ORNL/FTR--2916

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DATE:	July 12, 1988		
SUBJECT:	Report of Foreign Travel by C. W. Forsberg, Developmental Light Water Reactor Program (ORNL), and P. M. Lang (DOE/NE-42)		
TO:	A. Zucker		
FROM:	C. W. Forsberg		
PURPOSE:	To participate in (1) an IAEA Technical Committee Meeting (TCM) on Definitions and Understandings of Engineered Safety, Passive Safety and Related Terms; and (2) an IAEA International Working Group (IWG) on Advanced Technologies for Water-Cooled Reactors		
SITES VISITED:	5/30-6/3/88	IAEA/TCM and ABB-Atom Västerås, Sweden	T. Pedersen
	6/6-10/88	IAEA/IWG and IVO Helsinki, Finland	E. Aalto

ABSTRACT: The travelers participated in multiple International Atomic Energy Agency (IAEA) meetings on technologies for water-cooled reactors. At the Technical Committee Meeting, the travelers presented papers and worked with the committee to develop internationally agreed-upon definitions and understandings of safety terms for advanced reactors. At the International Working Group Meeting, the travelers worked with the group to plan future IAEA meetings on advanced water-cooled reactor technology. The meetings provided information on the direction and scope of foreign advanced and developmental water-cooled reactor research programs. In particular, a better understanding of the programs in Sweden, Canada, Italy, and Japan was obtained. Work in Canada at Chalk River on a developmental Candu reactor may be applicable in the United States for a developmental light-water reactor.

I. IAEA Technical Committee Meeting on "Definition and Understanding of Engineered Safety, Passive Safety and Related Terms," Västerås, Sweden, May 30-June 2, 1988

P. M. Lang and C. W. Forsberg attended and presented papers, both of which were well received. Copies of meeting papers obtained are available upon request from the travelers. A summary of the meeting is included below (Section A), as are initial definitions of key technical terms drafted as a group by the participants (section B). The remaining sections describe plant visits.

The goal of the meeting was to develop common international understandings and definitions of those safety terms considered desirable objectives for advanced water-cooled reactors. This provides a common starting point for understanding the relative strengths and weaknesses of various new approaches to enhancing reactor safety. The Technical Committee Meeting (TCM) had 25 participants from 12 countries and the IAEA.

A. Summary of Meeting Proceedings

The TCM was hosted by ABB Atom. The participants presented 13 papers related to the subjects of the meeting. Tor Pedersen of Sweden (ABB Atom) was chosen as the chairman.

The meeting was officially opened via a welcoming address by the President of ABB Atom, Mr. Fogelström, who briefly reviewed Swedish accomplishments, discussed the political complications facing nuclear power in Sweden, and expressed his best wishes for the International Working Group as a whole.

The first two days of the meeting were devoted to a series of oral presentations. The papers, which were presented in alphabetical order by country of origin, provided both understandings/definitions of terms and a perspective on foreign advanced reactor research programs. Many of the authors are involved in advanced reactor programs in their respective countries and used examples from their research to clarify understandings of terms.

The early papers that were presented revealed many conflicting perspectives. The last set of papers (Sweden, United States, and USSR) had somewhat similar understandings of safety terms and thus set the stage for later discussions. The Canadian paper emphasized the need for innovation in both advanced reactor design and the regulation of advanced design. The paper presented by L. Noviello claimed that the political reaction to Chernobyl was most severe in Italy, that the Italian situation parallels that of Shoreham/Seabrook, and that they must therefore establish and demonstrate much higher levels of safety if nuclear energy is to be accepted again. (In the subsequent discussion of terms, Noviello was particularly helpful in sorting out the potential public relations impacts of the various terms and their definitions - a type of impact for which he alone among the many participants appeared to share fully our sensitivity). The Soviet paper reflected the major review of safety philosophy for Soviet water-cooled reactors which is being undertaken.

Following the presentation of papers, the chairman structured discussions of terms by listing each term and all proposed understandings and definitions of it. Each term was then discussed by the entire group until a rough consensus was obtained. Generally, understandings of key terms were similar to those proposed by the United States and Sweden. There was some redundancy, such as the development of separate definitions for "passive components," "passive systems," and "passive features," rather than a single definition of "passive."

The following future IAEA activities are planned in this area:.

1. Each country was requested to comment on the proposed descriptions/definitions of terms generated in this meeting.

2. A small meeting of consultants (five people) will be held in Vienna to draft proposed wording/definitions for each term for broader circulation.

3. Proposed definitions of safety terms will be reviewed by other IAEA working groups, including those on HTGR/LMRs.

4. An IAEA publication of agreed-upon definitions for and understandings of safety terms will ultimately be issued.

B. Description of Key Terms Developed During Meeting (Preliminary/Partial List of Terms)

Terms such as inherently safe reactor (or intrinsically safe reactor) imply, according to the normal perception of the word inherent (or intrinsic), a reactor that is 100% safe. Since 100% safety seems to be impossible to attain for a power-producing reactor, terms of this type are not recommended unless a qualification (e.g, against fire or against core damage) is included so as not to be valid in a general sense.

Some of the terms of principal interest for which understandings were developed are as follows:

1. Active Component*
The functioning of this component depends on an external input such as actuation, on mechanical movement, or on supply of power and, therefore, influences system processes in an active manner.

2. Passive Component*
The functioning of a passive component does not depend on external input. It has no moving parts and, for example, only experiences a change in pressure, temperature, or fluid flow in performing its functions. In addition, certain components whose function is based on irreversible action or change may be assigned to this category.

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*(Slightly simplified from original text): Certain components such as rupture discs, check valves, injectors, and some solid-state electronic devices have characteristics that require special consideration before designation as an active or passive component.

3. Inherent Safety Feature
This term refers to characteristics resulting from the choice of material and design, which ensure that the plant will remain in a safe condition at all times, through the laws of nature only. (A prerequisite is that the original configuration will not change in any situation.)

4. Passive System
A passive system is composed of passive components and structures.

5. Passive Safety Feature
This function is achieved by means of passive components or systems.
The total list of terms discussed is available from the travelers.

C. Tour of ABB-Atom Research Laboratories

A half-day tour of the ABB-Atom facilities in Västerås, Sweden, was provided as part of the TCM. The tour included the LWR Service Center and the Atle Test Rig.

The LWR Service Center displayed a full-scale reactor hall mockup, including the refueling bridge, a 105° section of the reactor pressure vessel, pipe nozzles, instrumentation, control-rod guide tubes, recirculation pumps, and related equipment. The facility is used for training in reactor maintenance and refueling operations, along with certain types of research and development. The facility is an impressive, well-equipped training center.

The tour also included the Atle Test Rig, which is a full-height, thermal hydraulic test rig to verify the Rigel computer code. The Rigel computer code is used to simulate the operation of light-water reactors of the PIUS (passively safe) type. The facility design pressure is 2.5 MPa, with a design temperature of 225°C. The reactor core is simulated by electrically heated fuel elements, with a maximum power output of 2.5 MW(t). The power supply delivers up to 40,000 A to the simulated fuel bundles. It is estimated that such a test facility would cost $10 million to 20 million in the United States. The test program to provide experimental data for code verification has been completed, and the facility is currently on standby.

D. Plant Tour of Forsmark Nuclear Power Plant Complex

On the day after the TCM (June 3), a one-day tour of the Forsmark Nuclear Complex was arranged. This facility includes three boiling-water reactors (BWRs) (970, 963, and 1068 MWe) and the Swedish disposal facility for low- and intermediate-level radioactive wastes.

The group toured Forsmark Nuclear Power Plant, Unit 3, which is a 1068-MWe BWR designed by ABB Atom. This unit has many of the characteristics of the Advanced Boiling Water Reactor, including internal recirculation pumps and fine motion control rods. The plant is operated by a staff of 150 people, which includes seven operating shifts of seven people per shift. An additional 600 to 800 people are needed during the annual outage. The most notable characteristics of the operations were as follows:

- Plant availability has ranged between 89 and 92%.

- Plant capacity factors have been near 75%. Due to unique conditions, Swedish power plants coast down for two to three months before refueling. The Swedish grid has surplus hydroelectric power that makes this the preferred operating mode.

- The plant control room is adjacent to the job assignment room to ensure close coordination of maintenance and operations.

- The plant has a very spacious layout with large floor areas reserved for maintenance operations.

- The plant is kept exceptionally clean.

The group toured the Filtra vented containment system building at Forsmark Nuclear Power Plant, Unit 1. This facility is currently under construction and will become operational later this year. All Swedish reactors will have vented containments by the end of the calendar year. Upon containment overpressure, the system depressurizes containment via rupture discs, scrubs and filters the off-gas, and releases it to the atmosphere. The system consists of water venturi scrubbers followed by a rock-bed filter.

The group toured the Slutförvar for reaktoravfall-SFR, which is the disposal site for Swedish low- and intermediate-level wastes. It consists of a series of large underground caverns (20 x 19 x 160 m) and silos (69 x 30 m) under the Baltic Sea and is connected to the mainland by a tunnel. This facility opened in early 1988 and appears to be the most modern of its type in the world. The most notable features were as follows:

- The facility is very large. The bus used to transport us to Forsmark from Västerås was also used to tour the underground facilities.

- The standard low-level waste shipping package weighs 110 tons. The shipping package weight and handling characteristics match those of Swedish spent fuel shipping casks. This allows the same transport ship and handling equipment to be used for both low-level waste and spent fuel.

- All wastes (low-level and spent fuel) are transported from reactors to storage or disposal sites by ship. This eliminates public concerns about the use of railroads and highways.

- The decision for an undersea disposal site is based partly on environmental concerns. The only leakage path for wastes to the environment is by movement of groundwater. A hydraulic gradient must be present in order for groundwater to move. There is no hydraulic gradient for groundwater under the ocean; hence, no leakage of radionuclides from the disposal site.

II. IAEA International Working Group on Advanced Technologies for Water-Cooled Reactors, Helsinki, Finland, June 6-9, 1988

P. M. Lang as a delegate, and C. W. Forsberg, as an observer, were the U.S. attendees of the meeting, whose purpose was to plan future IAEA activities on advanced technologies for water-cooled reactors. John Taylor, of the Electric Power Research Institute (EPRI), was also present as an observer of OECD/NEA, for which he chairs a comparable group. The U.S. attendees worked to develop a program that could be mutually beneficial to the United States and the IAEA. The meeting had three major components: reports on member nation activities (Section A), planning of new IAEA activities (Section B), and a tour of the Loviisa Power Plant (Section C).

A. Reports on Member Nation Activities

Some highlights of reports by member nations are described below. Copies of papers and/or handouts are available from the travelers upon request.

Canada

Canada has two advanced reactor programs: (1) for an advanced, evolutionary Candu reactor in the mid-1990s, and (2) for a passively safe, developmental Candu reactor in the 2000-2020 time frame. The second activity being carried out is under the supervision of J. Lipsett, of the Chalk River Laboratory, with a two- to three-man equivalent level of effort.

China (Peoples Republic)

Discussions and studies are under way in China on the Swedish PIUS reactor for district heating as well as for an indigenous 600-MW(e) APWR with enhanced passive safety.

Japan

A Japanese developmental LWR program, has been initiated under Y. Kaneko, and includes five people at JAERI plus additional individuals at the University of Tokyo. The JAERI effort cooperates in some activities with the University of Tokyo but is separate from the University of Tokyo effort on Developmental LWRs.

Sweden

Filter-vented containments will be required of all reactors by December 1988. Work on Secure P (PIUS) reactor continues; the capital cost per kilowatt for the 600-MW(e) Secure P equals that for the 700-MW(e) ABB Atom BWR, about $1950/kW(e).

USSR

The USSR is conducting a major review of reactor safety. The following statistics were quoted for the Soviet VVER-1000: 160,000 new drawings and 6000 new typewritten pages of experimental and theoretical verification of safety. The significance of these numbers is uncertain.

Italy

As a result of Chernobyl, there has been a parliamentary decision that existing reactors are not suitable for Italy. Simultaneously, a decision was made to start an effort for reactors of greatly enhanced safety. The utility, which is government-controlled, has initiated a 5-year program to identify and justify the next reactor and gain Preliminary Design Approval.

Italian requirements for the next reactor include no evacuation required after an accident (reactor/containment can withstand core meltdown) and hence no need for emergency planning, no potential for land contamination, and no significant radioactivity release.

Under Italian conditions, nuclear power's competition is a gas-fired plant with an electric generation cost of 12¢/kWh. Any nuclear plant that is acceptable is likely to be very economical compared to this alternative. (Note: under Italian conditions, coal plants require NO_x/SO_x removal.)

B. Planning of New IAEA Activities

The primary purpose of this meeting was to plan future activities for the IAEA International Working Group on Advanced Technologies for Water-Cooled Reactors. The principal activity considered was the conduct of TCMs. Mr. E. Aalto (Finland), the meeting chairman, first requested proposals from the floor for future activities. Twenty-two proposals for TMCs were made and discussed. Following this discussion, the chairman requested that each country prepare a list of its priorities among the proposals.

The travelers prepared a list after soliciting the input of John Taylor (EPRI). The U.S. general perspective was that: (1) future technical meetings should concentrate on passive and inherent safety systems for water-cooled reactors and (2) the number of meetings per year should be limited to two. The reason for limiting the number of meetings was to ensure that resources of the participating countries would be available to make each meeting productive and successful.

After each country had prepared its list of priorities, the chairman tabulated the results. There was a general consensus for most of the proposed meetings. However, there were special circumstances, disagreements, and/or extended discussions in the following three areas:

1. Japan proposed that IWG planning meetings (such as this one) be held annually rather than every two years. Part of their rationale for annual meetings was to obtain more up-to-date reviews of the various national programs. Our perspective (and that of almost all of the other participants) was that annual planning meetings would be excessive in relationship to the level of IAEA activities and that national programs do not usually change significantly over a one-year period. After extensive discussion, it was decided to have planning meetings only every two years (as is the current policy).

2. The IWG covers all water-cooled reactors–light water and heavy-water reactors. Nations at the meeting which have heavy-water reactors supported a meeting on Advanced Technologies for Heavy-Water Reactors. It may be of value to have someone from the United States attend this meeting since some advanced heavy-water design concepts are applicable to advanced light-water reactors.

3. The third area of discussion was a proposal for a technical meeting on high conversion (tight lattice) water cooled reactors. We believed that such a meeting

was unnecessary because of: (a) related activities by NEA, (b) limited interest from only three countries–Japan/West Germany/France, and (c) a comprehensive meeting on this subject that was held by IAEA in 1984 at which the consensus seemed to be that these types of reactors were unlikely to be economic. The agency decided to schedule this meeting, however, no country volunteered to host it.

The last item of business involved discussion of a proposed coordinated research program on physical properties used for thermal hydraulic analysis of water-cooled reactors in and for various computer codes. This activity aroused little enthusiasm, but the agency tentatively decided to proceed with it in the absence of opposition.

After completion of the discussions by the International Working Group, the following future meetings were scheduled:

<u>1988</u>

1. Consultant's Meeting on Passive Safety
   (small meeting to draft a document on definitions and understandings of safety terms derived at Västerås, Sweden, meeting)
2. Technical Committee Meeting on Advanced Technologies for Heavy-Water Reactors (Montreal, Canada; December)

<u>1989</u>

3. Technical Committee Meeting on Passive Safety Features for Water-Cooled Reactors (USSR, first quarter)
4. Technical Committee Meeting on Design Requirements for Advanced Reactors (China, September/October)
5. Technical Committee Meeting on High Conversion Reactors (site not determined; November/December)

<u>1990</u>

6. International Working Group Meeting on Advanced Technologies for Water Cooled Reactors (Planning Meeting) (Vienna, May)
7. Technical Committee Meeting on Design Aspects for Advanced Water Reactors (Italy, second Quarter)
8. Technical Committee Meeting on Shortening Construction Times for Advanced Reactors (Finland, August)

<u>1991</u>

9. Technical Committee Meeting on Inherent Safety Features for Future Water Cooled Reactors
10. Technical Committee Meeting on Process and District Heating Reactors

The last three meetings remain highly tentative since priorities will be reassessed and new meetings will be scheduled at the IWG meeting in May 1990.

Finally, Italy, which was present only as an observer, was accepted as a member of the IWGATWR. The United Kingdom continues to be invited to the meeting but has not participated thus far.

C. Tour of Loviisa Power Plant

A tour of the Loviisa Power Plant following the meeting was arranged. The power plant consists of two Soviet-built PWRs, each with a rating of 445 MWe. Each reactor has six horizontal steam generators and two turbines. Nuclear fuel is supplied by the Soviets, and spent fuel is returned to the USSR. The contract with the USSR specifies payment for each unit of energy obtained from the fuel. Because of this provision, there is no incentive to consider extended-burnup fuel for these reactors or other design or operating changes that might reduce fuel cycle costs. The Finnish utility added a Westinghouse ice containment to the design to meet Finnish safety requirements. The following observations were made:

1. The station has the world record for plant availability for units on annual refueling cycles. Plant capacity factors are typically in the low 90s.
2. Typical once-a-year refueling outages last about 20 d.
3. The two units are refueled sequentially–one right after the other (July/August).
4. The steam generator experience is excellent; no steam generator tubes have leaked or become plugged in the history of the plant. This excellent performance has been attributed to the use of horizontal steam generators. (It is unclear as to why horizontal steam generators have not been considered in the west.) Part of the excellent performance can be attributed to the use of stainless steel support plates, which eliminates denting of tubes. Plant Manager Helske believes that his steam generators will last the lifetime of the plant but that all vertical steam generators in other nuclear plants will eventually require replacement.

APPENDIX A. ITINERARY

P. Lang (DOE/NE-42)

May 24, 1988	Travel to Vienna, Austria
May 25-28, 1988	Fuel Cycle Meeting at IAEA
May 28-29, 1988	Travel to Västerås, Sweden

C. W. Forsberg (ORNL)

May 27-29, 1988	Travel to Västerås, Sweden

P. Lang and C. W. Forsberg

May 30 - June 2, 1988	IAEA Committee Meeting on Engineered Safety, Passive Safety and Related Terms, Västerås, Sweden
June 2, 1988	Tour of ABB-Atom Laboratories, Västerås, Sweden
June 3, 1988	Tour of Forsmark Nuclear Power Station and Waste Complex, Forsmark, Sweden
June 4-5, 1988	Travel to Helsinki, Finland
June 6-9, 1988	IAEA International Working Group on Advanced Technologies for Water-Cooled Reactors
June 10, 1988	Tour of Loviisa Nuclear Power Station, Loviisa, Finland
June 11-12, 1988	Return to United States

APPENDIX B. PERSONS CONTACTED

[Note: Multiple meetings were held with the same participants in many cases. Locations of meetings are identified by abbreviations: S, Sweden; and F, Finland.]

Argentina	
Mr. H. M. Antunez Commission Hacional de Energia Atomica	F
Mr. R. Touzet Commission Hacional de Energia Atomica	S
Canada	
Mr. J. J. Lipsett Atomic Energy of Canada, Ltd. (Chalk River)	S, F
China	
Mr. W. Shen Ministry of Nuclear Industry	F
Mr. S. Zhang South-West Center of Reactor Engineering	F
Finland	
Mr. E. Aalto Imatran Voima Oy	F
Mr. A. Rastas Teollisuuden Voima Oy	F
Mr. B. Mohsen Imatran Voima Oy	S
Mr. Seppo Koski Teollisuuden Voima Oy	S
France	
Mr. Y. Dennielou EDF	S, F
Mr. J. L. Nigon CEA (Cadarauhe)	F
Federal Republic of Germany	
Mr. P. J. Meyer KWU	S, F
India	
Mr. C. Surendar	F
Mr. V. Raj	S

Italy		
	Mr. L. Noviello ENEL	S, F
	Mr. I. Tripputi ENEL	F
Japan		
	Mr. Y. Kaneko JAERI	S, F
	Mr. W. Mizumachi Toshiba Corporation	F
	Mr. T. Miwa Nuclear Power Engineering Test Center	F
	Mr. Y. Tatsuta MITI	F
	Mr. M. Aritomi Tokyo Institute of Technology	S
	Ms. K. Tominaga Nuclear Power Engineering Test Center	S
Sweden		
	T. Pedersen ABB Atom	S, F
	K. Hannerz ABB Atom	S
USSR		
	Mr. V. G. Fedorov	F
	Mr. G. V. Pleschanov	F
	Mr. V. A. Vozesensky	S, F
	Mr. V. V. Stekolnikov	S
	Mr. V. Y. Egorov	S
	Mr. S. A. Tchurilin	S
	Mr. M. V. Nikitin	S
NEA (Paris)		
	Mr. G. Stevens	F
	Mr. J. Taylor (also EPRI)	F

IAEA	
Mr. J. Kupitz	S, F
Mrs. W. Sheng	S, F
M. J. Fischer	S, F

APPENDIX C

Literature Acquired

Literature from Technical Committee Meeting on Definitions and Understandings of Engineered Safety, Passive Safety and Related Terms (Västerås, Sweden) - Papers

1. R. Touzet (Argentina) Development of Safety Terms for Both Qualitative Understanding and a Quantitative Application.
2. J. J. Lipsett (Canada), Advanced Reactor Concepts and Safety.
3. Z. Senru (China), Safety Category and Inherent Safety for Water Cooled Reactors.
4. P. J. Meyer (West Germany), Thoughts about Safety Concepts and Definitions of Safety Terms in the Federal Republic of Germany.
5. V. V. Raj (India), Definitions of Terms Related to Nuclear Reactor Safety and Some Discussions on Passive Cooling of Reactor Core Under Certain Operational States.
6. M. Aritomi and K. Tominaga (Japan), Definitions of Safety Related Terms.
7. L. Noviello and S. Reynaud (Italy), Definitions for New Safety Features and Their Consequences.
8. T. Pedersen and T. Öhlin (Sweden), Passive Safety versus Traditional Safety Concepts, Goals, Potentials, and Implications.
9. T. Pedersen (Sweden), A Note of Basic Assumptions to Underlie "Next Generation" Reactor Safety.
10. V. A. Voznesensky and V. G. Fyodorov (USSR), Basic Theses and Terms of Concepts of Light-Water Reactors with Improved Safety in the USSR.
11. C. W. Forsberg (USA), Implications of Passive Safety Based on Historical Industrial Experience.
12. P. Lang (USA), Definitions and Usages of Terms Implying Highly Desirable Nuclear Safety Characteristics.
13. T. Pedersen (Sweden), Discussions of Suggested Definitions of Terms Describing Passive Safety.
14. ABB Atom, PIUS 600.

Literature from Tour of ABB Laboratories and Forsmark Nuclear Power Complex

15. Asea Atom, LWR Service Center.

16. Asea Atom, The Atle Test Rig (PIUS Hydraulic Test Rig).

17. ASEA Atom, The Magne Demonstration Rig.

18. ABB Atom, Nuclear Waste Management Technology Products and Services.

19. ABB Atom, Annual Report 1987.

20. Karnkraftsakerhet och Utbildning Ab, Summary of Operating Experience at Swedish Nuclear Power Stations, 1987 (Feb. 1988).

21. ASEA Atom, Forsmark Nuclear Power Plant Unit 3.

22. SKB, Swedish Nuclear Fuel and Waste Management Company Activities.

23. SKB, M/S Sigyn.

Papers from IAEA International Working Group on
Advanced Technologies for Water Cooled Reactors

24. W. Shen et al., Research Work About APWR of China in 1987.

25. E. Aalto and B. A. Rastas, Status Report on Light Water Reactor Development in Finland (June 6, 1988).

26. Y. Dennielou et al., France Work in Progress in 1988.

27. C. Surendar, Indian PHWR Nuclear Power Program - A Report.

28. Y. Kaneko et al., Present Conditions of Water Reactor Technology Sophistication Programme in Japan (June 6-9, 1988).

29. T. Pedersen, Recent Swedish Achievements Related to Advanced Technologies for Water Cooled Reactors (June 6-9, 1988).

30. V. Fedorov and V. Voznesenski, Progress Report (USSR) (June 6-9, 1988).

31. C. Forsberg, Overview of United States Current and Planned Activities in Passive Safety Research and Development.

32. P. Adelfang et al., Programs on Advanced Fuel Cycles in the Argentina PHWRs.

Literature from Tour of Loviisa Power Station

33. Imatran Voima Oy, Loviisa Power Plant.

34. Imatran Voima Oy, Energy Innovation R&D 1987.

35. Imatran Voima Oy, Annual Report 1987.

36. Imatran Voima Oy, Reliability, Economy, Efficiency in Energy.

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(12-84)

United States Government | Department of Energy

memorandum

DATE: JUL 1 8 1988

REPLY TO
ATTN OF: NE-42

SUBJECT: Trip Report on Three International Atomic Energy Agency (IAEA) Meetings, May 23 - June 11, 1988

TO: Theodore J. Garrish
Assistant Secretary for Nuclear Energy

1. Summary

a. Name of Travelers: Peter M. Lang
Office of LWR Safety & Technology
Office of Reactor Deployment
Office of Nuclear Energy

Charles W. Forsberg
Chemical Technology Division
Oak Ridge National Laboratory

b.

Date	Installation & Purpose	City	Country	Participants
5/25-27	IAEA Advisory Group Meeting on Incentives for LWR Fuel Improvements	Vienna	Austria	Lang
5/29-6/3	ABB-Atom Technical Comm. Mtg. on Definition/Understanding of Safety Terms	Vasteras	Sweden	Lang, Forsberg
6/6-6/10	Imatran Voima Oy International Working Group on Advanced Technologies for Water Reactors	Helsinki	Finland	Lang, Forsberg

c. Abstract

The travelers participated in multiple IAEA meetings on fuel improvements and advanced technologies for light water reactors. The meeting in Vienna was a planning meeting to determine what should be done in an Agency-proposed study of many possible improvements to LWR fuel to improve its economics, reliability, and uranium utilization. The scope of reasonable improvements to be studied as recommended by the advisors was much smaller than Agency expectations; our future participation in this study may need to be re-examined after the Agency decides precisely what it hopes to accomplish.

At the Technical Committee Meeting in Sweden, the travelers presented papers and worked with the other participants to develop internationally agreed upon understandings and definitions of safety terms for advanced reactors. At the International Working Group Meeting, the travelers worked with the group to plan future IAEA activities, principally meetings, on advanced water cooled reactor technology.

The meetings provided an update of the directions and scope of foreign advanced and developmental water cooled reactor and fuel programs. In particular, a better understanding of the programs in Sweden, Canada, Italy, and the USSR was obtained. At each meeting, U.S. perspectives were presented, U.S. desires and positions were effectively represented, and Agency decisions and future activities were influenced accordingly.

Peter M. Lang
U.S. Delegate to the International Working Group on Advanced Technologies for Water Cooled Reactors
and
U.S. Delegate to the International Working Group on Water Reactor Fuel Performance and Technology

for Charles W. Forsberg
Chemical Technology Division
Oak Ridge National Laboratory

3 Attachments
Summaries of Each Meeting

cc:
D. B. Waller, IE-1
J. G. Coyne, MA-28, OR
D. F. Bunch, NE-2
C. [illegible] Ebbecke, NE-10
S. Rosen/C. Weber, NE-14
D. F. Giessing, NE-42
J. L. Langford, ORNL Distribution
D. J. McGoff, NE-40

Advisory Group Meeting on Incentives for Improvements in the Design and Utilization of Nuclear Fuel in Light Water Reactors, Vienna, Austria, May 25-27, 1988

The subject meeting was called by the IAEA's Nuclear Fuel Cycle Division (Mr. Vladimir Onufriev, Responsible Officer) to determine whether and how the Agency should initiate a "study" in this area, and in particular, which specific improvements should be studied. I attended at IAEA invitation and expense. The meeting was attended by 19 delegates from 11 countries and two international organizations (CEC and OECD/NEA). In preparation for the meeting, the IAEA had prepared a detailed proposal listing and discussing a vast range of proposed fuel improvements, including (A) many already developed and commercialized in the United States, (B) many "dead horses" which have been repeatedly proposed, studied, and discarded over the last 10 years, and (C) plutonium fuel, the economics of which is well known internationally to be inferior and which in addition is burdened by nonproliferation policy concerns when promoted in the very broad context of the many IAEA member states. No source of funding for these studies had been identified by the IAEA; presumably the member countries participating in this activity would have to provide all the technical work cost-free to the Agency. Furthermore, the current IAEA proposal appeared to be written in ignorance of the very similar INFCE work carried out in the 1978-1980 time period with comprehensive Agency involvement and assistance; it referred instead to more recent OECD/NEA fuel cycle economic studies that I had reviewed in detail and found unsatisfactory, as they appeared to be aimed mainly at justification of plutonium cycles and included no objective evaluation of fuel improvements.

Fortunately, prior to the Vienna meeting, I had the opportunity to meet with Mr. Onufriev at the ANS International Topical Meeting on LWR Fuel in Williamsbug, VA, in April. I spent about two hours with him in a detailed discussion of the 11 questions on the attached list, a copy of which was provided to him. Also provided to him was a copy of our 1978 INFCE Working Group 8 paper on LWR Fuel Improvements, on the assumption (which later proved correct) that this document could no longer be located in the IAEA files. During that discussion his approach was generally constructive and cooperative; this served to avoid overly extensive discussion of some of the more difficult issues (use of the OECD/NEA studies as a basis, safety as a criterion for fuel improvements, inclusion of fabrication improvement, and inclusion of plutonium fuel) at the full meeting in Vienna.

After the usual opening remarks welcoming participants by Mr. Zhu (Director, Nuclear Fuel Cycle Division), Mr. Onufriev gave a brief technical introduction to the meeting, during which he emphasized that we should not consider already commercialized "improvements" such as, for example, plutonium recycle fuel. During this introduction, he showed the master table summarizing the potential improvements from our 1978 INFCE paper as well as a newer but different-in-format summary table of recent fuel development trends prepared by A. Strasser (of S. M. Stoller Corporation) and presented at the 1986 Stockholm Symposium conducted by the

Furthermore, the delegate from Czechoslovakia (who may reflect the Soviet Union's position) indicated a desire to participate in the study but stated that it would be necessary to limit their contribution for VVERs to the range of burnup extensions already accepted for commercialization in the U.S. and Western Europe, rather than to contribute results for the considerably higher burnups now of interest. In view of these difficulties and the upcoming discontinuity in Agency leadership, our participation in this study will probably need to be re-examined in the light of more precise knowledge of the Agency's intentions, during or after the next scheduled meeting.

ISSUES FOR DISCUSSION RELATIVE TO PROPOSED IAEA STUDY "INCENTIVES FOR IMPROVEMENTS IN THE DESIGN AND UTILIZATION OF NUCLEAR FUEL IN LIGHT WATER REACTORS"

1. Source of funding for new studies; use of existing or new national studies.

2. The extent to which recent OECD/NEA studies can or should be used as a basis for the proposed IAEA work.

3. Possible use of INFCE work, as most of the proposed work was done then. Availability of INFCE Working Group 8 working papers, particularly the detailed individual submissions by participating countries, rather than the summary report. The question within INFCE on the international use and acceptance of nuclear fuel cycle costs, vs. the argument that these are nation-specific and not very meaningful for international studies. Technical progress (if any) since INFCE and its implications on what improvements should (and should not) be studied now.

4. Selection of valid, up-to-date, base cases for comparison.

5. Use of present unit costs vs. projections for distant future.

6. Avoidance (or detailed discussion and correction) of statements about utility and fuel supplier incentives for fuel improvements, as these are country-specific, depending on institutional structures in each country.

7. Possible consensus for elimination of certain issues virtually unaffected by fuel design (within the range of parameters under consideration), such as safety, waste management, load following capability.

8. Critical winnowing of list of proposed improvements to eliminate those already coming into widespread use, those already studied in depth and discarded, perennial proposals that have never been deemed practical, etc. so as to focus only on practical but still unimplemented improvements.

9. Need for separate consideration of improvements for PWRs, BWRs.

10. Feasibility of inclusion of potential fabrication improvements, given the company proprietary nature of fabrication.

11. Reprocessing/recycle; should IAEA lend itself to the promotion of these technologies which have been found commercially uneconomic (even within those countries implementing them for various policy reasons) in view of nonproliferation concerns?

IAEA Technical Committee Meeting on "Definition and Understanding of Engineered Safety, Passive Safety and Related Terms," Västerås, Sweden, May 30-June 2, 1988

P. M. Lang and C. W. Forsberg attended and presented papers, both of which were well received. Copies of meeting papers obtained are available upon request from the travelers. A summary of the meeting is included below (Section A), as are initial definitions of key technical terms drafted as a group by the participants (section B). The remaining sections describe plant visits.

The goal of the meeting was to develop common international understandings and definitions of those safety terms considered desirable objectives for advanced water-cooled reactors. This provides a common starting point for understanding the relative strengths and weaknesses of various new approaches to enhancing reactor safety. The Technical Committee Meeting (TCM) had 25 participants from 12 countries and the IAEA.

A. Summary of Meeting Proceedings

The TCM was hosted by ABB Atom. The participants presented 13 papers related to the subjects of the meeting. Tor Pedersen of Sweden (ABB Atom) was chosen as the chairman.

The meeting was officially opened via a welcoming address by the President of ABB Atom, Mr. Fogelström, who briefly reviewed Swedish accomplishments, discussed the political complications facing nuclear power in Sweden, and expressed his best wishes for the International Working Group as a whole.

The first two days of the meeting were devoted to a series of oral presentations. The papers, which were presented in alphabetical order by country of origin, provided both understandings/definitions of terms and a perspective on foreign advanced reactor research programs. Many of the authors are involved in advanced reactor programs in their respective countries and used examples from their research to clarify understandings of terms.

The early papers that were presented revealed many conflicting perspectives. The last set of papers (Sweden, United States, and USSR) had somewhat similar understandings of safety terms and thus set the stage for later discussions. The Canadian paper emphasized the need for innovation in both advanced reactor design and the regulation of advanced design. The paper presented by L. Noviello claimed that the political reaction to Chernobyl was most severe in Italy, that the Italian situation parallels that of Shoreham/Seabrook, and that they must therefore establish and demonstrate much higher levels of safety if nuclear energy is to be accepted again. (In the subsequent discussion of terms, Noviello was particularly helpful in sorting out the potential public relations impacts of the various terms and their definitions - a type of impact for which he alone among the many participants appeared to share fully our sensitivity). The Soviet paper reflected the major review of safety philosophy for Soviet water-cooled reactors which is being undertaken.

Following the presentation of papers, the chairman structured discussions of terms by listing each term and all proposed understandings and definitions of it. Each term was then discussed by the entire group until a rough consensus was obtained. Generally, understandings of key terms were similar to those proposed by the United States and Sweden. There was some redundancy, such as the development of separate definitions for "passive components," "passive systems," and "passive features," rather than a single definition of "passive."

The following future IAEA activities are planned in this area:.

1. Each country was requested to comment on the proposed descriptions/definitions of terms generated in this meeting.

2. A small meeting of consultants (five people) will be held in Vienna to draft proposed wording/definitions for each term for broader circulation.

3. Proposed definitions of safety terms will be reviewed by other IAEA working groups, including those on HTGR/LMRs.

4. An IAEA publication of agreed-upon definitions for and understandings of safety terms will ultimately be issued.

B. Description of Key Terms Developed During Meeting (Preliminary/Partial List of Terms)

Terms such as <u>inherently safe reactor</u> (or intrinsically safe reactor) imply, according to the normal perception of the word inherent (or intrinsic), a reactor that is 100% safe. Since 100% safety seems to be impossible to attain for a power-producing reactor, terms of this type are not recommended unless a qualification (e.g, against fire or against core damage) is included so as not to be valid in a general sense.

Some of the terms of principal interest for which understandings were developed are as follows:

1. <u>Active Component*</u>
   The functioning of this component depends on an external input such as actuation, on mechanical movement, or on supply of power and, therefore, influences system processes in an active manner.

2. <u>Passive Component*</u>
   The functioning of a passive component does not depend on external input. It has no moving parts and, for example, only experiences a change in pressure, temperature, or fluid flow in performing its functions. In addition, certain components whose function is based on irreversible action or change may be assigned to this category.

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*(Slightly simplified from original text): Certain components such as rupture discs, check valves, injectors, and some solid-state electronic devices have characteristics that require special consideration before designation as an active or passive component.

- Plant capacity factors have been near 75%. Due to unique conditions, Swedish power plants coast down for two to three months before refueling. The Swedish grid has surplus hydroelectric power that makes this the preferred operating mode.

- The plant control room is adjacent to the job assignment room to ensure close coordination of maintenance and operations.

- The plant has a very spacious layout with large floor areas reserved for maintenance operations.

- The plant is kept exceptionally clean.

The group toured the Filtra vented containment system building at Forsmark Nuclear Power Plant, Unit 1. This facility is currently under construction and will become operational later this year. All Swedish reactors will have vented containments by the end of the calendar year. Upon containment overpressure, the system depressurizes containment via rupture discs, scrubs and filters the off-gas, and releases it to the atmosphere. The system consists of water venturi scrubbers followed by a rock-bed filter.

The group toured the Slutförvar for reaktoravfall-SFR, which is the disposal site for Swedish low- and intermediate-level wastes. It consists of a series of large underground caverns (20 x 19 x 160 m) and silos (69 x 30 m) under the Baltic Sea and is connected to the mainland by a tunnel. This facility opened in early 1988 and appears to be the most modern of its type in the world. The most notable features were as follows:

- The facility is very large. The bus used to transport us to Forsmark from Västerås was also used to tour the underground facilities.

- The standard low-level waste shipping package weighs 110 tons. The shipping package weight and handling characteristics match those of Swedish spent fuel shipping casks. This allows the same transport ship and handling equipment to be used for both low-level waste and spent fuel.

- All wastes (low-level and spent fuel) are transported from reactors to storage or disposal sites by ship. This eliminates public concerns about the use of railroads and highways.

- The decision for an undersea disposal site is based partly on environmental concerns. The only leakage path for wastes to the environment is by movement of groundwater. A hydraulic gradient must be present in order for groundwater to move. There is no hydraulic gradient for groundwater under the ocean; hence, no leakage of radionuclides from the disposal site.

IAEA International Working Group on Advanced Technologies for Water-Cooled Reactors, Helsinki, Finland, June 6-9, 1988

P. M. Lang as a delegate, and C. W. Forsberg, as an observer, were the U.S. attendees of the meeting, whose purpose was to plan future IAEA activities on advanced technologies for water-cooled reactors. John Taylor, of the Electric Power Research Institute (EPRI), was also present as an observer of OECD/NEA, for which he chairs a comparable group. The U.S. attendees worked to develop a program that could be mutually beneficial to the United States and the IAEA. The meeting had three major components: reports on member nation activities (Section A), planning of new IAEA activities (Section B), and a tour of the Loviisa Power Plant (Section C).

A. Reports on Member Nation Activities

Some highlights of reports by member nations are described below. Copies of papers and/or handouts are available from the travelers upon request.

Canada

Canada has two advanced reactor programs: (1) for an advanced, evolutionary Candu reactor in the mid-1990s, and (2) for a passively safe, developmental Candu reactor in the 2000-2020 time frame. The second activity being carried out is under the supervision of J. Lipsett, of the Chalk River Laboratory, with a two- to three-man equivalent level of effort.

China (Peoples Republic)

Discussions and studies are under way in China on the Swedish PIUS reactor for district heating as well as for an indigenous 600-MW(e) APWR with enhanced passive safety.

Japan

A Japanese developmental LWR program, has been initiated under Y. Kaneko, and includes five people at JAERI plus additional individuals at the University of Tokyo. The JAERI effort cooperates in some activities with the University of Tokyo but is separate from the University of Tokyo effort on Developmental LWRs.

Sweden

Filter-vented containments will be required of all reactors by December 1988. Work on Secure P (PIUS) reactor continues; the capital cost per kilowatt for the 600-MW(e) Secure P equals that for the 700-MW(e) ABB Atom BWR, about $1950/kW(e).

USSR

The USSR is conducting a major review of reactor safety. The following statistics were quoted for the Soviet VVER-1000: 160,000 new drawings and 6000 new typewritten pages of experimental and theoretical verification of safety. The significance of these numbers is uncertain.

Italy

As a result of Chernobyl, there has been a parliamentary decision that existing reactors are not suitable for Italy. Simultaneously, a decision was made to start an effort for reactors of greatly enhanced safety. The utility, which is government-controlled, has initiated a 5-year program to identify and justify the next reactor and gain Preliminary Design Approval.

Italian requirements for the next reactor include no evacuation required after an accident (reactor/containment can withstand core meltdown) and hence no need for emergency planning, no potential for land contamination, and no significant radioactivity release.

Under Italian conditions, nuclear power's competition is a gas-fired plant with an electric generation cost of 12¢/kWh. Any nuclear plant that is acceptable is likely to be very economical compared to this alternative. (Note: under Italian conditions, coal plants require NO_x/SO_x removal.)

B. Planning of New IAEA Activities

The primary purpose of this meeting was to plan future activities for the IAEA International Working Group on Advanced Technologies for Water-Cooled Reactors. The principal activity considered was the conduct of TCMs. Mr. E. Aalto (Finland), the meeting chairman, first requested proposals from the floor for future activities. Twenty-two proposals for TMCs were made and discussed. Following this discussion, the chairman requested that each country prepare a list of its priorities among the proposals.

The travelers prepared a list after soliciting the input of John Taylor (EPRI). The U.S. general perspective was that: (1) future technical meetings should concentrate on passive and inherent safety systems for water-cooled reactors and (2) the number of meetings per year should be limited to two. The reason for limiting the number of meetings was to ensure that resources of the participating countries would be available to make each meeting productive and successful.

After each country had prepared its list of priorities, the chairman tabulated the results. There was a general consensus for most of the proposed meetings. However, there were special circumstances, disagreements, and/or extended discussions in the following three areas:

1. Japan proposed that IWG planning meetings (such as this one) be held annually rather than every two years. Part of their rationale for annual meetings was to obtain more up-to-date reviews of the various national programs. Our perspective (and that of almost all of the other participants) was that annual planning meetings would be excessive in relationship to the level of IAEA activities and that national programs do not usually change significantly over a one-year period. After extensive discussion, it was decided to have planning meetings only every two years (as is the current policy).

2. The IWG covers all water-cooled reactors–light water and heavy-water reactors. Nations at the meeting which have heavy-water reactors supported a meeting on Advanced Technologies for Heavy-Water Reactors. It may be of value to have someone from the United States attend this meeting since some advanced heavy-water design concepts are applicable to advanced light-water reactors.

3. The third area of discussion was a proposal for a technical meeting on high conversion (tight lattice) water cooled reactors. We believed that such a meeting

A tour of the Loviisa Power Plant following the meeting was arranged. The power plant consists of two Soviet-built PWRs, each with a rating of 445 MWe. Each reactor has six horizontal steam generators and two turbines. Nuclear fuel is supplied by the Soviets, and spent fuel is returned to the USSR. The contract with the USSR specifies payment for each unit of energy obtained from the fuel. Because of this provision, there is no incentive to consider extended-burnup fuel for these reactors or other design or operating changes that might reduce fuel cycle costs. The Finnish utility added a Westinghouse ice containment to the design to meet Finnish safety requirements. The following observations were made:

1. The station has the world record for plant availability for units on annual refueling cycles. Plant capacity factors are typically in the low 90s.
2. Typical once-a-year refueling outages last about 20 d.
3. The two units are refueled sequentially--one right after the other (July/August).
4. The steam generator experience is excellent; no steam generator tubes have leaked or become plugged in the history of the plant. This excellent performance has been attributed to the use of horizontal steam generators. (It is unclear as to why horizontal steam generators have not been considered in the west.) Part of the excellent performance can be attributed to the use of stainless steel support plates, which eliminates denting of tubes. Plant Manager Helske believes that his steam generators will last the lifetime of the plant but that all vertical steam generators in other nuclear plants will eventually require replacement.

APPENDIX A. ITINERARY

P. Lang (DOE/NE-42)

May 24, 1988	Travel to Vienna, Austria
May 25-28, 1988	Fuel Cycle Meeting at IAEA
May 28-29, 1988	Travel to Västerås, Sweden

C. W. Forsberg (ORNL)

May 27-29, 1988	Travel to Västerås, Sweden

P. Lang and C. W. Forsberg

May 30 - June 2, 1988	IAEA Committee Meeting on Engineered Safety, Passive Safety and Related Terms, Västerås, Sweden
June 2, 1988	Tour of ABB-Atom Laboratories, Västerås, Sweden
June 3, 1988	Tour of Forsmark Nuclear Power Station and Waste Complex, Forsmark, Sweden
June 4-5, 1988	Travel to Helsinki, Finland
June 6-9, 1988	IAEA International Working Group on Advanced Technologies for Water-Cooled Reactors
June 10, 1988	Tour of Loviisa Nuclear Power Station, Loviisa, Finland
June 11-12, 1988	Return to United States

APPENDIX B. PERSONS CONTACTED

[Note: Multiple meetings were held with the same participants in many cases. Locations of meetings are identified by abbreviations: S, Sweden; and F, Finland.]

Argentina		
	Mr. H. M. Antunez Commission Hacional de Energia Atomica	F
	Mr. R. Touzet Commission Hacional de Energia Atomica	S
Canada		
	Mr. J. J. Lipsett Atomic Energy of Canada, Ltd. (Chalk River)	S, F
China		
	Mr. W. Shen Ministry of Nuclear Industry	F
	Mr. S. Zhang South-West Center of Reactor Engineering	F
Finland		
	Mr. E. Aalto Imatran Voima Oy	F
	Mr. A. Rastas Teollisuuden Voima Oy	F
	Mr. B. Mohsen Imatran Voima Oy	S
	Mr. Seppo Koski Teollisuuden Voima Oy	S
France		
	Mr. Y. Dennielou EDF	S, F
	Mr. J. L. Nigon CEA (Cadarauhe)	F
Federal Republic of Germany		
	Mr. P. J. Meyer KWU	S, F
India		
	Mr. C. Surendar	F
	Mr. V. Raj	S

Italy		
	Mr. L. Noviello ENEL	S, F
	Mr. I.Ripputi ENEL	F
Japan		
	Mr. Y. Kaneko JAERI	S, F
	Mr. W. Mizumachi Toshiba Corporation	F
	Mr. T. Miwa Nuclear Power Engineering Test Center	F
	Mr. Y. Tatsuta MITI	F
	Mr. M. Aritomi Tokyo Institute of Technology	S
	Ms. K. Tominaga Nuclear Power Engineering Test Center	S
Sweden		
	T. Pedersen ABB Atom	S, F
	K. Hannerz ABB Atom	S
USSR		
	Mr. V. G. Fedorov	F
	Mr. G. V. Pleschanov	F
	Mr. V. A. Vozesensky	S, F
	Mr. V. V. Stekolnikov	S
	Mr. V. Y. Egorov	S
	Mr. S. A. Tchurilin	S
	Mr. M. V. Nikitin	S
NEA (Paris)		
	Mr. G. Stevens	F
	Mr. J. Taylor (also EPRI)	F

IAEA

Mr. J. Kupitz	S, F
Mrs. W. Sheng	S, F
M. J. Fischer	S, F

APPENDIX C

Literature Acquired

Literature from Technical Committee Meeting on Definitions and Understandings of Engineered Safety, Passive Safety and Related Terms (Västerås, Sweden) - Papers

1. R. Touzet (Argentina) Development of Safety Terms for Both Qualitative Understanding and a Quantitative Application.
2. J. J. Lipsett (Canada), Advanced Reactor Concepts and Safety.
3. Z. Senru (China), Safety Category and Inherent Safety for Water Cooled Reactors.
4. P. J. Meyer (West Germany), Thoughts about Safety Concepts and Definitions of Safety Terms in the Federal Republic of Germany.
5. V. V. Raj (India), Definitions of Terms Related to Nuclear Reactor Safety and Some Discussions on Passive Cooling of Reactor Core Under Certain Operational States.
6. M. Aritomi and K. Tominaga (Japan), Definitions of Safety Related Terms.
7. L. Noviello and S. Reynaud (Italy), Definitions for New Safety Features and Their Consequences.
8. T. Pedersen and T. Öhlin (Sweden), Passive Safety versus Traditional Safety Concepts, Goals, Potentials, and Implications.
9. T. Pedersen (Sweden), A Note of Basic Assumptions to Underlie "Next Generation" Reactor Safety.
10. V. A. Voznesensky and V. G. Fyodorov (USSR), Basic Theses and Terms of Concepts of Light-Water Reactors with Improved Safety in the USSR.
11. C. W. Forsberg (USA), Implications of Passive Safety Based on Historical Industrial Experience.
12. P. Lang (USA), Definitions and Usages of Terms Implying Highly Desirable Nuclear Safety Characteristics.
13. T. Pedersen (Sweden), Discussions of Suggested Definitions of Terms Describing Passive Safety.
14. ABB Atom, PIUS 600.

Literature from Tour of ABB Laboratories and Forsmark Nuclear Power Complex

15. Asea Atom, LWR Service Center.

16. Asea Atom, The Atle Test Rig (PIUS Hydraulic Test Rig).

17. ASEA Atom, The Magne Demonstration Rig.

18. ABB Atom, Nuclear Waste Management Technology Products and Services.

19. ABB Atom, Annual Report 1987.

20. Karnkraftsakerhet och Utbildning Ab, Summary of Operating Experience at Swedish Nuclear Power Stations, 1987 (Feb. 1988).

21. ASEA Atom, Forsmark Nuclear Power Plant Unit 3.

22. SKB, Swedish Nuclear Fuel and Waste Management Company Activities.

23. SKB, M/S Sigyn.

Papers from IAEA International Working Group on
Advanced Technologies for Water Cooled Reactors

24. W. Shen et al., Research Work About APWR of China in 1987.

25. E. Aalto and B. A. Rastas, Status Report on Light Water Reactor Development in Finland (June 6, 1988).

26. Y. Dennielou et al., France Work in Progress in 1988.

27. C. Surendar, Indian PHWR Nuclear Power Program - A Report.

28. Y. Kaneko et al., Present Conditions of Water Reactor Technology Sophistication Programme in Japan (June 6-9, 1988).

29. T. Pedersen, Recent Swedish Achievements Related to Advanced Technologies for Water Cooled Reactors (June 6-9, 1988).

30. V. Fedorov and V. Voznesenski, Progress Report (USSR) (June 6-9, 1988).

31. C. Forsberg, Overview of United States Current and Planned Activities in Passive Safety Research and Development.

32. P. Adelfang et al., Programs on Advanced Fuel Cycles in the Argentina PHWRs.

Literature from Tour of Loviisa Power Station

33. Imatran Voima Oy, Loviisa Power Plant.

34. Imatran Voima Oy, Energy Innovation R&D 1987.

35. Imatran Voima Oy, Annual Report 1987.

36. Imatran Voima Oy, Reliability, Economy, Efficiency in Energy.