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Organisation de Coopération et de Développement Economiques
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NUCLEAR ENERGY AGENCY
COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

NEA/CSNI/R(2004)2
Unclassified

DEBRIS IMPACT ON EMERGENCY COOLANT RECIRCULATION

SUMMARY AND CONCLUSIONS
of a Workshop organised in Albuquerque, NM, USA
in collaboration with the U.S. Nuclear Regulatory Commission

25-27 February 2004

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), Korea (12th December 1996) and the Slovak Republic (14 December 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 28 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

CSNI

The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of senior scientists and engineers, with broad responsibilities for safety technology and research programs, and representatives from regulatory authorities. It was set up in 1973 to develop and coordinate 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 cooperation in nuclear safety amongst the OECD Member countries. CSNI's main tasks are to exchange technical information and to promote collaboration between research, development, engineering and regulation organizations; to review the state of knowledge on selected topics of nuclear safety technology and safety assessments, including operating experience; to initiate and conduct programs to overcome discrepancies, develop improvements and reach consensus on technical issues; to promote coordination of work, including the establishment of joint undertakings.

GAMA

The CSNI Working Group on the Analysis and Management of Accidents (GAMA) is mainly composed of technical specialists in the areas of thermal-hydraulics of the reactor coolant system and related safety and auxiliary systems, in-vessel behavior of degraded cores and in-vessel protection, containment behavior and containment protection, and fission product release, transport, deposition and retention. Its general functions include the exchange of information on national and international activities in these areas, the exchange of detailed technical information, the discussion of progress achieved in respect of specific technical issues, the performance of International Standard Problem exercises, and the preservation of knowledge and competence in its area of work. Severe accident management is one of the important tasks of the group.

WGOE

The main mission of the CSNI Working Group of Operating Experience (WGOE) is to analyse and develop insights from operating experience, in particular the safety significance of operating events, and to communicate these insights to CSNI, CNRA (Committee on Nuclear Regulatory Activities) and government and industry bodies. The functions of the WGOE include the review and analysis of operating experience from nuclear power plants and fuel cycle facilities, the development of improved techniques and methods for the review of operating events, the operation and maintenance of operating experience data bases (common cause failures, computer-based control systems important to safety, human performance) and Incident Reporting System (IRS) with IAEA.

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SUMMARY AND INTRODUCTION

1. Sponsorship

The Workshop on Debris Impact on Emergency Coolant Recirculation was held from 25 to 27 February 2004 in Albuquerque, NM (USA). It was organised under the auspices of the Committee on the Safety of Nuclear Installations (CSNI) of the OECD Nuclear Energy Agency (NEA), in collaboration with the US Nuclear Regulatory Commission (NRC).

2. Background of the Workshop

On 28 July 1992, a steam line safety relief valve inadvertently opened in the Barsebäck-2 nuclear power plant in Sweden. The steam jet stripped fibrous insulation from adjacent piping system. Part of that insulation debris was transported to the wetwell pool and clogged the intake strainers for the drywell spray system after about one hour. Although the incident in itself was not very serious, it revealed a weakness in the defense-in-depth concept which under other circumstances could have led to the emergency core cooling system (ECCS) failing to provide recirculation water to the core.

The Barsebäck incident spurred immediate action on the part of regulators and utilities alike in several OECD countries. Research and development efforts of varying degrees of intensity were launched in many countries and in several cases resulted in findings that earlier strainer clogging data were incorrect because essential parameters and physical phenomena had not been recognized previously. Such efforts resulted in substantial backfittings being carried out for BWRs and some PWRs in several OECD countries.

An international workshop organised in Stockholm in 1994 under the auspices of CSNI revealed a rather confusing picture of the available knowledge base, examples of conflicting information and a wide range of interpretation of guidance for assessing BWR strainers and PWR sump screen performance contained in US NRC Regulatory Guide 1.82. An International Working Group was set up by the CSNI to establish an internationally agreed-upon knowledge base for assessing the reliability of ECC water recirculation systems. The report of the International Working Group was published in 1996 with the title "Knowledge Base for Emergency Core Cooling System Recirculation Reliability" [NEA/CSNI/R(95)11].

An initiative was taken by the CSNI in 1998 to revisit the subject. The general objective was to make an update of the knowledge base for strainer clogging. The specific objective was to review the knowledge base developed since the former CSNI report in 1996, to review the latest phenomena for PWRs and to provide a survey of actions taken in member countries. Workshops were held in 1999 and 2000. The backfittings made with respect to strainer clogging, and the situation in fifteen countries at the end of 2001, were described in report NEA/CSNI/R(2002)6, "Knowledge Base for Strainer Clogging – Modifications Performed in Different Countries Since 1992".

New information contained in NUREG/CR-6771 indicated that the core damage frequency could increase by one to two orders of magnitude because of strainer clogging. Consequently, the CSNI decided to continue its previous efforts in the area. In addition, the CSNI decided to ask its working groups GAMA ands WGOE to develop a plan outlining activities that CSNI should undertake in the area of strainer clogging during the next few years.

3. Purpose of the Workshop

The overall purpose of the Workshop was to discuss the impact of new information made available since 1996 and to promote consensus among member countries on identification of remaining technical issues important to safety, and on possible paths for their resolution.

The specific purposes of the Workshop were:

a. To review the knowledge base which has been developed since report NEA/CSNI/R(95)11, was issued, and in particular information developed after 1999, and to consider the validity of the conclusions drawn.

b. To exchange information on the current status of research related to debris generation, debris transportation, and sump strainer clogging and penetration phenomena, in particular for PWRs, and to assess uncertainties. In particular, to critically review and then consolidate and expand the current, still incomplete and partially ambiguous, knowledge base.

c. To exchange and disseminate information on recent and current activities and practices in these areas.

d. To identify and discuss differences between approaches relevant to reactor safety.

e. To identify technical issues and programs of interest for international collaborative research and develop an Action Plan outlining activities that CSNI should undertake in the area of strainer or sump screen clogging during the next few years.

4. Scope and technical content of the Workshop

Since 1992 and again after the completion of report NEA/CSNI/R(95)11, a number of efforts have been carried out, new insights have been gained, and safety improvements, essentially larger strainers and exchange of insulation, have been implemented. Although several of the sump strainer clogging phenomena are similar for BWRs and PWRs, the report NEA/CSNI/R(95)11 focused on BWR phenomena. There could be differences in, for example, transportation and clogging characteristics of insulation debris and characteristics of failed coating which could warrant separate analyses for PWRs. There was, therefore, a need to consider clogging phenomena that are common to BWRs and PWRs, and also such phenomena that are unique for PWRs and VVERs. All sizes of breaks (small, medium, and large) were to be considered, as well as short and long term effects on the emergency coolant recirculation.

5. Workshop attendance

Over 130 experts attended the Workshop. They came from Belgium, Canada, the Czech Republic, Finland, France, Germany, Japan, Mexico, The Netherlands, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and the USA.

6. Summary of the main findings

a. The safety significance of the sump strainer clogging depends on the plant design (e.g. sump strainer, ECCS) and backfitting measures performed.

b. The following are examples of PWR design features that could influence the debris impact on the ECCS sump performance:

- Type of insulation (material, combination of materials, protection).
- Break size to be postulated.
- Transport in containment with or without containment spray system (CSS).
- Degree of turbulence and flow velocities in the sump influenced by CSS, water level, break flow location and sump geometry.
- Redundancy of sumps and residual heat removal system (RHRS).
- Strainer design (area, mesh size).
- Positioning of recirculation pumps and vortex protection.
- Amount of latent debris (e.g. use of qualified coatings, size of unprotected ferritic surfaces, cleanliness regime after outages).
- Chemical effects due to NaOH.

c. Sump strainer clogging may substantially increase the total core damage frequency. This statement depends strongly on the design features mentioned above and the assumption made to estimate the amount of insulation material reaching the sump strainer and the resulting pressure loss. Presently, different assumptions are used in different countries regarding debris generation and transport.

d. Timely resolution of the sump strainer clogging issue is essential. Some participants presented solutions to the problem based on:

- new strainer designs;
- reduction of insulation material generation;
- development of strainer cleaning procedures e.g. back-flushing.

e. Timely solutions to the sump strainer clogging problem are plant design specific and debris specific.

f. Assessment methods should continue to be enhanced. However, some countries have developed solutions or implemented compensatory measures.

g. Chemical effects have to be taken into account.

h. Latent debris continues to be of concern.

i. Thin bed effect is one of the major concerns impacting strainer head loss and core cooling.

OPEN ISSUES, CONCLUSIONS AND RECOMMENDATIONS

A plenary session was conducted which included a presentation of the IRSN proposal on an experimental program, a summary of the open issues based on the input of the participants, and a discussion on recommendations for issue resolution and perspective for future actions. These were input to the draft CSNI action plan in the area of strainer and sump screen clogging.

WORKSHOP RECOMMENDATIONS

Following are highlights of preliminary recommendations collected from workshop attendees during the Plenary Session.

Debris Generation Assessment Method Considerations

Conical or spherical model can be applied with L/D validated for specific plant design and insulation types. Other robust conservative assumptions can also be used.

Head loss

Head loss should be assessed by conducting plant specific and material specific tests. For most plants, the thin bed effect may occur and should either be avoided or accommodated.

Chemical effects

Chemical effects need to be taken into account for potential impact on pressure drop across sump screens.

Emergency procedures

Emergency procedures need to be enhanced or developed to handle potential debris blockage events.

Downstream effects

In seeking solutions to this issue, utilities need to find a balance between screen grid size, total screen area, and debris approach velocity. Downstream pumps, throttle valves, heat exchangers, diaphragms, containment spray nozzles and fuel elements should be considered in the assessment.

Plant cleanliness

It is highly recommended that utilities keep the plant, particularly the containment, clean. The foreign material exclusion program needs to be enhanced and enforced.

SESSION HIGHLIGHTS

SESSION 1

SAFETY ASSESSMENT AND REGULATORY REQUIREMENTS

Seven papers were presented in Session 1.

Taking benefit of the lessons from the Barsebäck accident, many countries have improved their units since 1992. In Sweden, new strainers were developed for PWR installations which included large sacrificial strainers and self-cleaning "wing-strainer" to provide robust debris handling.

The Canadian Nuclear Safety Commission (CNSC) and Canadian industry worked closely together to solve the strainer issue. AECL performed extensive tests and developed finned strainers to provide added strainer areas.

Despite the issue of an official recommendation in 1998, German technical support organisations and utilities performed further experiments to demonstrate the function of the sump suction after LOCAs. These works are still ongoing and will result in a modified recommendation in near future.

As for France, IRSN has conducted an experimental program since 2000, and concluded that sump screen blockage is a potential problem for the 58 existing PWR units. At present, DGSNR and EDF agree that there is a need to assess the sump screen blockage issue and to implement improvements on all French PWR units. In addition, an experimental program was proposed by IRSN to resolve two problems considered by the French to be still pending – debris generation and the water chemical effects.

While conducting technical assessment regarding the debris impact on sump performance, the present objective is to confirm or to define approved safety requirements to solve this safety issue for existing reactors and also for future reactors. A universal description of the LOCA progression and corresponding debris generation and behavior is not easy due to variability of plant designs and their respective safety requirements.

During the panel discussion at the end of the session, main topics covered were summarised as follows.

1. Debris generation and distribution

The key parameters were the following:

- Location of the break.
- Size of the break:
  - influence of break preclusion concept;
  - duration of the jet;

- insulation material;
- other potential debris (paints, concrete);
- coating qualifications.

2. Other latent debris

Quantity of latent debris in the containment depends mainly on the cleanliness of the containment. In addition, a good evaluation of dust (quantity, granulometry) is needed.

As conclusion, a good cleanliness of the containment is required.

3. Vertical transport and horizontal transport

The French paper presented debris transport tests results from IVANA and VITRA loops. The German paper emphasised the results of their new large scale and plant specific transport experiments. As conclusion, beyond differences due to different plant designs, some uncertainties remained in the assessment methods for debris transport. These uncertainties could be reduced using qualified CFD models (if available) or using well scaled tests appropriate for the respective plant design.

4. Chemical effects on the fiber bed

Taking into account the results obtained from experiments realized, several participants emphasised the risk of potential increased head loss across the fixed fiber bed on the screens considering possible chemical effects and creation of gelatinous material. For the creation of the gelatinous material, the main parameters are the temperature of the water containing boron and NaOH, the insulation material, and latent debris (e.g. dust, concrete, paints).

As conclusion, chemical effects on the fiber bed should be considered as part of the assessment of debris impact on sump performance.

5. Compensatory measures including emergency procedures

The USNRC emphasised the need for compensatory measures to minimize the potential for sump failure in the time period before final corrective actions are implemented.

As conclusion, depending on the plant's configurations, the efficiency of compensatory measures has to be thoroughly analysed, because some countries' experiences have shown that the risk of strainer clogging may not be lowered substantially.

6. Effects on components downstream from the filters

Investigations on downstream component effects have already been performed in different countries. These effects may occur, if the strainer mesh size is comparatively large (e.g. 9 mm x 9 mm).

As conclusion, the following downstream effects have to be considered:

- The mesh size of the filters and their total area (potential adverse effect of ingestion of debris and particulates can occur if the area is too large).
- The critical components are: pumps, valves, exchangers, diaphragms, spray nozzles and the fuel assemblies.

8. Future reactors

Future reactor vendors are required to address severe accidents (core melt) as part of design certification. In case of core melt, the parameters to be considered can be different, in particular the primary temperature due to hot gas circulation and consequently the total amount of debris generated after spray system activation during core melt progression may differ compared to design basis accidents.

Consequently, the main question is related to the respective safety requirements to be used to design the ECCS system for design basis accidents to prevent core melt, the Containment Heat Removal System used for severe accident mitigation, and passive systems.

As conclusion, regulatory requirements for future reactor designs dealing with debris impact on recirculation cooling have to be developed and plant vendors should consider the effects of debris generation for severe accident analyses.

SESSION 2

EXPERIMENTAL WORK

Seven papers were presented in Session 2.

Extensive investigation and tests on this issue were performed in Germany, and the conclusion was that no major backfitting was necessary on their Siemens PWRs. This was largely due to the use of strong cassette type insulation only on the primary system; special efforts to ensure break preclusion for the main coolant lines thus allowing application of reduced break sizes in their debris generation calculations; the fact that no containment spray systems exist in these plants; high water levels in the sump allowing increased sedimentation; and the enforcement of containment cleanliness after refuelling.

The general sense of the session was that because of the different containment designs and insulation materials used, more tests were needed for debris generation, debris transportation, head loss and downstream effects. Many tests were performed on this issue for the BWR plants, however, since PWR plant reactor coolant operates at higher pressure and temperature than those for the BWR plants, the debris generation test data (e.g. damage pressure, the L/D parameter, etc.) performed for BWR plants should not be blindly applied for the PWR plants. In addition, since these tests are very debris type specific, more tests will be needed for different debris types.

Regarding the head loss correlation presented in NUREG/CR-6224, some countries found it to be not suitable for their particular debris type and plants, and as a result they generated their own correlation instead. Since the head loss correlation presented in NUREG/CR-6224 is debris type specific, caution should be exercised in its use.

The IRSN representative presented the experimental program and results from the test loops (namely ELISA, MANON, IVANA, and VITRA) designed for the specific conditions of the plant type investigated and realised during the year 2001. Those results have been directly used to assess the risk of sump plugging in France.

The Canadian paper discussed the strainers implemented in the CANDU stations (between 64 and 1 200 m^2 of surface area). Those strainers have been designed and implemented such that other new modules can be added to those which are now in place. Considerable efforts have been expended to characterise and quantify debris (walk downs, etc.).

Other presenters discussed various experimental programs and results on latent debris inside containments, potential chemical reactions between the exposed material and post-LOCA containment environment, large scale tests of mineral wool insulation behaviour in German PWR plants, data to validate containment CDF models and head loss tests.

SESSION 3

ANALYTICAL WORK

Session 3 comprised six papers; four of them were presented in the workshop. The main topics dealt with the debris transport in water, the debris impact on pump performance, and break characterisation (break size and location) of pipes using fracture mechanics methods to determine the debris source term.

The approaches to investigate water-borne debris transport were the following: calculate debris generation from the break location by using basic hydraulic equations, use computational fluid dynamics (CFD) to determine the flow field in the sump region and particle transport, and open channel flow modelling. Significant efforts had been made and were still ongoing to validate the CFD calculations by special effect tests. Some of these experiments were discussed in Session 2.

The main goal of computing the flow field in the sump region was to identify locations where the flow velocities exceed the tumbling or lifting velocities of the anticipated debris types. This knowledge supported the estimation of the potential transport fraction of debris from the sump to the sump suction strainers. In addition, the effect of barriers could be assessed in changing the flow field and trapping debris in locations of low flow velocities.

First attempts have been made to include particle motion in CFD calculations. The results from simple test geometries indicated that the Eulerian-Eulerian approach in describing particle motion were successful. It will take at least another year for first calculations on real reactor sump conditions.

Analytical work on impact of debris passing the strainer is a difficult challenge. The first approach is to assess the debris impact on pumps, valves, heat exchangers and spray nozzles by screening existing operating experiences on components which are operating in fluid conditions that comprise particle loads. Thus pump failure rates such as those for pumps in raw water systems can be used to estimate the increase of failure rates of safety system pumps of similar design if operating under post-LOCA conditions including debris loads. The discussion showed that increased failure rates for post-LOCA operation with debris loads seem likely for multi-stage pumps, throttle valves and some heat exchanger designs. Thus, it seems to be highly safety significant to reduce the amount of debris penetrating the sump strainers.

SESSION 4

INDUSTRY SOLUTIONS

Five papers were presented in this session which described industry solutions for this issue in Belgium, Switzerland and the US. Two kinds of presentations were given. The first three presentations were from utilities or their engineering support that were studying the sump clogging issue, looking for solutions. The other two presentations concerned researches conducted by the industry, focusing on specific topics related to the debris source term (coatings and insulation materials).

1. Search for a solution

Most utilities seem to be convinced that the sump clogging is a real issue that must be addressed and solved. One part of the solution seems to be a significant increase of the strainer surface area. Another possibility to improve the situation is to modify the spray and/or on the recirculation flow rate, aiming to reduce the amount of debris generated and transported to the sump strainers. The impact of these actions on the safety studies and on the equipment was discussed.

Several utilities and designers presented that their specific designs are such that the sump clogging is not a significant safety concern for their plants if certain combinations of insulation materials are avoided or minimised. This is the case for German design PWRs. The associated debris impact assessment considered the use of strong cassette type insulation, the break preclusion concept, and the German PWR design which has no spray system with a sump geometry resulting in a low degree of turbulence at the sump floor. According to these specificities, the Germans and Swiss considered that the debris source term as well as the debris fraction transported to the strainers are relatively small and the sump should not be clogged during the recirculation phase.

Plant-specific ECCS blockage solutions anticipated to be used by US PWRs were reviewed by Framatome ANP of USA. These include solutions such as: reduction of ECCS flow rate or containment spray flow (for plants with excess decay heat removal margin) to reduce debris transported to the sump screen; enhancement of housekeeping efforts to reduce latent debris; installation of debris traps; use of enlarged passive strainers; use of active strainers, etc.

2. Industry research on specific topics (coatings and insulation materials)

As far as coating is concerned, especially no-DBA-qualified coatings, similar to insulation materials, it is important to determine the amount of generated debris and the behaviour of these with regard to the transportation and to the head losses on the strainers. The head losses due to insulation, including the effect of particles, seem to be well known. Detailed and validated correlations were developed in NUREG/CR-6224. The use of the NUREG/CR-6224 correlation to predict the head-losses for a specific case is a very difficult task that has to be performed only by experts.

EPRI and the Nuclear Utility Coating Council (NUCC) are conducting a research programme to investigate the actual effect of PWR post-LOCA environment on original equipment manufacturer's (OEM) protective coatings (paint) on components installed in US PWR containments.

Appendix 1

ORGANIZING COMMITTEE MEMBERS

The members of the Committee contributed text to the conclusions and to the session summaries.

Bhagwat **Jain** (NRC), later replaced by Anthony **Hsia** (NRC) - *Chairman*

Yves **Armand** (IRSN)

Juhani **Hyvärinen** (STUK), at the beginning of the work

Michael **Maqua** (GRS)

Jean-Marie **Matteï** (IRSN)

Bernhard **Pütter** (GRS)

Oddbjörn **Sandervåg** (SKI)

André **Vandewalle** (AVN), replaced at the Workshop by Béatrice **Tombuyses** (AVN)

Pekka **Pyy** (OECD/NEA)

Jacques **Royen** (OECD/NEA)

Appendix 2

OECD Nuclear Energy Agency (NEA)

Committee on the Safety of Nuclear Installations (CSNI)

Working Group on Analysis and Management of Accidents (GAMA)

Working Group on Operating Experience (WGOE)

AEN NEA Agence pour l'énergie nucléaire
Nuclear Energy Agency

NEA/NRC WORKSHOP ON DEBRIS IMPACT ON EMERGENCY COOLANT RECIRCULATION

Albuquerque, NM (USA)
25-27 February 2004

Organized in Collaboration with the U. S. Nuclear Regulatory Commission

Tuesday, 24 February, 2004

18h00 – 20h00 Registration/Refreshments, DoubleTree Hotel, Albuquerque

Wednesday, 25 February, 2004

8h00 Registration (cont'd) DoubleTree Hotel, Albuquerque

9h00 **Welcome and Opening Addresses**
CHAIRPERSONS: Dr. A. Hsia (USNRC), Dr. O. Sandervag (SKI)

- Opening Address: Dr. Sher Bahadur, Office of Nuclear Regulatory Research (USNRC)
- OECD/NEA Opening Address: Dr. J. Royen

9h40 **Workshop Objectives and related CSNI work**

- Workshop Objectives and Programme:
  Dr. A. Hsia (USNRC), Workshop General Chairman
- Introduction to CSNI Work in the Field of Strainer Clogging:
  Dr. O. Sandervag (SKI)

10h20 **Logistics and Local Information**
Dr. D.V. Rao (LANL), Workshop Technical Host

10h30 **Coffee Break**

Session 1: Safety Assessment and Regulatory Requirements

11h00 **Session 1 Begins**
CHAIRPERSONS: Dr. J.-M. Matteï (IRSN), Mr. J. N. Hannon (USNRC)

- Assessment on the Risk of Sump Plugging Issue on French PWR:
  Y. Armand, J.-M. Matttei (IRSN)

- The Sump Screen Clogging Issue in Belgium from the Standpoint of the Authorized Inspection Organisation (AIO):
  B. Tombuyses, P. De Gelder, A. Vandewalle (AVN)

12h00 **Lunch Break**

Wednesday, 25 February, 2004, cont'

Session 1: Safety Assessment and Regulatory Requirements, cont'd

13h00 **Session 1 Continues**
CHAIRPERSONS: Dr. J.-M. Matteï (IRSN), Mr. J.N. Hannon (USNRC)

- Conclusions Drawn from the Investigation of LOCA-Induced Insulation Debris Generation and its Impact on Emergency Core Cooling (ECC) at German NPP's – Approach Taken by / Perspective of the German TSO (TüV):
  J. Huber (TüV Süddeutschland)

- Uncertainties in the ECC Strainer Knowledge Base—The Canadian Regulatory Perspective:
  C. Harwood, V.Q. Tang (CNSC),
  J. Khosla (NSA Inc.),
  D. Rhodes, A. Eyvindson (AECL)

- NRC Approach to PWR Sump Performance Resolution
  J.N. Hannon (USNRC)

- Overview of Related Research in the U.S.
  A. Hsia (USNRC)

15h00 **Break**

15h30 **Session 1 Continues**
CHAIRPERSONS: Dr. J.-M. Matteï (IRSN), Mr. J.N. Hannon (USNRC)

- Results of Tests with Large Sacrificial and Self-cleaning Strainers:
  M. Henriksson (Vattenfall)

- Sump Plugging Risk – Open questions:
  Y. Armand, J.-M. Matteï (IRSN)

16h30 **Panel discussion with all Session 1 speakers**

17h30 **End of Day One**

Thursday, 26 February, 2004

Session 2: Experimental Work

8h30 **Session 2 Begins**

CHAIRPERSONS: Dr. Y. Armand (IRSN), Dr. B. Letellier (LANL)

- Risk of Sump Plugging—Experimental Program:
  Y. Armand, J.-M. Matteï (IRSN),
  Batalik, B. Gubco, J. Murani, I. Vicena (VUEZ),
  V. N. Blinkov, M. Davydov, O. I. Melikhov (EREC)

- Emergency Core Cooling Strainers—The CANDU Experience:
  A. Eyvindson, D. Rhodes (AECL),
  P. Carson (NBP),
  G. Makdessi (AECL)

10h00 **Coffee Break**

10h30 **Session 2 Continues**

CHAIRPERSONS: Dr. Y. Armand (IRSN), Dr. B. Letellier (LANK)

- Characterization of Latent Debris from Pressurized-Water-Reactor Containment Buildings:
  M. Ding, A. Abdel-Fattah, B. Letellier, P. Reimus, S. Fischer (LANL)
  T.Y. Chang (USNRC)

- Debris Accumulation and Head-Loss Data for Evaluating the erformance of Vertical PWR Recirculation Sump Screens:
  C. Shaffer (ARES Corp.),
  M.T. Leonard (Dycoda),
  A.K. Maji, A. Ghosh (UNM),
  B.C. Letellier (LANL),
  T.Y. Chang (USNRC)

- Experimental Investigations for Fragmentation and Insulation article Transport Phenomena in Water Flow:
  S. Alt, R. Hampel, W. Kaestner, A. Seeliger (Univ. Zittau)

12h00 **Lunch Break**

Session 2: Experimental Work, cont'd

13h30 **Session 2 Continues**
CHAIRPERSONS: Dr. Y. Armand (IRSN), Dr. B. Letellier (LANL)

- Effects of Debris Generated by Chemical Reactions on Head Loss Through Emergency-Core Cooling-System Strainers:
  K. Howe, A. Ghosh, A.K. Maji (UNM),
  B.C. Letellier, R. Johns (LANL),
  T.Y. Chang (USNRC)

- Results of the Latest Large-Scale Realistic Experiments Investigating the Post-LOCA Behavior of Mineral Wool Debris in PWRs (Fragmentation, Transport, Deposition on Sump Strainers, Slip Through Strainers, Pressure Losses):
  U. Waas, G.-J. Seeberger (Framatome ANP)

15h00 **Panel Discussion in the presence of all Session 2 speakers**

15h30 **Coffee Break**

Session 3: Analytical Work

16h00 **Session 3 Begins**
CHAIRPERSONS: Dr. M. Maqua (GRS), Dr. T.Y. Chang (USNRC)

- Simple Evaluation Model for Long Term Debris Transport Velocity in the Torus of a Mark I Containment:
  J.U. Klügel (KKW Gösgen)

- Numerical Investigations for Insulation Debris Transport Phenomena in Water Flow:
  E. Krepper, A. Grahn (FZ Rossendorf)

- Debris Ingestion Effects on Emergency Core Cooling-System Pump Performance:
  F.W. Sciacca (Omicron Safety & Risk Technologies),
  D.V. Rao (LANL)

- Separate Effects Tests to Quantify Debris Transport to the Sump Screen:
  A.K. Maji (UNM),
  D.V. Rao, B.C. Letellier, L. Bartlein (LANL),
  K. Ross (Alion Science & Technology),
  C.J. Shaffer (ARES Corp.)

- Break Area for Use in Determining Debris Generation: 1
  T.S. Andreychek, B. Maurer, D.C. Bhomick, J. Ghergurovich, J. Petsche, D. Ayres (Westinghouse),
  A. Nana (Framatome ANP),
  J. Butler (NEI)

- Containment Sump Channel Flow Modeling: 2
  T.S. Andreychek, D.U. McDermott (Westinghouse)

17h20 **Panel discussion in the presence of all Session 3 speakers**

Collection of Input from participants regarding the open issues for Day 3 final discussion

18h00 **End of Day 2**

[1] This paper will be included in the Proceedings but will not be presented during the Workshop, because of lack of time and late submission.

[2] This paper will be included in the Proceedings but will not be presented during the Workshop, because of lack of time and late submission.

Friday, 27 February, 2004

Session 4: Industry Solutions

8h30 **Session Begins**

CHAIRPERSONS: Ms. B. Tombuyses (AVN), Mr. J. Butler (NEI)

- Actions Taken in the Belgian Nuclear Power Plants for the Resolution of the GSI-191:
  J.-C. Delalleau, C. Delveau, G. Du Bois d'Enghien, L.Vandermeeren, J. Pirson (Tractebel)

- Safety Analysis Performed in Switzerland for the Resolution of the Strainer Clogging Issue:
  J.U. Klügel, (KKW Gösgen)

- Original Equipment Manufacturers' (OEM) Protective Coating Design Basis Accident Testing:
  J. Cavallo (Corrosion Control Consultants & Labs),
  A. Griffin (EPRI)

10h00 **Coffee Break**

10h30 **Session 4 Continues**

CHAIRPERSONS: Ms. B. Tombuyses (AVN), Mr. J. Butler (NEI)

- Overview of Site Specific PWR Blockage Solutions:
  J.W. Walker, H. L. Williams (Framatome ANP)

- LOCA Induced Debris Characteristics for Use in ECCS Sump Screen Debris Bed Pressure Drop Calculations
  G. Zigler (Alion Science & Technology)
  G. Hart (ARTEK Inc.)
  J. Cavallo (Corrosion Control Consultants & Labs)

11h30 **Panel discussion in the presence of all Session 4 speakers**

12h00 **Lunch Break**

Plenary Session : WORKSHOP FINAL DISCUSSION AND CONCLUSIONS

13h30 **Final Discussion/Conclusions**

Moderated by Workshop General Chairman

- Assessment of the Risk of Sump Plugging Issue - Contribution to an Action Plan Proposal
  Y. Armand, J.-M. Matteï (IRSN)
- Summary of the open issues based on the participants replies
- Discussion, recommendations for issue resolution and perspectives for future actions
- Input to the CSNI Action Plan on “Sump Strainer Clogging”

Closing remarks

16h30 **End of the Workshop**

Appendix 3

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