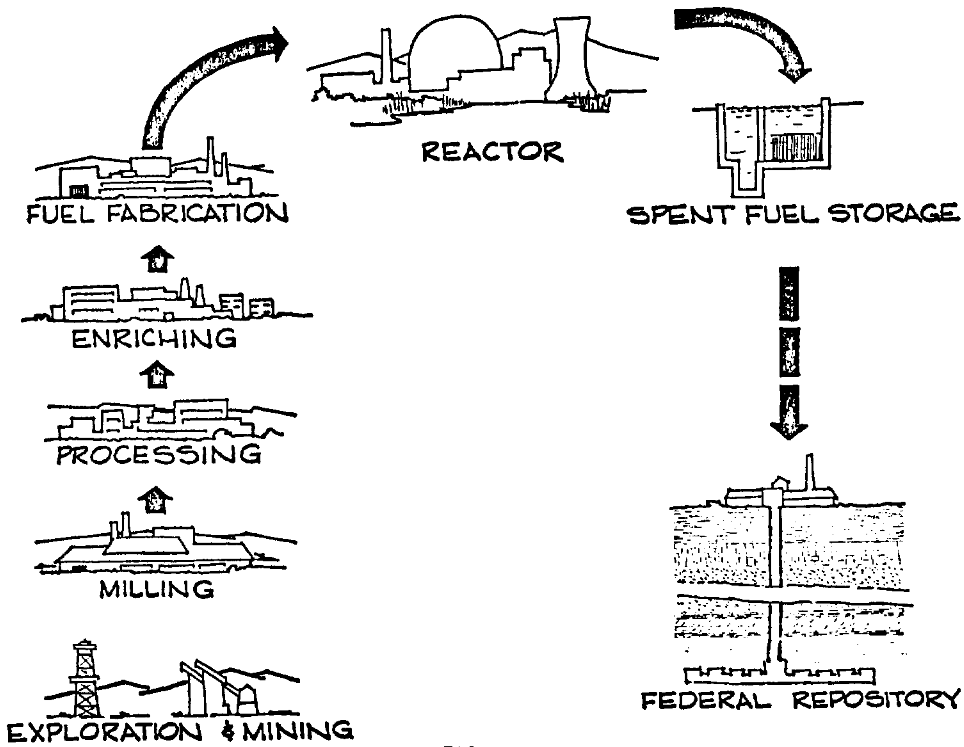


FIGURE 1

"ONCE-THROUGH" FUEL CYCLE

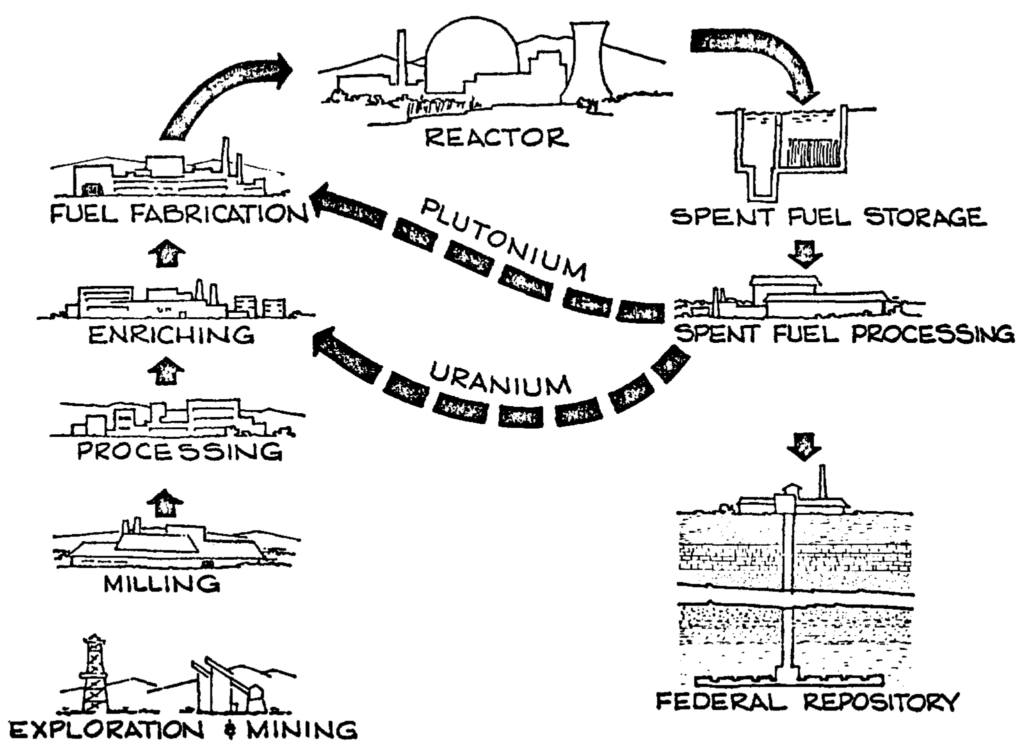


FIGURE 2

PROSPECTIVE "CLOSED" FUEL CYCLE

TABLE 1

ASSUMPTIONS USED IN DERIVING FUEL CYCLE COSTS

(1,000 MWe PWR)

Annual Replacement Loading (initially)

| | | |
|---|---|---|
| Quantity of uranium | - | 27,000 kgU |
| Enrichment | - | 3.3% |
| No. of assemblies | - | 59 |
| Weight per assembly | - | 457.6 kgU |

Exposure

| | | |
|---|---|---|
| Burnup | - | 33,000 MWD/MTU |
| Average specific power | - | 30 MW/MTU |

Spent Fuel Discharges (initially)

| | | |
|---|---|---|
| Quantity of heavy metal | - | 26,055 kgHM |
| Quantity of uranium | - | 25,785 kgU |
| Enrichment | - | 0.83% U-235 |
| Quantity of plutonium | - | 246 kgPu (70% fissile) |

Losses to Waste

| | | |
|---|---|---|
| Conversion | - | 0.5% of input thereto |
| Fabrication | - | 1.0% of input thereto |
| Reprocessing | - | 1.0% of input thereto |

Recycle of Plutonium

Natural uranium is blended with plutonium in fabricating mixed oxide fuel.

Mixed oxide fuel must have 25% more fissile plutonium than the fissile uranium it replaces on recycle.

Plutonium recovered from the spent fuel of the reactor is totally recycled to mixed oxide fuel and reintroduced to the reactor.

$UO_2$ and $UO_2$-$PuO_2$ assemblies are reprocessed together.

Recycle of Uranium

Uranium recovered during reprocessing is recycled to enrichment.

Fuel Cycle Costs

| | | |
|---|---|---|
| Uranium | - | \$25/lb $U_3O_8$ (\$65/kgU) |
| Conversion | - | \$5.50/kgU (approximate current price) |
| Enrichment | - | \$149.85/kgSWU (DOE price in effect on 9/7/83) |
| Fuel Fabrication | | |
| $UO_2$ | - | \$165/kgU (approximate current price) |
| MOX | - | \$860/kgU (INFCE cost, escalated to 1983) |
| Reprocessing | - | \$283/kgU (using utility financing methods) |
| Waste Disposal | | |
| Spent Fuel | - | \$283/kgU (DOE costs escalated to 1983) |
| Reprocessing Wastes | - | \$226/kgU (assumed to be 20% lower than for spent fuel) |
| Transportation | - | Estimated as shown in Tables 2 and 3 |

TABLE 2

COMPARISON OF ANNUAL FUEL CYCLE COSTS FOR ONCE-THROUGH FUEL CYCLE AND RECOVERY AND RECYCLE OF URANIUM AND PLUTONIUM -- 1,000 MWe PWR*

(1983 Dollars)

| | Once-Through Fuel Cycle | | | Recovery & Recycle of Uranium & Plutonium | | |
|---|---|---|---|---|---|---|
| | Quantity | Unit Price ($) | Total Cost ($000) | Quantity | Unit Price ($) | Total Cost ($000) |
| Uranium Concentrates | 181,345 KGU | $ 65.00 | $11,787 | 113,702 KGU | $ 65.00 | $ 7,391 |
| Transport--$U_3O_8$ | 181,345 KGU | .14 | 25 | 113,702 KGU | .14 | 16 |
| Conversion | 180,438 KGU | 5.50 | 992 | 113,133 KGU | 5.50 | 622 |
| Transport--$UF_6$ (Nat) | 180,438 KGU | .21 | 38 | 113,133 KGU | .21 | 24 |
| Enrichment | 120,219 KGSWU | 149.85 | 18,015 | 88,456 KGSWU | 149.85 | 13,255 |
| Transport--$UF_6$ (Enr) | 27,273 KGU | .75 | 20 | 20,267 KGU | .75 | 15 |
| Fuel Fabrication | | | | | | |
| $UO_2$ | 27,000 KGU | 165.00 | 4,455 | 20,064 KGU | 165.00 | 3,311 |
| MOX | - | - | - | 6,936 KGU+Pu | 860.00 | 5,965 |
| Transport--Fresh Fuel | | | | | | |
| $UO_2$ | 27,000 KGU | 1.71 | 46 | 20,064 KGU | 1.71 | 34 |
| MOX | - | - | - | 6,936 KGU+Pu | 2.94 | 20 |
| Transport--Spent Fuel | 27,000 KGU | 30.80 | 832 | 27,000 KGU | 22.00 | 594 |
| Reprocessing | - | - | - | 27,000 KGU | 283.00** | 7,641 |
| Transport--Recovered Product | | | | | | |
| $UF_6$ | - | - | - | 25,465 KGU | .21 | 5 |
| $PuO_2$ | - | - | - | 330 KGPu | 49.00 | 16 |
| Transport--Repr. Waste | - | - | - | 27,000 KGU | 18.00 | 486 |
| Transport--Fab. Waste | - | - | - | 27,000 KGU | .20 | 5 |
| Waste Disposal | 27,000 KGU | 283.00 | 7,641 | 27,000 KGU | 226.00 | 6,102 |
| TOTAL . . . . . . . . . . . . . . . . . . . . . . . . . . | | | $43,851 | | | $45,502 |

*Excludes interim storage of spent fuel in AFR storage facilities or expanded reactor facilities.

**Based on utility-type financing.

TABLE 3

COMPARISON OF ANNUAL FUEL CYCLE COSTS FOR ONCE-THROUGH FUEL CYCLE AND RECOVERY AND RECYCLE OF URANIUM AND SALE OF PLUTONIUM -- 1,000 MWe PWR*
(1983 Dollars)

| | Once-Through Fuel Cycle | | | Recovery & Recycle of Uranium & Sale of Plutonium | | |
|---|---|---|---|---|---|---|
| | Quantity | Unit Price ($) | Total Cost ($000) | Quantity | Unit Price ($) | Total Cost ($000) |
| Uranium Concentrates | 181,345 KGU | $ 65.00 | $11,787 | 149,140 KGU | $ 65.00 | $ 9,694 |
| Transport--$U_3O_8$ | 181,345 KGU | .14 | 25 | 149,140 KGU | .14 | 21 |
| Conversion | 180,438 KGU | 5.50 | 992 | 148,394 KGU | 5.50 | 816 |
| Transport--$UF_6$ (Nat) | 180,438 KGU | .21 | 38 | 148,394 KGU | .21 | 31 |
| Enrichment | 120,219 KGSWU | 149.85 | 18,015 | 117,314 KGSWU | 149.85 | 17,580 |
| Transport--$UF_6$ (Enr) | 27,273 KGU | .75 | 20 | 27,273 KGU | .75 | 20 |
| Fuel Fabrication | 27,000 KGU | 165.00 | 4,455 | 27,000 KGU | 165.00 | 4,455 |
| Transport--Fresh Fuel | 27,000 KGU | 1.71 | 46 | 27,000 KGU | 1.71 | 46 |
| Transport--Spent Fuel | 27,000 KGU | 30.80 | 832 | 27,000 KGU | 22.00 | 594 |
| Reprocessing | - | - | - | 27,000 KGU | 283.00** | 7,641 |
| Transport--Recovered U Product | - | - | - | 25,527 KGU | .21 | 5 |
| Transport--Repr. Waste | - | - | - | 27,000 KGU | 18.00 | 486 |
| Waste Disposal | 27,000 KGU | 283.00 | 7,641 | 27,000 KGU | 226.00 | 6,102 |
| TOTAL . . . . . . . . . . . . . . . . . . . . . . . . . . . | | | $43,851 | | | $47,491 |

*Excludes interim storage of spent fuel in AFR storage facilities or expanded reactor facilities.

**Based on utility-type financing.

would have probably been well over \$34/lb $U_3O_8$ today were it not for the numerous cancellations and delays of nuclear power projects in the U.S. and the lack of any additional orders therefor during the past few years. The cost of MOX fuel fabrication was generally expected to be 3-4 times the cost for $UO_2$ fuel fabrication prior to the 1977 indefinite deferral of reprocessing and recycle in the U.S., and new cost effective designs for MOX fuel fabrication facilities could reasonably be expected to reduce the cost therefor to the range \$550-650/kgHM. There are many prospective areas for savings in the cost of disposal of reprocessing wastes over that involved for the disposal of spent fuel (through higher waste loadings per package, smaller repositories, etc.) that could achieve the reductions in cost required to make the "closed" fuel cycle a breakeven situation. The elimination of the need for krypton recovery facilities and plutonium conversion facilities could result in a large portion of the required \$400-million reduction in the capital costs of the reprocessing facility.

From the data shown in Table 3 it can be seen that, based on the assumptions used, reprocessing and recycle of only the recovered uranium would result in a deficit of about \$3.7-million/year compared to the "once-through" fuel cycle. However, if the recovered plutonium could be sold or credited to a breeder reactor program for a price of about \$21/gram (fissile), a net cost which represents a breakeven situation with the "once-through" fuel cycle would be realized.

$$\frac{\$3{,}640\text{-million}}{(246\ \text{kgPu})(70\%\ \text{fissile})} = \$21.1/\text{gPu (fissile)}$$

From the foregoing it can be seen that reprocessing can be made to be economic with respect to the "once-through" fuel cycle, if the facilities are financed by leveraged methods such as are used by utility companies for financing electric generating facilities, and if the recovered plutonium can be sold for \$20-25/gram for a plutonium stockpile for future breeder use. Moreover, reprocessing and recycle of recovered uranium and plutonium to LWRs can be expected to be economic with respect to the "once-through" fuel cycle in a growing nuclear economy in which uranium concentrates are in growing demand and where cost reductions are achievable in spent fuel reprocessing, mixed oxide fuel fabrication and waste disposal.

It should be recognized that while economics are an important aspect in decision-making in fuel cycle activities, they are not the only consider ation. Conservation of energy resources, assurance of continuing fuel supply and energy independence all play an important role in such decisions. The reprocessing of spent fuel and the recycle of recovered uranium and plutonium requires only about 63 percent of the uranium concentrates and only about 74 percent of the enrichment services of that required by the "once-through" fuel cycle. Moreover, the availability of plutonium for development, demonstration and initial fuel loadings of breeder reactors is likely to be worth considerably more than the breakeven price of \$20-25/kg plutonium (fissile), discussed earlier in this paper. These factors doubtlessly have contributed to the fact that utilities in several nations have contracted for reprocessing services costing \$600-800/kg uranium compared to the \$283/kg price shown in Tables 2 and 3.