Review of the IAEA Nuclear Fuel Cycle and Material Section Activities Connected with Nuclear Fuel Including WWER Fuel

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1. Introduction

At the beginning of 2001, 438 nuclear power reactors were in operation in about 30 countries with a total electricity capacity of 350 GWe. These countries conduct a wide range of nuclear fuel cycle activities: from fuel production to disposition of spent fuel. In addition, 23 countries, many of them with no nuclear power programme, produce uranium for nuclear fuel and/or have R&D programmes in the area of the nuclear fuel cycle. Research reactors and their fuel management are of great importance to 58 countries that have one or more research reactors, 40 of which are developing countries. Today, more than 50 countries are involved in nuclear fuel cycle activities.

The Nuclear Fuel Cycle and Materials Section (NFC&MS) is responsible for the implementation of the IAEA programme in this important area. The programmatic activities of NFC&MS cover in a comprehensive manner various aspects of the nuclear fuel cycle in order to increase the capability of Member States for policy making and strategic planning, technology development and implementation of safe, reliable, economically-efficient, proliferation-resistant, and environmentally-sound nuclear fuel cycle programmes. Specifically, in order to achieve these objectives, the Section focuses on four areas of activities, viz. Uranium resources, nuclear fuel performance and technology, spent fuel management, research reactor fuel cycle and fuel cycle issues and information systems.

Programmatic Activities on Nuclear Fuel Cycle and Materials:

- Area of raw materials (B.1.01);
- Area of fuel performance and technology (B.1.02);
- Area of spent fuel management (B.1.03);
- Area of fuel cycle issues and information System (B.1.04);
- Area of support to technical co-operation activities (B.1.05).

2. Project B.1.02 – Fuel Performance and Technology

Objectives:

- To maintain and improve power reactor fuel performance and technologies for ensuring nuclear fuel cycle competitiveness and safety;
- To assist in fuel technology development transfer in order to harmonize nuclear fuel design, fabrication and utilization.

In order to support and assist the IAEA Secretariat in the direction, formulation and performance of its water reactor fuel programme and to facilitate exchange of information on the progress of national, multilateral and international activities related to water reactor fuel, the Technical Working Group on Water Reactor Fuel Performance and Technology (TWGFPT) was established in 1976.

At present, the TWGFPT comprises 34 fuel experts from 26 countries, OECD/NEA and EU. TWGFPT meets annually.

Every two years, TWGFPT members present an information on fuel performance, including fuel failure rates, fuel operation experience, national/ international fuel R&D programmes. TWGFPT assists in the preparation of the IAEA meetings, studies, CRPs and in the preparation of the important documents, especially related to fuel safety.

2.1. Main Outcome in Fuel Performance and Technology in 2000

The technical knowledge on high burnup fuel modelling including the degradation of fuel conductivity, fission product retention and UO_2 and MOX fuel behaviour was shared at a TCM held in Windermere, UK, in 2000: The Technical Committee first reviewed the important role that fuel modelling plays in improving fuel performance, especially in increasingly demanding conditions. In addition, new materials, including advanced cladding alloys and alternative fuel types such as mixed oxide (MOX) fuel and doped fuels, have created a need for a more mechanistic under-standing of fuel behaviour. The Committee reviewed key issues in high burnup fuel modelling (e.g., degradation of fuel conductivity, fission product retention and fuel behaviour in transient conditions) and identified important deficiencies where current models need improvement.

The methodology of the evaluation of delayed hydride cracking of pressure tubes and modelling of activity transfer in primary circuits of NPPs was developed in two CRPs and transferred to several developing countries: Within the framework of a

CRP on Hydrogen Pick-up and Hydrogen and Hydride Degradation of the Mechanical and Physical Properties of Zirconium Alloys, an Agency study of delayed hydride cracking of pressure tube material achieved a very effective transfer of know-how at the laboratory level. Delayed hydride cracking has led to the failure of pressure tubes in CANDU reactors and may also contribute to fuel cladding failure in water reactors. CRP participants carried out a round-robin exercise reporting delayed hydride cracking of CANDU pressure tube material measured in different laboratories. The results show that much of the usual spread in data across laboratories can be dramatically reduced simply by careful experimental controls.

Support to TC activities included the procurement of a sipping test system for failed fuel assembly detection and measurement. This system will be provided to the Kozloduy NPP in 2001. Procurement of a visual examination (non destructive) stand is also envisaged for WWER-1000 fuel elements: Within the framework of a Technical Co-operation project with Bulgarian institutions, the Agency procured an on-line sipping test system to detect and measure failed fuel assemblies. The system, which can quickly diagnose suspected assembly failures, will be provided at the beginning of 2001. It will be installed first in one WWER-440 unit for testing, and then moved to a WWER-1000 unit.

2.2. Activities in the Area of Fuel Performance and Technology in 2001

TWGFPT meeting, Vienna, 18-20 April: The Technical Working Group on Fuel Performance and Technology held its 2001 plenary meeting in Vienna. Country reports were presented and provided a comprehensive picture of the status of nuclear power worldwide and specifically on fuel performance experiences as well as ongoing research and development efforts. It was noted that China, India, Korea, Japan and Russia are pursuing impressive nuclear power development programmes. In Western Europe, a picture of current slowdown is visible with the exception of the Finish industry that is planning nuclear unit 5. However, in order to maximize the utilization of existing plants, there is a general tendency to increase burnups with attention being given to transient fuel behaviour. The TWG was informed about the ongoing Technical Co-operation projects in the fuel area and expressed its support.

The Group concluded that the progress of work was consistent with the plans discussed at the last meeting, especially the successful CRPs.

Advanced post-irradiation examination techniques for water reactor fuel, Dimitrovgrad, Russia, 14-18 May: The Technical Committee considered the most important directions of destructive and non-destructive PIE techniques as applied to water reactor fuel. Current nomenclature and development level of PIE techniques used in different countries and organizations for fuel rod control and investigation are adequate to the requirements aid down by regulatory and licensing bodies. Sufficient information can be obtained on geometrical changes of fuel and structural components of fuel assemblies, fuel failure causes, fission product distribution, structure and property of cladding and fuel materials, etc.

Significant progress has been reached in development and use of such comprehensive non-destructive methods as of neutronography and tomography. They have recently been complemented by new methods for fuel-clad gap control and for precise measurement of fuel rod cladding diameter. Significant attention is paid to further development of non-destructive methods including control of defects, if any, in fuel rods under irradiation. It is of special importance for fuel assembly repair.

Destructive methods are widely used in hot laboratories in many countries directed on obtaining information on composition, structure and properties of fuel and structural materials. Further development has been noticed in the use of Secondary Ion Mass Spectrometry (SIMS) for irradiated fuel. This will allow receiving a new knowledge on structure and composition of irradiated fuel necessary for understanding fuel behaviour at high burnup. In-pile methods are very effective to receive the most complex information on irradiation impact on fuel and structural materials. Their further development is expedient.

On the request of the IAEA Technical Working Group on Water Reactor Fuel Performance and Technology, the issue of the revision of “Catalogue of PIE Facilities” (published by the Agency in 1996) was raised and discussed during the Panel Discussion. The revision was supported by the TCM participants with further transformation of the Catalogue into a database. The database developed and maintained by RIAR (Russian Federation) was evaluated as a good model for this purpose.

Fuel behaviour under transient and LOCA conditions, Halden, Norway, 10-14 September: The Technical Committee covering the following topics: review of fuel research relevant to transient and accident conditions, transient analysis, cladding properties after high temperature oxidation, high burnup phenomena relevant to LOCA.

Existing LOCA criteria include maximum cladding temperature limit (PCT-Peak Cladding Temperature) of 1204°C (2200°F) and maximum oxidation limit (ECR-Equivalent Cladding Reacted) of 17%. The primary rationale for the 17% criterion is retention of cladding ductility at temperatures higher than 135°C (saturation temperature during reflood) and it is tied to the use of Baker-Just correlation. PCT criterion was selected on the basis of Hobson’s slow-ring compression tests at 25-150°C conducted in the early 70’s on unirradiated ring specimens. It was agreed that, for irradiated claddings at present burnups, these criteria are applicable by taking into account the thickness of oxide layer formed during normal operation, Hydrogen pick-up lower than 600 ppm (it was noticed that the hydrogen limit depends on the chemical and phase composition of each specific alloy) and axial tensile loads below 600 N. It is expected that high burnup fuel LOCA criteria will be clarified in course of the running and planned programmes. In particular, the role of clad enhanced deformation, fuel relocation, combined effect of Hydrogen and Oxygen on post-quench ductility, pellet-clad bonding, pellet rim, specifics of MOX fuel and some others have to be studied and understood. Also, LOCA related thermohydraulic aspects, i.e. thermal gradients, quenching and coolability of blocked arrays, should be in-pile tested.

RIA tests have been analysed by several groups of fuel specialists who have developed RIA fuel failure criterion/criteria. For example, the US nuclear industry strategy to resolve the technical and licensing issues associated with RIA events in LWRs was presented by R. L. Yang at LWR Fuel Performance Conference in Park City, in 2000. This strategy is based on a probabilistic and deterministic approach. Mr. Carlo Vitanza proposed a RIA failure criterion based on cladding strain: for cladding that still retains ductility, failure is predicted beyond a 1% diameter strain, and for cladding that has been embrittled due to large corrosion, spalling and hydriding, a zero ductility is assumed, i.e. the failure threshold is at onset (0%) of permanent strain.

Based on CABRI REP Na (except REP Na-1) and ANL laboratory tests and the use of this criteria, one derives that the lowest failure limit at 60 MWd/kg HM is approximately 65-70 cal/g, which applies to heavily corroded/hydrided fuel in the presence of oxide spalling. For corrosion resistant fuel and in the absence of spalling, the failure threshold at the same burnup is approximately 100 cal/g. Of course, this criterion is not assumed, at least at the present time, to be a license criteria. Further effort in the study of this criterion was recommended. New techniques to assess the mechanical behaviour of Zr-based alloys and impact of fission gas release during RIA were presented at the TCM and further developments in this area were recommended.

On the basis of reports by French and Russian specialists, the advantage of Nb-alloyed cladding materials, i.e. Zr-1%Nb and alloy 635 (Russia), M5 (France) and Zirlo (USA), compared to Zircaloy-4 alloy in normal operation, was confirmed by a large amount of experimental data. However, it was emphasized that the behaviour of these alloys in accident conditions is very similar to the behaviour of Zircaloy-4. It was understood that the difference in experimental results, when testing mechanical properties of different cladding materials at high temperatures and load rates, sometimes is caused not by a difference in actual alloy properties, but by a difference in test methodology. Standardization and unification of methods to evaluate mechanical properties of Zr-based alloys at high temperatures and load rates were recommended.

2.3. International Research Programmes

Finalization of the CRP on modelling of activity transfer in primary circuits of NPP: In 2000, the programme also completed a Co-ordinated Research Project on transport models of radioactive substances in primary circuits of water-cooled reactors. The Project evaluated models incorporated in nine national codes using a blind exercise based on activity measurements data provided by five countries operating PWR, WWER and CANDU power plants. Participants conducted sensitivity analyses to evaluate more specifically the different models and the precise role of each parameter and identified important improvements that can be made in national models and codes.

The final report as a result of the CRP is under preparation.

Start of the CRP on data processing technologies and diagnostics for water chemistry and corrosion control in NPPs (DAWAC, 2001-2005): DAWAC CRP follows up WACOL CRP (High temperature On-line Monitoring of Water Chemistry and Corrosion, 1995-2000). WACOL CRP established recommendations for the development, qualification and plant implementation of methods and sensors for on-line monitoring of water chemistry and corrosion. Methodology and technology of data collection, data evaluation, diagnostics and assessment as well as analysis of calculating modules used in Water Chemistry Expert Systems in all types of water cooled power reactors, e.g. CANDUs, BWRs, PWRs and WWERs, were defined as major topics for a new DAWAC CRP.

There are 18 participants in the DAWAC CRP from Bulgaria, Canada, China, Czech Republic, Finland, France, Germany, Hungary, India, Japan, Romania, Russian Federation, Slovakia, Sweden, UK, Ukraine, USA (2 organizations).

The participants of the DAWAC CRP will provide contributions to introduce data processing and diagnostic systems for operating plants in order to improve safety, reliability, as well as availability of these plants. In this first stage of the project, the participants (2001) will agree on the basic structure and the needed ingredients of a data processing and diagnostic system. The participants are expected to contribute to one or several items given above. The 1-st RCM will be in November 2001 with a purpose to create a project matrix (grouping by reactor types, selection of group leaders, action list and report content).

In the course of the CRP performance, all participants will exchange information and experience in collection and evaluation of water chemistry and corrosion data in NPPs and in the development of diagnostic and assessment systems to advise the operators on the status of the plant. At the end of the CRP, it is expected that all participants will have the required technical knowledge in the area as well as the established methods for development, qualification, and plant commissioning of Data Processing Technologies for Water Chemistry and Corrosion Control. A TECDOC will be published. At the initial stage of the project, it is clear that it will cover all water-cooled power reactor types.

Preparation of a new CRP on fuel modelling at extended burnup (FUMEX II, 2002-2006): The major objective of the CRP is to increase the performance of the models used in fuel behaviour modelling for extended burnup. In continuation of the first CRP on this subject (FUMEX I, 1993-1996), it is necessary to focus now on specific topics linked to extended burnup such as thermal performance, fission gas release and pellet to clad interaction, to support the models.

The results of this CRP will allow to use a common fuel experiment database, to make calculations in order to be able to improve the models used both for western and eastern design and, finally, to dispose of a well adapted and upgraded version of models to predict the fuel behaviour for high burnup. It is in full agreement with the overall project objective: to maintain and improve power reaction fuel performance and technologies for ensuring nuclear fuel cycle transfer in order to harmonize western and eastern cultures in nuclear fuel design, fabrication and utilization. The proposal to initiate the FUMEX II CRP was supported by fuel behaviour specialists and fuel modellers from 19 countries and finally endorsed by the TWG on Water Reactor Fuel Performance and Technology at its 16-th Plenary Meeting.

2.4. TC Projects to Support Member States

Technical Co-operation projects are aimed to provide technical assistance and to respond to priority national and regional needs; to produce sizeable economic and social impacts, and to attract strong government commitment.

Examples:

- TC Project with Bulgaria to provide the system to detect and measure failed FAs for Kozloduy NPP;
- TC Project with Romania on Recovered Uranium and Slightly Enriched Uranium Fuel Cycle Options for Chernavoda NPP.

3. Project B.1.03 – Spent Fuel Management

Objectives:

- To support Member States in their decision making process on selecting safe and reliable technologies in spent fuel storage;
- To improve existing spent fuel storage facilities and their operation with regard to environmental, safety, health and proliferation resistant aspects;
- To enhance capabilities in Member States for the use of burnup credit, repatriation programmes for research reactor fuel and regional/ international solutions;
- To support non-proliferation through conversions of research reactors from HEU to LEU fuel.

3.1. Main Outcome in Spent Fuel Management in 2000

Implementation of burnup credit (BUC) in spent fuel management systems: Burnup credit is defined as the consideration of the reduction in reactivity associated with the use of fuel in power reactors. Changes in the isotopic composition during fuel burnup which result in a reduced reactivity can be conveniently characterized by the reduction of the net fissile content, the build-up of actinides, the increase of the concentration of fission products, and the reduction of burnable absorber concentration where applicable. In practice, the conservative use of burnup credit requires consideration of all fissile isotopes, and allows consideration of any neutron absorbing isotopes for which properties and quantities are known with sufficient certainty. The actinide only burnup credit is used in many cases today.

Motivation for using burnup credit in criticality safety applications is generally based on economic considerations. Although economics may be a primary factor in deciding to use burnup credit, other benefits can be realized. Many of the additional benefits of burnup credit that are not strictly economic, can be considered to contribute to public health and safety, resource conservation and environmental quality. The use of burnup credit allows loading more fuel into one transport or storage cask, which reduces the number of transports or the space needed for storage.

Information on applications of burn-up credit in spent fuel management has been in continuous demand and implementation of this task should provide a useful source of information to many Member States and possibly further demand in the future.

A Technical Committee Meeting was held in July 2000 to consider and report on the progress made in the implementation of burnup credit. This meeting was attended by 35 participants from 17 countries and 2 international organizations.

Extremely long-term spent fuel storage facilities: As in the past, less than one third of the spent fuel will be reprocessed and this mainly in Europe. The trend to higher fuel burnup, and consequently higher enrichment of the fresh fuel, and the use of plutonium in mixed oxide fuel, lead to other spent fuel characteristics i.e. higher decay heat and flatter downward curve over time. This demands a longer storage period than for the present spent fuel in many countries with burnup lower than 40 GWd/t. The lifetime of existing storage facilities will be extended and new facilities for long-term storage have to be built. The design of new facilities has to take into account not only the fuel behaviour during long-term storage but also the behaviour of the materials, equipment and installation.

In 2000, a Technical Committee Meeting and a Consultancy were held on the requirements for long-term storage facilities. This TCM was attended by 41 experts from 21 countries. 29 presentations were given and the matter discussed in more detail in four working groups.

The Co-ordinated Research Programme on "Spent Fuel Performance Assessment and Research (SPAR)" deals also with the questions of spent fuel and structure material behaviour during long-term storage under wet and dry condition. The second Research Co-ordination Meeting was held in May 2000.

Guidance to meet the problems of spent fuel long-term storage has been of continuous interest for most of our Member States. The implementation of these tasks should provide a useful basis for their information and support.

Spent fuel treatment: Spent fuel treatment is a key technical basis. Historically the PUREX technology for separation of plutonium by reprocessing of spent fuel has been extensively used. For this reason, it has been regarded with sensitive considerations. However, there are other technical varieties of spent fuel treatment as dry treatment of spent fuel materials or conditioning of spent fuel assemblies or rods for packaging and encapsulation.

In the past decade, the Secretariat has published several technical documents on the status and prospects on spent fuel treatment technologies reporting mostly the activities of existing reprocessing plants. In the AGM held this year, some additional information with special focus on the emerging technologies were examined, in addition to the routine updating of status and prospects on spent fuel reprocessing.

3.2. Activities in the Area of Spent Fuel Management in 2001

Selection criteria for AFR storage facilities: The importance of AFR storage for spent fuel management has been growing in many Member States as more and more AR storage pools are filled up with spent fuel. The past efforts to extend the capacities of AR pools have maximized the storage densities almost to the technical limits. The step to AFR storage will sooner or later be inevitable for the majority of Member States. Some Member States have already implemented AFR storage facilities and a growing number of States are taking actions to build such facilities. Looking at the technological trend for AFR storage, there can be seen a clear tendency toward dry storage in recent years, although wet storage in pools is still predominant as large buffer storage for reprocessing plants. Different options are available for dry storage of spent fuel and about a dozen of vendors offer commercial packages to the prospective market. There are a variety of factors to be considered in selecting an option or product and careful assessment of relevant criteria would be essential in setting up successful plans for implementation of AFR storage.

This task is an initiative to identify factors associated with the selection of AFR storage facilities and assess the criteria that would have to be considered in the selective process, with a view to provide a useful guide to Member States in particular to developing countries.

Spent fuel performance and research (SPAR), Spain, 1-5 October: See details in Chapter International Research Programmes.

Technical and institutional aspects of regional spent fuel storage facilities, Vienna, 5-9 November: The question can be raised as to whether developing a strictly "national" approach for spent fuel storage is reasonable in the case of countries with a small nuclear power programme or only research reactors producing a small amount of spent fuel and waste. This "national" approach may lead in those countries to inappropriate use of already scarce resources, which, otherwise, could be used for different, equally important, social or economic purposes. In this respect, the concepts of "multinational" or "regional" spent fuel storage facilities would appear to make good sense. Several Member States of the International Atomic Energy Agency (IAEA) have already expressed their interest in such options.

However, such concepts involve political and public acceptance issues and, therefore, a consensus among countries or within regions eventually concerned by the development of multinational storage is a prerequisite for their realisation.

In this context, it was deemed appropriate that the IAEA identifies and assesses the important factors to be taken into account in the process of such consensus building.

The successful implementation of long-term storage programmes on a regional level could increase transparency in spent fuel management programmes, nuclear safety and protection as well as non-proliferation issues. Broad adherence to international instruments such as the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management could significantly contribute to the acceptance of the international concepts of regional spent fuel facilities and radioactive waste repositories.

The objective of this meeting is to encourage the discussion of the aspects of "multinational" or "regional" spent fuel storage facilities and to enhance political and public acceptance.

AGM on implications of changes in fuel fabrication and reactor core management (Advanced Fuel) for long term storage (Influence of fuel design for high burnup and MOX fuel and advanced reactor operations on spent fuel): The new fuel design and changes in reactor operation with the aim to increase the economy of power generation have implication on spent fuel storage. Therefore this task is aimed to reach a common understanding of front-end effects on backend fuel cycle with particular regard to long-term storage of spent fuel.

Support of spent fuel storage for WWER and RBMK operators: The Government of Japan provided extra-budgetary funds from 1995 to 1999 to increase the safety of spent fuel storage from WWER and RBMK reactors. Lecturers from Member States with advanced technologies and experts from WWER and RBMK operating countries were invited. Workshops on the safety of WWER and RBMK spent fuel storage were held. These Workshops were aimed to bring together experts from representative Western countries and from Eastern European Member States, operating WWER and RBMK nuclear power plants, in order to exchange information and experience on design, commissioning, operation, monitoring and maintenance of spent fuel storage facilities, fuel degradation mechanisms, consideration of damaged/ failed fuel and economical considerations. For this type of workshop, it was important that there is continuity in the assistance and support given by the Agency. Such a workshop is very helpful for all Eastern European countries operating WWER and RBMK reactors.

For the year 2000, no funds were available. The last Workshop, held in July 2001 in Prague, was on the COBRA-SFS code available to the WWER operating countries. This thermo-hydraulic code for spent fuel storage was already benchmarked for WWER fuel but only available on mainframe computers and not on PC's. A handbook was written and experts showed how to work with this code on thermo-hydraulic WWER spent fuel storage problems.

Training course on Implementation of Burnup Credit in Spent Fuel Management Systems, Argonne, 15-26 October: See details in Chapter Training Courses.

3.3. International Research Programmes

Co-ordinated research programmes are performed by the Agency in relation to fuel behaviour and long term storage of spent fuel.

History of the befast and spar co-ordinated research programmes:

The storage period is highly dependent upon the individual national strategies to close the nuclear fuel cycle but generic questions related to spent fuel storage are common to all nuclear programmes.

Three CRPs called BEFAST were held starting 1981.

A new programme SPAR was proposed to address the effects of new parameters on long-term storage and to determine their consequences for disposal.

The SPAR programme (1997-2003) involves 10 organisations from 10 countries: Canada, France, Germany, Hungary, Japan, Republic of Korea, Russia, Spain, UK, and USA. Sweden participates in the programme as an observer.

Three Research Co-ordination Meetings (RCM) are supposed to be held during the course of the SPAR CRP: The first was in April 1998 in Washington, DC, the second in May 2000 in Ahaus, Germany; the third and last one will be in October 2001, in Spain. The results will be published as a TECDOC.

3.4. TC Projects to Support Member States

Technical Co-operation projects are aimed to provide technical assistance and to respond to priority national and regional needs; to produce sizeable economic and social impacts, and to attract strong government commitment.

Examples:

- TC project with Romania on spent fuel storage to support the design of a dry storage facility for Cernavoda. It was started in 1998;
- TC project with Bulgaria on spent fuel storage: Re-racking the existing AFR Spent Fuel Storage Facility at Kozloduy NPP for increased storage capacity.

3.5. Training Courses

Regional and Interregional Training Courses on Spent Fuel Storage are planned in co-operation with TC. The courses are designed for staff of utilities, nuclear power plant operators, regulators and technical support organisations involved in spent fuel management in the countries receiving assistance from the IAEA through its Technical Co-operation Programme.

The purpose of these courses is to provide technical information, safety fundamentals, and safety issues associated with spent fuel storage as related to design, operation, and regulation of on-site and away-from-reactor storage facilities. The courses will meet the needs of engineers and technical staff for a basic understanding of the key issues in the technique and safety of spent fuel storage covering different spent fuel storage options for nuclear power plants. The courses will also address regulatory issues and safety reports, practical examples and experience as well as problems in spent fuel storage.

3.6. Symposium on Spent Fuel Storage From Power Reactors (2003)

The IAEA gives continuous attention to the collection, analysis and exchange of information on spent fuel storage. Its role in this area is to provide a forum for exchanging information and to co-ordinate and encourage closer co-operation among Member States in certain research and development activities that are of common interest.

Symposia on this topic have been organised about once every four years since 1987. The purpose of the Symposia is to exchange information on the state-of-the-art and prospects of spent fuel storage, to discuss the worldwide situation and the major factors influencing the national policies in this field and to identify the most important directions that national efforts and international co-operation in this area should take.

The Symposia consist of several oral sessions and one poster session. The oral sessions address four major topics:

- National programmes;
- Technology;
- Experience and licensing;
- R&D and special aspects.

Usually, 120 to 150 participants from 35 countries and 4 international organisations attend the presentations of papers and the poster session, which reflects the world-wide interest in these important topics covered in the Symposia.