1.2 The contribution of the CSNI Principal Working Group on Confinement of Accidental Radioactive Releases to the technical consensus and spreading of knowledge on severe accidents

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Abstract

The Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and co-ordinate the activities of the NEA concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the Member countries. Five Principal Working Groups (PWG) operate under the leadership of CSNI. PWG4 is named "Confinement of Accidental Radioactive Releases" and its main activities are State of the Art Reports, International Standard Problem exercises, Specialist Meetings and Technical Opinion Papers. Together with other groups of experts involved in severe accident work, PWG4 has strongly contributed to the understanding of phenomena and the development of the knowledge base in that area, to the resolution of technical issues, and to the dissemination of the results. Taking examples from the products of the work of PWG4, the paper shows how this working group fosters international co-operation in the area of severe accidents and their management, and contributes to the development of a technical consensus.

Keywords: international co-operation, severe accidents, OECD/NEA/CSNI

1. Introduction

The Nuclear Energy Agency (NEA) Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers. It was set up in 1973 to develop and co-ordinate the activities of the NEA concerning the technical aspects of the design, construction and operation of nuclear installations insofar as they affect the safety of such installations. The Committee's purpose is to foster international co-operation in nuclear safety amongst the Member countries.

Five Principal Working Groups (PWG) operate under the leadership of CSNI. PWG4 is named "Confinement of Accidental Radioactive Releases" and its objective is to address the safety issues and physical processes concerned with the retention of fission products within the nuclear plant, including the termination of core degradation and debris attack on structures, together with the consequential sources of fission products and of material and energy that can threaten the containment, and the evaluation and prevention of threats to the integrity of the containment building.

The main activities of PWG4 are State of the Art Reports, International Standard Problem exercises, Specialist Meetings and Technical Opinion Papers. Taking examples from these products, the paper shows how PWG4 fosters international co-operation in the area of severe accidents and their management, and contributes to the development of a technical consensus.

2. PWG4 activities

Generally speaking, the Principal Working Groups (PWG) consist of experts designated by the members of CSNI. They meet annually to discuss and review the work of the past year, and agree on the future programme to be proposed to the CSNI.

Specialist meetings and workshops are organised regularly, focusing on well-defined topics and issues. They are an excellent mechanism to take stock of the situation and to make substantial progress. They are frequently organised in the most complex and technically advanced parts of the programme.

State-of-the-Art Reports (SOAR) and "situation reports" (Technical Notes in most cases) have proven particularly useful to Member countries; they bring together the latest developments in a given area or give a "snapshot picture" of the international situation regarding a particular issue, stimulate the formation of common understanding and consensus technical opinions, and provide a source of up-to-date information for those countries that may not have an activity in the area. While some of the reports produced for the CSNI and CNRA (Committee on Nuclear Regulatory Activities) are restricted to Member governments (frequently because they include provisional or still incomplete information), most are available as "unclassified" or for sale at OECD Publication and Information Centres.

The purpose of Technical Opinion Papers (TOP) is to make results of important CSNI/PWG activities known to a wider audience (including authorities, utilities, manufacturers, decision-makers, parliamentarians, journalists, etc.) than the specialists having direct access to CSNI Reports.

International Standard Problems (ISP) Exercises are comparative exercises in which predictions of different best-estimate computer codes for a given physical problem are compared with each other or with the results of a carefully specified experimental study. The main goal of ISP exercises is to increase confidence in the validity and accuracy of tools which are used in assessing the safety of nuclear installations. Moreover, they enable code users to improve their ability, gain experience and demonstrate their competence. ISP exercises are performed as "open" or "blind" problems. In an open Standard Problem exercise the results of the experiment are available to the participants before performing the calculations, while in a blind Standard Problem exercise the results are locked until the calculational results are made available for comparison.

PWG4's **general programme of work** is the following :

- Exchange information on national and international activities in the field of confinement of accidental radioactive releases (fission product phenomena in the primary circuit and the containment, severe accident phenomena in the containment, containment aspects of severe accident management);

- Discuss technical issues/reports and their implications, and the results of International Standard Problem exercises and specialist meetings; submit conclusions to CSNI; give technical guidance to specialised Task Groups;

- Prepare Technical Opinion Papers on major issues;

- Review main orientations, future trends, emerging issues, co-ordination and interface with other groups in the field of confinement of accidental radioactive releases; identify necessary activities and propose programme of work to CSNI.

PWG4's **specific achievements** over the period 1993-1997 can be deduced from Tables 1 to 4.

PWG4's **plans** for the 1998-1999 period are :

In the area of containment severe accident management :

- a Technical Note on Issues Associated with the Impact on Long-Term Plant or Site Recovery of Short-Term Severe Accident Management Actions;
- a Technical Note on accident management aspects of the control of iodine, caesium, strontium and other fission products in the containment during a severe accident;
- a Workshop on Iodine Chemistry Aspects of Severe Accident Management;
- review of key issues of containment aspects of severe accident management;

In the area of severe accident phenomena :

- a State-of-the-Art Report (SOAR) on Containment Thermal-Hydraulics and Hydrogen Distribution;
- a SOAR on Flame Acceleration and Deflagration to Detonation Transition in Nuclear Safety;
- a Technical Note on Carbon Monoxide/Hydrogen Interactions in the Containment;
- a review of ex-vessel hydrogen sources;
- a Technical Opinion Paper on Fuel/Coolant Interactions (in collaboration with PWG2 on Coolant System Behaviour);
- a Workshop on Ex-Vessel Debris Coolability.

In the area of fission product phenomena :

- a Specialist Meeting on Nuclear Aerosols in Reactor Safety;
- an ISP (ISP-40) based on a STORM experiment on aerosol deposition and resuspension in the primary circuit.
- a Technical Note on the Technical Bases for the Management of Severe Reactor Accident Source Terms.
- an ISP (ISP-41) based on a Radioiodine Test Facility (RTF) experiment on iodine behaviour in containment under accident conditions;
- an ISP based on a KAEVER experiment (behaviour of aerosol components typical of core melt under representative thermal-hydraulic conditions);
- an ISP based on the PHEBUS FPT-0 Test.

3. Development of a technical consensus

To illustrate the way PWG4 fosters international co-operation in the area of severe accidents and their management, and contributes to the development of a technical consensus, four examples have been selected among the achievements of the last few years.

3.1 SOAR on High-Pressure Melt Ejection and Direct Containment Heating [NEA/CSNI/R(96)25]

A significant amount of work in the area of High-Pressure Melt Ejection (HPME) and Direct Containment Heating (DCH) had been done since 1989, within the United States in particular. It appeared in 1994 that the time was appropriate to produce a final international assessment. CSNI endorsed the preparation of a State-of-the-Art Report, under the co-ordination of the US Nuclear Regulatory Commission, in the framework of PWG4. The report, based on information collected in OECD Member countries, summarises the state of knowledge on HPME and DCH for light-water reactors. As a result of similarities between containments in different countries, the results sponsored by the USNRC, as well as other plant specific results, and those supported by the Electric Power Research Institute, can be applied to other containments with the same general configuration.

Nevertheless, there are differences between containment configurations and these need to be considered using the available experiments and analyses (generally integral computer codes) on a plant specific basis. Therefore, the combination of operator procedures to intentionally depressurize the reactor system, the likelihood of unintentional depressurization for those highly unlikely events in which no recovery actions can be taken, the ways in which the vessel integrity can be protected and the substantial mitigating potential demonstrated by large scale experiments for the containment are sufficient to provide the structure for resolution of this issue. The formulation of resolution is expected to be dependent upon the specific country since each country has somewhat different regulatory framework. However, the necessary information for the defence-in-depth structure for resolution is available.

3.2 TOP on Implementation of Hydrogen Mitigation Techniques During Severe Accidents in Nuclear Power Plants [NEA/CSNI/R(96)27]

The rates and quantities of hydrogen produced during a severe accident in a water-cooled reactor depend on the particular severe accident scenario and also on the reactor type. The goal of hydrogen mitigation techniques is to prevent loads, resulting from hydrogen combustion, which could threaten containment integrity. The purpose of the TOP was to present a snapshot, from a technical viewpoint, of the current situation regarding the implementation of hydrogen mitigation techniques for severe accident conditions in nuclear power plants.

It appeared from a Workshop on the Implementation of Hydrogen Mitigation Techniques organised by the OECD in Winnipeg, Manitoba, Canada in May 1996 that the current trend among the countries implementing hydrogen mitigation measures in large dry containments favoured the installation of passive autocatalytic recombiners (PARs), possibly supplemented by other measures (igniters or post-accident dilution). PARs are also seen as a promising alternative to older thermal (active) recombiners which are installed for long term hydrogen control following Design Basis Accidents. The installation of PARs is also under discussion for future reactor concepts. The installation of catalytic recombiners is being considered for the AP600 Reactor for design basis accidents. For the advanced CANDU reactors and the European Pressurised Water Reactor (EPR), it is favoured for all accident scenarios including severe ones.

3.3 Fourth OECD Workshop on the Chemistry of Iodine in Reactor Safety [NEA/CSNI/R(96)6 and 7]

The purpose of the Workshop, which was held at Würenlingen, Switzerland in June 1996, was to exchange information on the iodine chemistry and other important fission products relevant to reactor safety, to discuss the status of the open issues identified during the previous Workshop held in 1991, to define remaining reactor safety issues, and to discuss developments and future plans. At the 1991 Workshop, conclusions of the status of understanding of iodine chemistry relevant to reactor safety had been compiled and numerous recommendations had been made as to the areas where further work was needed to reduce significant uncertainties of iodine behaviour under accident conditions. Included in these recommendations was the need to: better understand iodine interactions with organic compounds and surfaces; establish the rates and mechanisms of H_2O_2 and I_2 hydrolysis reactions; determine and quantify the role of organic radiolysis on pH and iodine chemistry; identify the minimum pH required to suppress iodine volatility to acceptable levels under accident conditions; ensure that surface phenomena are adequately addressed in iodine models, databases and codes; include the temperature dependence of reactions in iodine kinetic databases; and validate iodine codes/models against realistic integral data.

The papers presented at the 1996 iodine Workshop demonstrated that substantial progress had been made internationally in each of the above areas since the previous Workshop. Although additional research is still needed in several areas, the nuclear industry is at a point where it has become possible to define the principles of closure of iodine issues and to prioritise remaining issues that have an impact on the source term and accident management strategies.

3.4 International Standard Problem (ISP) 35: NUPEC Hydrogen Mixing and Distribution Test M-7-1 [NEA/CSNI/R(94)29]

The Final Comparison Report summarises the results of the ISP-35 exercise which was based on NUPEC's Hydrogen Mixing and Distribution Test M-7-1. Twelve organisations from ten countries took part in the exercise. During the test, a steam/light gas (helium) mixture was released into the lower region of a simplified model of a PWR containment. At the same time the dome cooling spray was activated. The transient time histories for gas temperature and concentrations were recorded for each of the twenty-five compartments of the model containment. The wall temperatures as well as the dome pressure were also recorded.

The ISP-35 participants simulated the test conditions and attempted to predict the time histories using their accident analysis codes. They found qualitative agreement in modelling the dominant parameters of hydrogen mixing. However, from a quantitative view point, discrepancies were observed between calculated and experimental results. Since the spray shower enhanced the natural circulation in the containment vessel, the helium concentrations in almost all the compartments in the containment vessel were predicted very well. There were discrepancies in calculated concentrations in the dead-ended and complex-shaped compartments; however, because of the very low concentrations in these compartments and the small volume of those compartments, these discrepancies did not influence the helium distributions in other regions of the containment vessel. The mentioned discrepancy in the dome wall temperature also did not appear to influence the helium distributions in the containment vessel during the test period. It was apparent that user experience with noding schemes and flow resistances influenced the calculational results. The observation indicated that user's knowledge can lead to better agreement with experimental results.

4. Conclusions

One of the main functions of the CSNI is to initiate and conduct programmes to overcome discrepancies, and develop improvements and reach international consensus on technical issues. PWG4 participates actively to that effort. Together with other groups of experts involved in severe accident work, it has strongly contributed to the understanding of phenomena and the development of the knowledge base in that area, to the resolution of technical issues, and to the dissemination of the results. It has a positive effect on the development and the maintenance of technical competence at a time when, because of reductions in research budgets in particular, there is growing risk of moving backward rather than forward in the field of severe accident phenomena understanding and severe accident management.

Table 1: PWG4 Technical Opinion Papers

Ref.	Title	Pub.Date
NEA/CSNI/R(96)2	Current Evaluation of the Chernobyl Reactor Accident Release	Feb 1996
NEA/CSNI/R(96)27	Implementation of Hydrogen Mitigation Techniques During Severe Accidents in Nuclear Power Plants	Dec 1996

Table 2: PWG4 Reports (last 5 years)

Ref.	Title	Pub.Date
NEA/CSNI/R(93)1	Positive/Negative Aspects of Measures Designed to Protect the Containment	Feb 1993
NEA/CSNI/R(93)2	Hydrogen Management Techniques in Containment	Feb 1993
NEA/CSNI/R(93)6	Effects of Hydrogen Combustion on Fission Products and Aerosols	Feb 1993
NEA/CSNI/R(93)7	Physical and Chemical Characteristics of Aerosols in the Containment	Feb 1993
NEA/CSNI/R(94)4	Low Temperature/Low Pressure Chemistry Inside the Containment	Feb 1994
NEA/CSNI/R(94)5	Survey of Containment Designs for New/Advanced Water Reactors	Feb 1994
NEA/CSNI/R(94)6	In-Vessel Core Debris Cooling Through External Flooding of the Reactor Pressure Vessel	Feb 1994
NEA/CSNI/R(94)7	Non-Condensable Gases in Boiling Water Reactors	Feb 1994
NEA/CSNI/R(94)28	Specific Features of Caesium Chemistry and Physics Affecting Reactor Accident Source Term Predictions	Aug 1994
NEA/CSNI/R(94)30	Short Overview on the Definitions and Significance of the Late Phase Fission Product Aerosol/Vapour Source	Sep 1994
NEA/CSNI/R(94)32	Core Debris Cooling with Flooded Vessel or Core Catcher Heat Exchange Coefficients under Natural Convection	Sep 1994
NEA/CSNI/R(95)23	AHMED Code Comparison Exercise	Oct 1995
NEA/CSNI/R(95)24	The Chernobyl Reactor Accident Source Term Development of a Consensus View	Nov 1995
NEA/CSNI/R(95)25	Containment Bypass and Leaktightness	Oct 1995
NEA/CSNI/R(96)24	Ex-Vessel Core Melt Debris Coolability and Steam Explosions	Dec 1996
NEA/CSNI/R(96)25	High-Pressure Melt Ejection and Direct Containment Heating	Dec 1996

Table 3: PWG4 Workshops (held since 1992)

Ref.	Title	Date
NEA/CSNI/R(93)3	Instrumentation to Manage Severe Accidents	Mar 1992
NEA/CSNI/R(93)5	Core Debris/Concrete Interactions	Apr 1992
NEA/CSNI/R(94)11 NEA/CSNI/R(94)31	Large Molten Pool Heat Transfer	Mar 1994
NEA/CSNI/R(94)33 NEA/CSNI/R(95)3	Selected Containment Severe Accident Management Strategies	Jun 1994
NEA/CSNI/R(96)8 NEA/CSNI/R(96)9	The Implementation of Hydrogen Mitigation Techniques	May 1996
NEA/CSNI/R(96)6 NEA/CSNI/R(96)7	The Chemistry of Iodine in Reactor Safety	Jun 1996
NEA/CSNI/R(97)10 NEA/CSNI/R(97)27	Operator Aids for Severe Accident Management	Sep 1997

Table 4: PWG4 ISPs (last 5 years)

Ref.	Title	Pub.Date
NEA/CSNI/R(93)4	ISP-29: Distribution of Hydrogen within the HDR Containment under Severe Accident Conditions	Feb 1993
NEA/CSNI/R(94)27	ISP-34: Falcon Experiments FAL-ISP-1 and FAL-ISP-2	Dec 1994
NEA/CSNI/R(94)29	ISP-35: NUPEC Hydrogen Mixing and Distribution Test M-7-1	Dec 1994
NEA/CSNI/R(96)26	ISP-37: VANAM M3 - A Multi Compartment Aerosol Depletion Test with Hygroscopic Aerosol Material	Dec 1996