Status of Sump Clogging Issue in Japan

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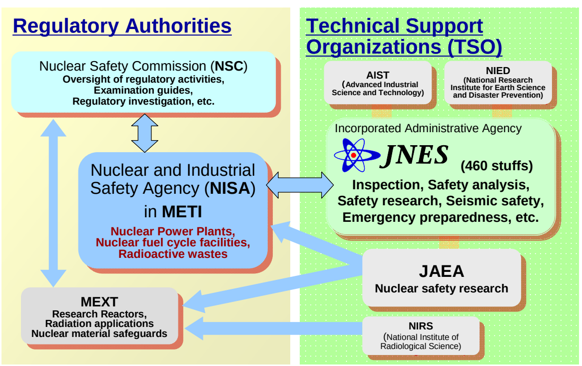
Contents

Who is JNES?



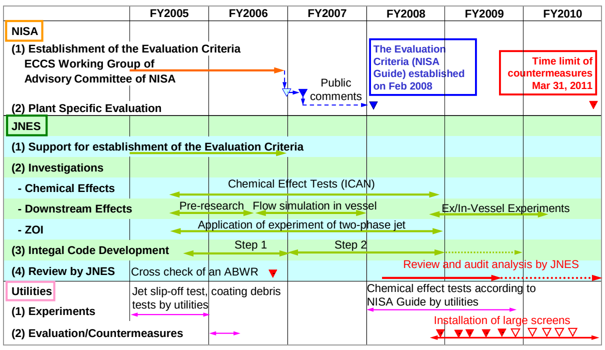
Progress in Japan

- **Strainer clogging occurred in 1990s**
  - Barsebäck (1992), Perry (1993), Limerick (1995), etc.
  - It was judged to be irrelevant to Japanese NPPs at that time
- **Licensees reported inadequate management of variety of foreign materials in containment in 2004**
- **Insulators were scattered in the turbine building by secondary piping rupture at Mihama Unit 3 in 2004**
- **NISA directed licensees**
  - to report data of Insulators
  - to execute interim compensatory measures (**ICMs**) up to the completion of permanent measures (**PMs**)

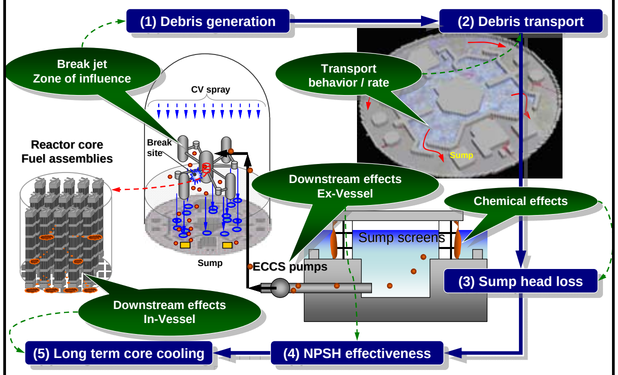
Progress in Japan

- **Rulemaking and Review Guides**
  - The Technical Standard (Ministerial Order No.62) was revised so as to incorporate PMs against sump clogging issue
  - The BWR review guide was issued in October 2005, and revised guideline was issued adding the guide to PWR in February 2008 based on licensees' reports and results of studies by JNES
  - The guideline required licensees to conduct head loss tests considering plant specific chemical effect conditions
- **Current status**
  - All BWR had replaced with new Insulators and larger strainers
  - PWR licensees need to complete PMs till the end of March 2011
  - Licensing reviews of new sump screens are under way and several PWR utilities have replaced with larger sump screens

Progress in Japan



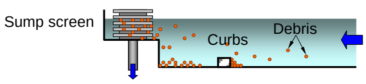
Sump clogging issues and evaluation phases



Motivation of debris transport evaluation

1. **Need for rational and balanced decision making to reconsider upstream as well as downstream**

2. **Need for prediction of flow and debris transport in containment vessel under wide LOCA conditions considering plant specifics with uncertainties**
   – Little attention has been given to flooding flow that might promote debris transport → full scale transient simulation
   – Able to take credit of debris settling or capture by curbs?
   – Expect to compensate lack of experiments by analyses



Approach to debris transport evaluation

1. **JNES developed a CFD code SANSUI 2.0 based on a Lagrangian particle method (MPS*) with a multiphase model and a turbulence model**
   – Particle method has advantage over mesh method in free surface, moving boundary and large deformation

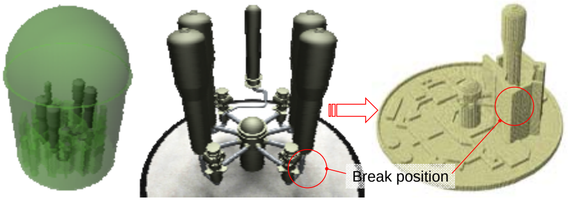
2. **Code validation**
   – Comparison with the open channel debris transport experiments
   – Results show that this model can simulate debris transport behaviors such as resuspention, lifting curbs, and settling

3. **Application to full scale PWR simulation**
   – Accelerated by parallel computing

MPS: Moving Particle Simulation method, Koshizuka (1996)

Application to full scale simulation

- **Debris transport simulation on LBLOCA condition**



(a) CV model (b) Primary system model (c) Particle model

Geometry Model

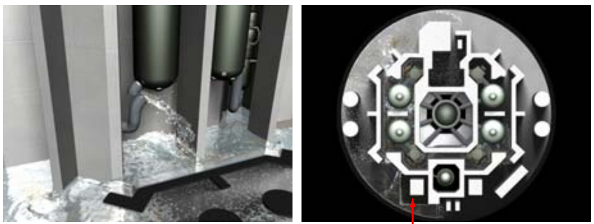
Application to full scale simulation

- **Debris transport simulation on LBLOCA condition**

2.8(s) after break

Application to full scale simulation

- **Debris transport simulation on LBLOCA condition**

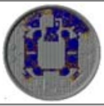
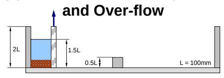
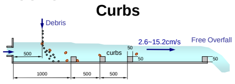


18.9(s) after break

The amount of debris which reached sump across the surrounding curb was evaluated by this analysis

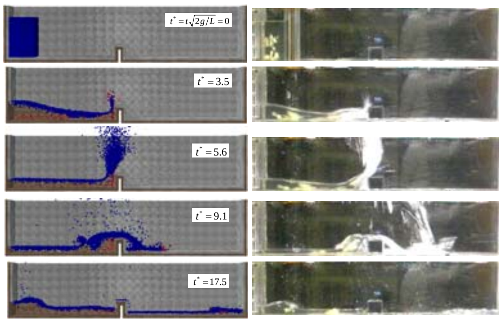
Validation

- **Comparison of the simulation and experiments**

Situation of containment floor under LOCA condition	Experimental Setup
(1) Blowdown Phase Floor is not filled by water Fast, shallow, flooding in a few minutes 	**(1) Dam-break, Breaking Wave and Over-flow** 
(2) Washdown Phase Floor is filled by water Slow, deep flow A few minutes later 	**(2) Open Channel Flow with Curbs** 

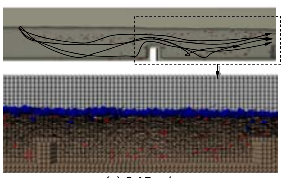
Validation (1) Blowdown Phase

- **Dam-break, breaking wave and over-flow**



Validation (2) Washdown Phase

- **Open channel flow with curbs**



(a) 0.15 m/s

(b) 0.026 m/s

Analyses

(a) 0.15 m/s

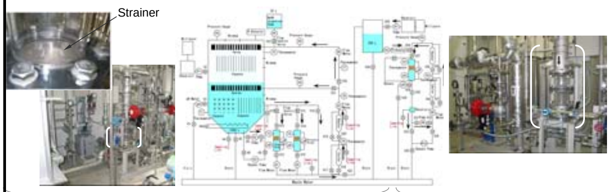
(b) 0.10 m/s

(c) 0.026 m/s

Experiments

Chemical / Downstream Effect Tests

- **Integrated Chemical Effect Assessment on NPSH (ICAN) Test Facility**
  - Head loss tests under condition of chemical effects
  - Temperature control assuming recirculation mode
  - Condition of both PWRs and BWRs in Japan
    - e.g. Rockwool (RW), NaOH and Hydrazine as pH buffer, etc.

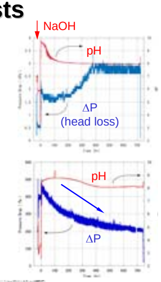


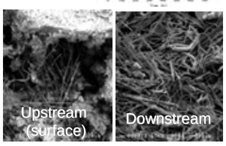
Chemical Effect Test Loop　　Head Loss Test Loop

Chemical / Downstream Effect Tests

- **ICAN Tests (~2007)**
  - Head loss due to chemical effect was observed and it depended on test conditions.
  - Precipitates mainly deposit on the upstream of fiber debris.
  - HCl that assumed to be produced by cable degradation made fiber debris brittle and suppressed head loss increase.

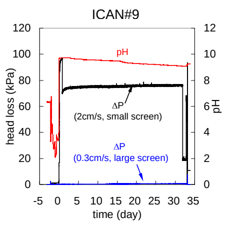
Run	Condition
ICAN#1	Typical PWR (Rockwool, small amount of Al)
ICAN#2	Typical PWR (CalSil on Rockwool debris)
ICAN#3	Effect of temperature
ICAN#4	PWR with Ice Condenser ($Na_2B_4O_7$)
ICAN#5	PWR with Hydrazine (H_2NNH_2)
ICAN#6	Typical BWR (No chemical except HCl)
ICAN#7	Re-examination of ICAN#1
ICAN#8	Fine fibrous debris with Hydrazine





Chemical / Downstream Effect Tests

- **ICAN Tests (~2008)**
  - With small amount of Al, carbon steel causes significant head loss increase.
  - Precipitate from carbon steel corrosion is estimated to be hydroxides.
  - Without temperature decrease, precipitates can be deposited on debris of the screen.
  - Tests demonstrated effectiveness of enlarged screen, which reduces flow velocity and precipitates per unit area.



Run	Objective	Tank	Spray (Initial 4hours)	pH	Flow velocity (sump screens)
ICAN#9	NaOH plant w/o HCl	H_3BO_3 (2800ppmB)	NaOH: 8348g	10	2cm/s (small)
ICAN#10	N_2H_4 plant w/o HCl		$N_2H_4H_2O$: 994g	7.5	0.3cm/s (large)
ICAN#11	BWR plant w/o HCl	No borate	No pH buffers	6-8.5	0.56 cm/s (large)

Chemical / Downstream Effect Tests

- **ICAN Tests**
  - So far, we have seen several tendencies
    - Reflected to the NISA guide as attention for chemical effect tests
    - Used as references to judge validity of conservativeness of licensees
  - It is not easy to predict behavior of chemical head loss
- **Downstream tests are under way**
  - **Debris penetration test**
    - assuming enlarged screens
  - **Fuel rod precipitation test**
    - With an electrically heated rod on ICAN facility assuming long term core cooling
  - **Head loss test at lower nozzle of fuel assembly**
    - Relation among debris amount, head loss and flow velocity will be examined under long term core cooling condition

Summary

- **Prospect for rational resolution**
  - It seems difficult to resolve all issues with past approaches
    → Need revised guides based on state-of-the-art knowledge
  - Balance through all phases is needed
    →reconsider upstream for downstream
    (e.g. ZOI, debris transport rates)
- **Expectation for simulation**
  - Lagrangian CFD approach might be a breakthrough
  - "Trustworthiness will be corroborated by accumulation of evidence"
    → Verification and Validation (V&V)
    → Phenomena Identification and Ranking Table (PIRT)
  - Uncertainty and initial value sensitivity should be considered
    → Uncertainty / statistical evaluation (e.g. BEPU, ensemble forecast)

Summary (cont'd)

- **JNES activities**
  - **Support of rule making and licensing review**
  - Comprehensive investigations; some are under way
    - Numerical simulations, chemical/downstream effect tests, etc.
- **Current chemical and downstream effect tests**
  - Debris penetration test assuming replaced screens (Ex-vessel)
  - Fuel rod precipitation test (In-vessel)
  - Head loss test at lower nozzle of fuel assembly (In-vessel)
- **Our activities are opened on Website**
  - Detail information, numerical modeling, and experimental results are available on JNES website, journals and proceedings of conferences.