April 5, 2004

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THRU: Michele G. Evans, Chief /RA/ A. Hsia for
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Division of Engineering Technology

FROM: T. Y. Chang, Project Manager /RA/
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SUBJECT: TRIP REPORT ON THE NEA/NRC WORKSHOP ON DEBRIS IMPACT ON EMERGENCY COOLANT RECIRCULATION

I attended the subject workshop in Albuquerque, NM from February 25 to 27, 2004. This workshop was initiated by the NRC, and co-sponsored by NRC and the NEA/CSNI of OECD, and is the third international workshop on the topic of debris impact on emergency coolant recirculation. This topic is directly related to the NRC Generic Safety Issue (GSI) 191, "Assessment of Debris Accumulation on PWR Sump Performance," which is being resolved by RES, NRR and the industry.

The objective of this workshop was for the countries who were faced with this issue to share current and planned research; to share current and planned regulatory activities; to identify and discuss different issues and approached for resolution; to identify areas for possible collaboration; and to develop an action plan for CSNI.

The workshop consisted of five sessions. More than 130 people representing the industry, the research community, and regulatory bodies from 14 countries participated in this workshop. The attached trip report provides more detailed information about this workshop, and includes the background, objective, program description, summary of sessions, summary of actions by different countries, CSNI action plan, workshop recommendations, and NRC follow-up activities.

Attachment: Trip Report

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Trip Report on the NEA/NRC Workshop on
Debris Impact on Emergency Coolant Recirculation
Albuquerque, NM, 2/25/04 - 2/27/04

## I. BACKGROUND

In the event of a LOCA within a nuclear power plant containment, thermal insulation and other materials in the vicinity of pipe break could be dislodged as debris by the break steam/water-jet impingement. Debris could be in the form of fragmented insulation and other materials, such as paint chips, paint particulates and concrete dust. This issue was resolved for BWRs in the late 1990's, the on-going NRC Generic Safety Issue (GSI)-191, "PWR Sump Blockage" was established to address this issue for the PWRs in the U.S.

This is the third international workshop on this issue. This workshop was initiated by the NRC, and co-organized by NRC and the NEA/CSNI of OECD (Nuclear Energy Agency / Committee on the Safety of Nuclear Installations, of the Organization for Economic Cooperation and Development). Prior workshops organized by NEA/CSNI took place in Stockholm, Sweden in 1994 and 1999.

## II. OBJECTIVE

The objective of this workshop was for the countries who are faced with this issue to: 1) share current and planned research, 2) share current and planned regulatory activities, 3) identify and discuss different issues and approaches for resolution, 4) identify areas for possible collaboration, and 5) develop an action plan for CSNI.

## III. WORKSHOP PROGRAM DESCRIPTION

The workshop consisted of five sessions (for details see IV below). All together 25 papers were accepted and included in the five sessions, and 23 were presented. More than 130 people representing the industry, the research community, and regulatory bodies from 14 countries participated in this workshop.

Sher Bahadur, Deputy Director of DSARE/RES, delivered the opening address to the workshop participants. Anthony Hsia, Section Chief, ERAB/DET/RES, was a member of the Organizing Committee and served as the General Chairman of the workshop. He presented the "Overview of Related Research in the U.S." in Session 1. John Hannon, Branch Chief, SPLB/DSSA/NRR, was Co-Chairman of Session 1, and presented the "NRC approach to PWR Sump Performance Resolution." In addition, T.Y. Chang, Project Manager, ERAB/DET/RES, was the Co-Chairman of Session 3. Five papers were presented by the NRC contractors on NRC-sponsored research.

The detailed program of the workshop is attached as Appendix A. The complete attendee's list is attached as Appendix B.

## IV. SUMMARY OF SESSIONS

The workshop consists of five sessions. Following are highlights from each session:

Session 1, Safety Assessment and Regulatory Requirements

Seven papers were presented in Session 1.

In Sweden new strainers were developed for PWR installations which include large sacrificial strainers and self-cleaning "wing-strainer" to provide robust debris handling.

The approach taken by Canada was for the industry and the regulatory body, Canadian Nuclear Safety Commission (CNSC) to work closely. AECL performed extensive tests (a paper in Session 2) and also developed finned strainers to provide added strainer areas.

PWR plant owners in Germany investigated the issue from 1997 to 1999, and concluded that plant backfitting in German PWRs was not necessary to ensure ECC following a LOCA with insulation debris generation. The rationale for this conclusion was summarized in Session 2 below.

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 an agreement exists among EDF, DGSNR and IRSN on the need to consider the problem and to implement improvements on all the French units. In addition, an experimental program is proposed by IRSN (see V, CSNI Action Plan below) to resolve two problems considered by the French to be still pending - debris generation and the water chemical effects.

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 backfitting was necessary on their Siemans PWRs, largely because of the effort to adopt the break preclusion principle in their debris generation calculations, the fact that no containment spray systems exist in these plants, and the enforcement of controlled cleanliness after refueling.

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.

Session 3. Analytical Work

Four papers were presented in this Session. In addition, two papers were included in the proceedings but were not presented due to late receipt and limitation of time.

The conclusion of the session was that even though big strides have been made, the computational fluid dynamics (CFD) method was still generally not mature enough for accurate debris transportation prediction. While using this method, validation by tests must be performed to confirm the analyses.

Session 4, Industry Solutions

Five papers were presented in this session which described industry solutions for this issue in Belgium, Switzerland and the US.

Belgian plants had implemented or are evaluating interim compensatory actions, and these actions are identical to the ones suggested in NRC Bulletin 2003-01. In Switzerland, an action program was initiated on this issue by the Swiss Federal Nuclear Safety Inspectorate in 1992. The issue was considered closed in 1994 based on implemented modifications of suction strainers (flow area increased by a factor of 7 to 30) for BWRs and the approval of strainer designs based on plant-specific analysis for PWRs.

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

Plant-specific ECCS blockage solutions anticipated to be used by U.S. 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.

Plenary Session, Workshop Final Discussion and Conclusion

This session 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 into a CSNI action plan which was formulated the day after the conclusion of the workshop (2/28/04) by the Organization Committee (Anthony Hsia is a member), and are summarized in V and VI below.

## V. SUMMARY OF ACTIONS BY DIFFERENT COUNTRIES

The NRC participants in the workshop did a survey of actions by different countries regarding this issue. They are attached as Appendix C.

## VI. CSNI ACTION PLAN

The objective of the Action Plan is to outline activities that CSNI should undertake on this issue for the next three years. Following are highlights of the Action Plan.

### IRSN proposal

During the Plenary Session, IRSN presented a proposal to improve the knowledge of debris generation and chemical effects by experimental programs. CSNI recommends that each member country review the proposal and provide comments by April 16, 2004.

### Permanent Website

A permanent website "Information on debris impact on recirculation performance" will be established by CSNI and under the responsibility of OECD, which will contain reports, documents, data bases, events, chat room, new designs, etc.

### Future Workshops

Two European regional workshops are being planned to involve Eastern European countries. The first one, a General Topics Workshop, is proposed to take place in Bratislava, Slovakia in the Spring of 2005. Particular attention will be paid on chemical effects. The second one, a Special Topics Workshop, is proposed to take place close to EREC (a test facility) in Russia in the Spring of 2006. Particular attention will be paid on debris generation.

A General Topics Workshop will be organized in the fall of 2006 for Asian countries. The location is yet to be determined.

The next international workshop could be combined with the workshop in Asia in 2006 or 2007.

### Technical Opinion Paper

A technical opinion paper will be prepared in 2005 by the Working Group on Analysis and Management of Accidents (GAMA) and the Working Group on Operating Experience (WGOE) of NEA. The purpose of this technical paper will be: to provide a concise view and update of this issues, and to provide recommendations to decision makers.

### Interim Compensatory Measures

Bulletin 2003-01 was issued by the US NRC in June 2003, requesting licensees to provide interim compensatory measures. Since there are many different designs of nuclear power plants, therefore, compensatory measures should be design specific.

WGOE and GAMA should form a task force by the end of 2004 to further study this issue and provide recommendations to minimize sump plugging consequences.

### Future Reactors (Generation III+) - Including Passive Safety System Designs

CSNI recommends that GAMA integrate future reactor sump blockage issue assessment and resolution into its work on advanced reactor safety.

## VII. 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.

## VIII. NRC FOLLOW-UP ACTIVITIES

AECL of Canada performed extensive short-term (up to 10 days) and long-term (up to 90 days) head loss tests. The RES staff is trying to contact AECL to explore the possibility for obtaining the test information and results.

## IX. APPENDICES

Appendix A. Workshop Program
Appendix B. Workshop Attendee's list
Appendix C. Summary of Actions by Different Countries

Appendix A

Program for
NEA/NRC Workshop on
Debris Impact on Emergency Coolant Recirculation
Albuquerque, NM, 2/25/04 - 2/27/04

## 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. Mattei (IRSN), Mr. J. Hannon (USNRC)**

- Assessment on the Risk of Sump Plugging Issue on French PWR: Y. Armand, J.-M. Mattei (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**

## 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. Mattei (IRSN), J. 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 (Ontario Power Generation)

10h00 **Coffee Break**

10h30 **Session 2 Continues**
**CHAIRPERSONS: Dr. Y. Armand (IRSN), Dr. B. Letellier (LANL)**

- 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 Performance 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 Particle Transport Phenomena in Water Flow:
  S. Alt, R. Hampel, W. Kaestner, A. Seeliger (Univ. Zittau)

12h00 **Lunch Break**

## Session 3: Analytical Work, cont'd

- Break Characteristic Modeling for Debris Generation Following a Design Basis Loss of Coolant Accident: [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.

## 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. Mattei (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 B

## Workshop Attendee's List

*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

## *Participant List*


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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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3218

*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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*Workshop on Debris Impact on Emergency Coolant Recirculation*
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*Workshop on Debris Impact on Emergency Coolant Recirculation*
*25-27, February 2004 ~ Albuquerque, New Mexico*

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# Appendix C

## Summary of Actions by Different countries

## GERMANY

The following information was formulated after discussions with a number of German delegates to the NRC/NEA workshop. I spoke primarily with Dr. Andreas Schaffrath, TUV Nord Gruppe, and he prefaced his comments to say that they represented his own personal opinions and not necessarily those of the German government.

*Have any of the reactors in Germany made hardware or procedural modifications to address the debris accumulation concern? If so, what?*

- Larger strainers were installed at 2 of the 13 PWRs. Screen sizes were increased from 5 sq. meters to 20 sq. meters. In the second case, the plant owners wanted to avoid potential complications before the generic study was published in December 2003. The modification involved placing a 3x3 mm screen in front of the as built 9x9 mm screen.
- The modification was installed at the cost of about $200k before returning to power operation after a refueling outage in mid 2003, based on economic considerations, even though it was felt that a safety problem was not present. The modification was made to minimize the amount of debris that would be transported to the core inlet.

*Has the regulator taken any regulatory actions (e.g., their equal to generic communications, Orders, increased inspections) to address the debris accumulation concern? If so, what?*

- Containment close-out cleanliness inspections are routinely verified by technical support organizations. These inspections were initiated independently from the strainer clogging considerations. Also, a 9-question letter has been sent to the plant owners to obtain plant specific information. This letter is focused on validating previously approved assumptions used in ECC analysis, taking into account new experimental data in Germany and other investigations on this topic from foreign countries.

- Generic investigations have been completed on representative material (MD2), strainer size (20 sq. meters), and velocity in front of the strainer (see presentations by J. Huber, Dr. Wass). This generic investigation was presented by utilities at the end of 2003. What is missing up to now is a plant specific assessment.

- In early 2003 comparisons between the strainers in the first NPPs with typically small strainer areas were made with the later designs. During this exchange of information there were discussions about the technical details (e.g., slip through strainers). At this time the technical support organizations and GRS had only selected information about the transport experiments (the report was not published until the end of 2003).

- During this technical discussion, the reloading of the 2nd plant was completed and the plant owners were faced with the consideration of slip of insulation and debris impact in the core. To avoid a standstill, the utility decided to install the finer mesh screen, even though they did not think a safety problem existed.

- In general, finer mesh screens have advantages for debris impact on the core, especially for RDT2 mineral wool insulation, which tends to produce larger pressure drops that MD2 mineral wool. As discussed in the generic report, these conclusions are conservative and plant specific information will be needed to specify exact amounts.

*Has the regulator or industry conducted experiments or analytical studies? If so, why?*

- Yes, studies and experiments were completed in December 2003 and were reported on at this workshop by Mr. Josef Huber, TUV Suddeutschland , Dr. Waas, Framatome-ANP GmbH, Mr. Alt, University of Applied Sciences Zittau/Goerlitz, and Dr. Krepper, FZ Rossendorf. Confirmatory CFD studies, model development and code validation will be conducted by the University of Applied Science and the Research Center at Rossendorf and are planned to be completed by end of 2006. These studies will model debris transport and focus on pressure drop across fuel filters caused by downstream debris (mineral wool that may have passed through the screen and not fallen to the floor in the sump). In Germany there is a general agreement (not a requirement) to avoid boiling at the fuel pin (no local boiling due to pressure drop caused by debris buildup).

*Has the regulator or industry considered changing the design or licensing basis of the reactors to address the debris accumulation concern?*

- Regulatory authorities in Germany have given at least the following reasons for concluding that the debris accumulation concern is not a safety problem for their PWRs:

    1. The application of break exclusion minimizes the break size to 0.1A which greatly diminishes the debris generation.
    2. Mineral wool insulation is encased in cassettes which are not likely to be dislodged under blow down loads.
    3. Only stainless steel is used for safety systems inside containment, greatly reducing the potential for corrosion and chemical reactions in post-LOCA environment.
    4. Only qualified coatings are used inside containment.
    5. No CSS is employed, minimizing dirt and debris wash down.
    6. Containment cleanliness is verified by inspection.
    7. Behavior of mineral wool insulation compared to other types of insulation shows that mineral wool is less likely to cause sump strainer blockage.

*If the regulator or industry has not taken any actions, but plans to do so, do they have a target date or schedule?*

- As stated above, the responses to the plant specific assessments will be performed in 2004. Additionally, investigations to be completed by the end of 2006 include experiments at the University of Applied Science and analytical studies by Research Center Rossendorf Zittau.

John N. Hannon
February 27, 2004

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Subject: Survey of International Actions Associated with GSI-191, PWR Sump Debris Accumulation Concerns

Assigned Country: Spain

Staff Member Reporting: Joel Page

Date: March 3, 2004

1. Have any of the reactors in that country made hardware or procedural modifications to address the debris accumulation concern? If so, what?

   No hardware modifications have been done. Procedural actions (backflushing) have been implemented.

2. Has the regulator taken any regulatory actions (e.g., their equal to generic communications, Orders, increased inspections) to address the debris accumulation concern? If so, what?

   Regulator formally endorses NRC regulatory guidance so far.

3. Has the regulator or industry conducted experiments or analytical studies? If so, why?

   Collaborating in research and testing with WOG and Framatome.

4. Has the regulator or industry considered changing the design or licensing basis of the reactors to address the debris accumulation concern?

   No input on this question.

5. If the regulator or industry has not taken any actions, but plan to do so, do they have a target date or schedule?

   Actions associated with research and tests results are expected by the end of 2004.

# INFORMATION ON SUMP BLOCKING IN CHECH REPUBLIC

Person Interviewed: Dr. Bohumir Kujal, Senior Consultant
Interviewer: K. Parczewski NRR/DE/EMCB

Chech Republic has four VVER- 440 type reactors at Ducovany and two, recently constructed, VVER-1000 type reactors at Temelin

(1) *Has any of the reactors in that country made hardware or procedural modifications to address the debris accumulation concern? If so what?*

The VVER-440 Mwe reactors were modified by replacing:

a. the original multi-row arrangement of internal strainers by module arrangement and the inlet strainer with 10 X 10 mm mesh was replaced by perforated metal sheet with 10 mm diameter holes. This arrangement has a good gravitational self-cleaning effect.

b. the total area of internal strainers was increased from 5.05 $m^2$ to 19.8 $m^2$ for one screen.

c. finer wire with square mesh was used for inner strainers.

These modifications were based on the results and studies performed in the dynamic experimental facility of GOSNICAES in Kashira Russia and in the Research Institute of Energetic Installations (VUEZ) in Livice, Slovakia.

The reactors VVER1000 type were of a newer design. The design was based on the analyses and tests similar to the VVER-440 type reactors which have been performed by the same organizations. The only difference was that a special mockup model was build at VUEZ for performing plant specific tests.

(2) *Has the regulator taken any regulatory actions (e.g,., their equal to generic communications, Orders, increased inspections) to address the debris accumulation concern? If so what?*

The reviewed person could not answer this question.

(3) *Has the regulator or industry conducted experimental or analytical studies? If so why?*

The industry has conducted analytical and experimental studies (see the answer to question 1).

(4) *Has the regulator or industry considered changing the design or licensing basis of the reactors to address the debris accumulation issue?*

In the design of the VVER-440 type reactors modifications were made to address the debris accumulation concern. In the VVER-1000 type reactors no such modifications were needed, because all the design modifications which were made in the VVER-440 reactors were incorporated in the original design of the VVER-1000 type reactors.

(5) *If the regulator or industry has not taken any actions, but plan to do so, do they have a target date or schedule?*

N/A

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Summary of information regarding Belgium actions to increase reliability of PWR sumps

Belgium has seven PWRs, and at two of them, hardware changes were made to increase the size of the sump strainers in 1996 (after issuance of RG 1.82, rev 1). They have a formal 10-year safety evaluation of each plant, and these two plants were apparently the first. Then, after the LANL parametric study was issued in 2002, the Belgian Safety Authority requested that action plans be developed for all plants. The plants made a comparison of cases with similar screen area to debris volume ratios and evaluated all plants and determined that adequate NPSH exists for newer (2002) estimates of debris, but there was little margin at some plants. Also, following issuance of Bulletin 2003-01, the Belgian Safety Authority requested that compensatory actions be developed, and the plants began to develop operating procedure changes including: delaying spray actuation, shutting off the unnecessary train of ECCS (to slow transport and approach velocity), and adding procedures for obtaining additional water sources. They are reconsidering the possible action of shutting off an ECCS train, due to concerns about restarting the pumps, and are awaiting a WOG report before modifying any procedures. The plants also began performing walk-downs for cleanliness and latent debris. Following issuance of draft NEI guidance, they reduced the scope of walk-downs, but then increased the scope due to calcium silicate and latent debris concerns.

The Belgians have not performed sump testing of their own, but have performed analytical studies for each of the plants, as discussed above. They are awaiting additional information, including any test results (mostly from the U.S. and France). They realize that they have little or no margin in available NPSH at some of the plants, and that there will be need for additional actions, beyond the current activities, in order to fully resolve the sump issue. One specific action being studied is the use of a jet pump design for recirculation, similar to one installed in the French Chooz A plant (which resolved an NPSH problem there). They are also evaluating the sump screen mesh size to be compatible with the fuel assembly debris catchers. They indicated that they would not wait for the formal 10-year review at each of the plants in order to require specific actions needed to address this issue.

C. Hammer
3/2/04

03-03-04
T.Y. Chang

# INFORMATION FROM CANADA ON SUMP PERFORMANCE ISSUE

**Person Interviewed:**

David Rhodes, Manager, Mechanical Equipment and Seal Development, Atomic Energy of Canada Limited (AECL), Chalk River Laboratories, Chalk River, Ontario, Canada.

AECL is the engineering company that designs, develops and services the CANDU pressurized heavy water reactors. Our counter part, the CNSC (Canadian Nuclear Safety Commission, its predecessor before 1999 was the Atomic Energy Control Board, AECB), was not represented at the workshop, even though 2 CNSC staff members co-authored a paper with David Rhodes and others on the topic of "Uncertainties in the ECC Strainer Knowledge Base - The Canadian Regulatory Perspective," which was presented by David Rhodes at the Workshop.

**Status of Canadian operating NPPs:**

Canada has 20 CANDU nuclear power plant units in operation today (from 4 utilities at 5 different sites), in terms of utilities, they are:
*1.* Ontario Power Generation - Pickering A (4 units), Pickering B (4 units), Darlington (4 units).
*2.* Bruce Power - Bruce A [4 units, but only 2 units are in operation. Bruce A (1)(2) are mothballed for refurbishment, Bruce A (3)(4) were mothballed but were restarted recently], Bruce B (4 units).
*3.* Quebec Hydro - Gentilly 2 (1 unit).
*4.* New Brunswick Power - Point Lepreau (1 unit).

**Questions and Answers:**

*1.* Has any of the reactors in that country made hardware or procedural modifications to address the debris accumulation concern? If so, what?

All operating plants have either completed or near completion of some sort of hardware modifications. This generally is a combination of: (1) mainly replacing the original strainers with new *Finned Strainers* which have much larger strainer surface areas, and (2) some change out of calcium silicate insulation. 14 NPP units have either already installed or are nearing completion of installing the AECL-designed *Finned Strainers.* The surface area of strainers in those plants before the Barseback event were in the range of 4 $m^2$ to 10 $m^2$, after installation of the *Finned Strainers*, the surface area of strainers are in the range of 64 $m^2$ to 1200 $m^2$ (Darlington station now has 1200 $m^2$ of strainer surface area due to the high particulate to fiber ratio of 8:1). According to David, changing out CalSil is costly, the estimate is on the order of 1 Million dollars per plant chiefly because of requirements for minimizing radiation for workers and not from the material cost.

In spite of all the tests conducted (see 3 below), David said AECL believes that there are still a lot of uncertainties on this issue. Therefore additional conservatism were applied in the

following areas: an extra margin of factor of 2-4 for head-loss, some stations have 2 100% capacity pumps and strainers, and 80% credit for viscosity.

*2.* Has the regulator taken any regulatory action (e.g., their equal to generic communications, Orders, increased inspections) to address the debris accumulation concern? If so, what?

Yes, after the Barseback event in Sweden, CNSC in 1997 issued a Notice to all Canadian utilities requiring them to review their ECC strainer capability in view of the potential increase in pressure drop, and address any deficiencies.

*3.* Has the regulator or industry conducted experiments or analytical studies? If so, what?

In response to the CNSC Notice, the Canadian utilities contracted AECL, through the CANDU Owners Group (COG), to perform extensive fundamental testing to establish the important parameters governing ECC strainer performance. As a result of all the testing, a substantial body of knowledge was produced and has been used by the utilities to support their final ECC strainer design solutions in their submittals to CNSC.

Tests conducted include:

(1) Small-scale tests: Debris strength and density, deposition rate of particulate and fibrous debris, effect of temperature on debris, effect of particulate size on generic clogging, bench-top flow loop to observe flow passage through a strainer. Debris tested include fiber glass, calcium silicate, rust, dust, dirt, and paint chips.

(2) A number of short term (~ 2 days) and long term (20 to 90 days) tests were conducted to obtain measurements of head loss and the head loss correlation. Two types of tests were performed:

a. Medium-scale tests: Head-loss tests were conducted in a Jacuzzi-sized tank connected to a flow loop with flow and temperature control. A strainer is positioned in the tank, afore-mentioned debris were added to the flow to monitor pressure drop across the strainer. Over 150 test were conducted with duration ranging from less than 1 hour to 90 days.

b. Large-scale tests: Head-loss tests were conducted in a tank 1.5 m (deep) x 2.5 m (wide) x 5 m (long), again connected to a flow loop with flow and temperature control. This tank is large enough to accommodate a complete *Finned Strainer* module. Temperature can be adjusted from 20C to 55C, and flow rate is up to 240 L/s.

One interesting piece of information regarding the chemical effects: David mentioned the tests were conducted attempting to replicate the post-LOCA condition in a CANDU plant, which includes the flow, temperature, pH value, etc. He mentioned that no "gelatinous" material was observed in the tests, including the 90-day tests. However he said the post-LOCA sump pool pH value in a CANDU containment is in the range of 10 - 10.5 (chemically lithium is controlling), which is higher than the pH values we usually see in U.S. PWRs. Whether this difference in pH value will have any bearing on the "gelatinous" material formation remains to be seen by our impending tests.

Another observation is that during one long term test, on the 25th day the temperature of the loop dropped from 40C to 15C (he said due to cooling from ocean) and the head-loss across the strainer worsened. They believe this is due to the big increase in viscosity of flow at this temperature.

*4.* Has the regulator or industry considered changing the design or licensing basis of the reactors to address the debris accumulation concern?

No input on this question.

*5.* If the regulator or industry has not taken any actions, but plan to do so, do they have a target date or schedule?

N/A.