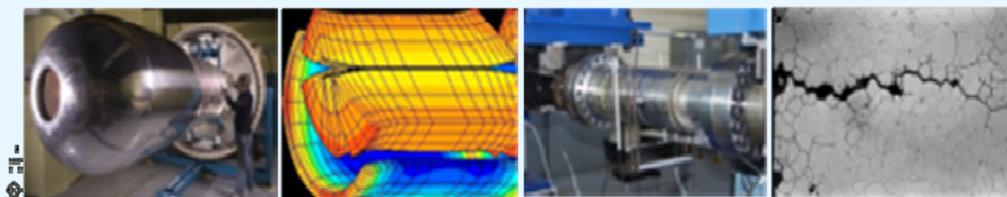




Centre of Excellence for Nuclear Materials

Workshop

Materials Innovation for Nuclear Optimized Systems



December 5-7, 2012, CEA – INSTN Saclay, France

Tetsuo SHOJI

University of Tohoku (Japan)

**Materials Ageing Degradation Programme in Japan
and Proactive Ageing Management in NPP**

Workshop organized by:

Christophe GALLÉ, CEA/MINOS, Saclay – christophe.galle@cea.fr

Constantin MEIS, CEA/INSTN, Saclay – constantin.meis@cea.fr



Materials Ageing Degradation Programme in Japan and Proactive Ageing Management in NPP

Tetsuo SHOJI¹

¹Tohoku University, New Industry Creation Hatchery center, LMRR unit (Sendai, Japan)

Predictive and preventive maintenance technologies are increasingly of importance for the long term operation (LTO) of Light Water Reactor (LWR) plants. In order for the realization LTO to be successful, it is essential that aging degradation phenomena should be properly managed by using adequate maintenance programs based on foreseeing the aging phenomena and evaluating their rates of development, where Nuclear Power Plants can be continued to operate beyond the original design life depending upon the regulatory authority rules. In combination with Periodic Safety Review (PSR) and adequate maintenance program, a plant life can be extended to 60 years or more. Plant Life Management (PLiM) is based upon various maintenance program as well as systematic safety review updated based upon the state of the art of science and technology. One of the potential life time limiting issue would be materials ageing degradation and therefore an extensive efforts have been paid worldwide. In 2007, NISA launched a national program on Enhanced Ageing Management Program and 4 nationwide clusters were formed to carry out the national program where materials ageing degradation was one of the major topics. In addition to these degradation modes, one important activities in this program is proactive materials degradation management directed by the autor which is a kind of the extension program of NRC PMDA program based upon more fundamental approach by a systematic elicitation by the experts nominated from all over the world. NISA program can be devived into two phases, one is from fiscal years (FY) 2006 - 2010 and the other FY 2011. Later phase is focusing more on System Safety due to Fukushima NPP accident.

The main objectives of the Phase I is to evaluate potential and complex degradation phenomena and their mechanisms in order to identify future risks of component aging in nuclear power plants. The following items are of particular concern in this phase: (a) investigation of potential materials ageing phenomena and corresponding plant issues, and (b) investigation of the effectiveness of evaluation techniques, concerning potential aging phenomena. In NISA PMDM Phase I, three approaches are considered to be essential for proactive aging management. First one is a deductive science- based approach, second one is an intuitive based approach based upon a careful analysis of operating experiences and third one is systematic elucidation. In particularly, the deductive method based on a fundamental scientific understanding of material degradation is highlight for the management of possible latent or cascade materials degradation processes which have not yet become obvious in operating plants. Proactive management issues associated with materials aging in LWRs were discussed in terms of suggested research topics that should be undertaken in either the short or long-term. Based on these discussions prioritized lists of medium and long term research projects were established for both PWRs and BWRs. In this paper, the research subjects to be considered for the aging degradation phenomena in PWR structural materials, which were discussed at the Proactive Aging Management Experts' Panel Meeting of the NISA Project, are introduced as follows.

1. Pressurized Water Reactor (PWR)

1.1 Research subjects for shorter term projects to be completed in ~5 years

- 1) SCC initiation phenomena, including the effects of surface stress/strain, residual stress, microstructure and strain localization,
- 2) Development of qualified mechanisms-based lifetime models for PWSCC propagation in nickel base alloys,
- 3) Characterization of weld metals, dilution at interfaces and heat affected zones,

- 4) Strain localization, strain history and relationship to cold work, microstructure and compositional banding,
- 5) Effect of environment on fatigue and fracture resistance in PWRs,
- 6) Flow-accelerated corrosion in PWRs.

1.2 Research subjects for longer term projects to be completed in ~5 to 10 years.

- 1) Effects of irradiation flux and fluence on stainless steels and nickel base alloys and the effect on SCC,
- 2) Modeling and validation of residual stress/strain profiles in complex welded geometries and how these may change with neutron fluence,
- 3) Initiation of SCC in structural alloys, modeling stochastic features, heat to heat variability, effects of long exposure periods,
- 4) Quantification of potential synergistic effects between competing degradation modes for PWRs,
- 5) Quantitative modeling of oxidation and EAC based on fundamental physical principles for PWRs.

In particular, oxidation localization and acceleration is a key process of these environmentally assisted cracking and we proposed a novel approach to characterize this oxidation localization behavior based upon the profile analysis of metal/oxide interface. Oxidation localization dynamics can be quantitatively evaluated by the parameter, depth of localized oxidation penetration. Analyzed results can be summarized as Fig. 1.

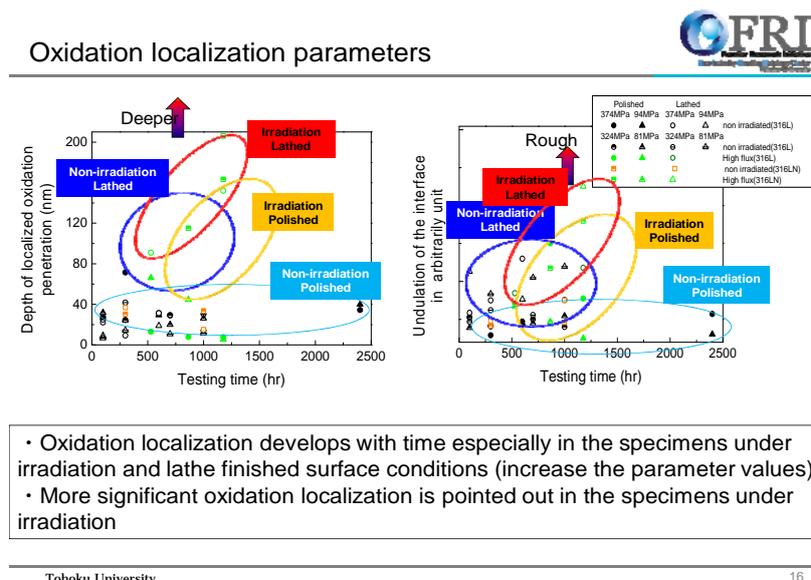


Fig. 1: Oxidation localization behavior and influence of surface finish (polished and lathed) and neutron irradiation on 316L stainless steel in oxygenated water.

References

- [1] J. Muscara, Expert Panel Report on Proactive Materials Degradation Assessment. USNRC NUREG Report, CR-6923, February 2007.
- [2] T. Shoji et al., Proactive Material Degradation Research Subjects for Light Water Reactors. E-Journal of Advanced Maintenance Vol. 4, No. 2 (2012) pp. 36 - 56, Japan Society of Maintenology.

Acknowledgements

This work has been performed as part of the Program of Enhancement of Ageing Management and Maintenance of Nuclear Power Plants organized by the Nuclear and Industrial Safety Agency, NISA, in the Ministry of Economy, Trade and Industry, METI, of Japan. The authors would like to thank the Experts' Panel members for their contributions without which no success of the program would never be made.

Workshop **Materials Innovation for Nuclear Optimized systems**

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Materials ageing degradation program in Japan and proactive ageing management in NPP

Dec. 6, 2012

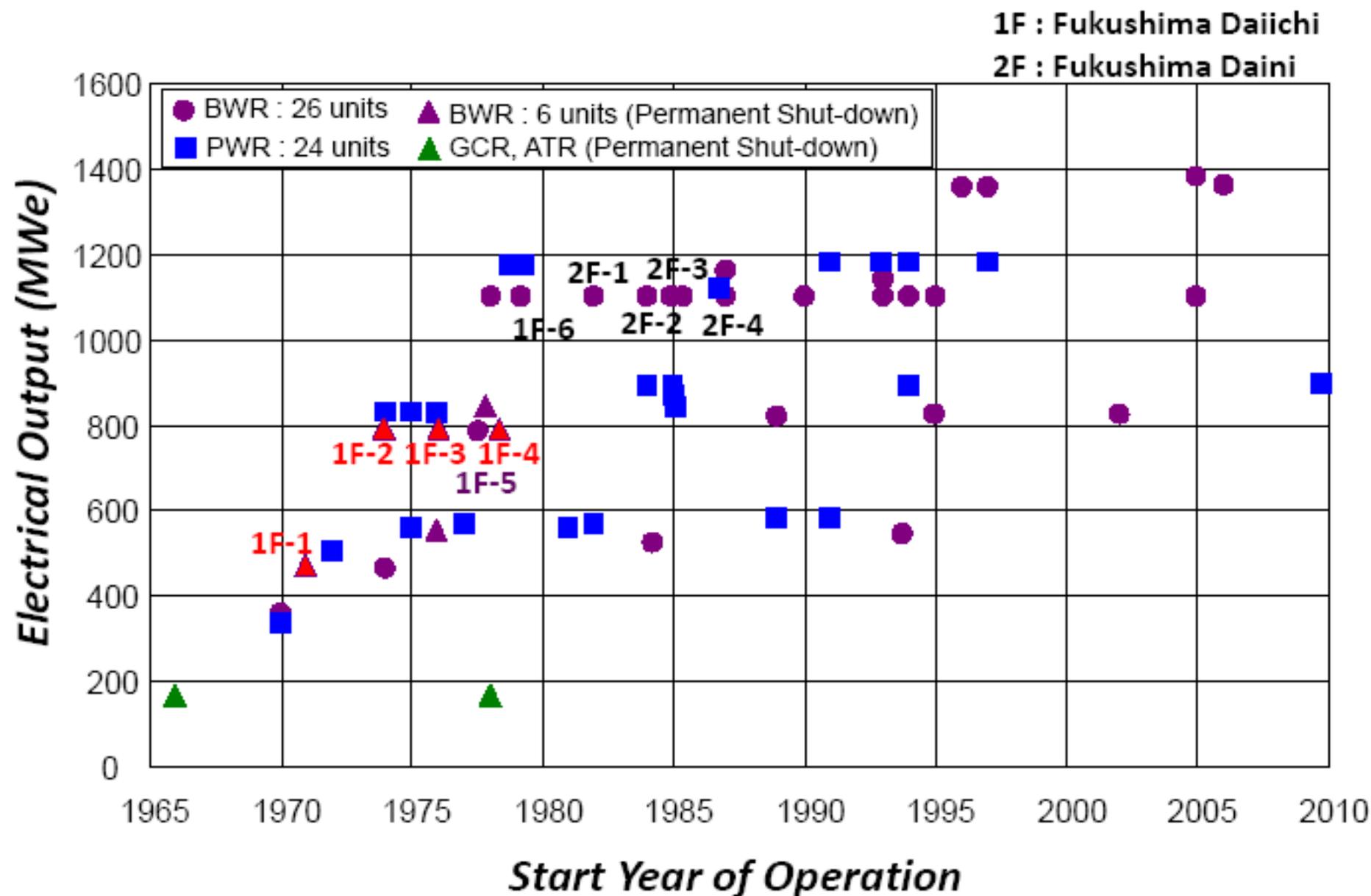
Tetsuo Shoji

**Frontier Research Initiative, FRI
Long-term Materials Reliability Research unit
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Content

- **Introduction and background**
- **Technical Evaluation of Aging Management**
 - **Degradation, Materials, Systems, PDCA**
- **Proactive Materials Aging Degradation Management**
 - **Annual Experts' Panel Meeting**
 - **Proactive Issues raised and summarized by the Experts' Panel**
 - **Proactive Issues raised by FRI from the outcomes of NISA, NRA projects**
- **Fukushima Daiichi Accident**
 - **Sequence, Actions taken or being taken for future and lesson learn**
 - **Long-and Mid term road map for decommissioning**
- **Summary**

Nuclear Power Plants in Japan



Introduction and Background

Ageing Management is a mandatory action for safety and reliable NPP operation and also as a consequence, it can improve the plant availability and economy. Also, it is important to consider Ageing Management before plant constructions to design the systems, structures and components for better maintainability for Ageing Management.

Understanding of Ageing Mechanism is fundamental for above and continuous concerns and check and review about potential ageing degradation is required for Preventive and Predictive ageing management, PROACTIVELY

**LTO beyond original design life to 60 years/80 years or more
Global standard and common understanding based upon scientific/technical basis**

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Current Periodic Inspection, Periodic Safety Review and Ageing Management Technical Evaluation in Japan

Start of Commercial Operation

Periodic Inspection (every 13~24 Months)

Periodic inspection is an inspection for important components conducted in required period.

Government official inspector stands aside the licensee's Periodic Check and confirm licensee's check record



Periodic Safety Review (PSR) (every 10 Years)

10 Years

10 Years

10 Years

10 Years

10 Years

10 Years



August 2008, NISA established PSR Implementing Guideline. As evaluation objects, implementing status of operational safety activities, feedback status of latest technical knowledge to licensees' operational safety activities and PSA are provided, however, it is desirable to implement PSA in voluntary manner.

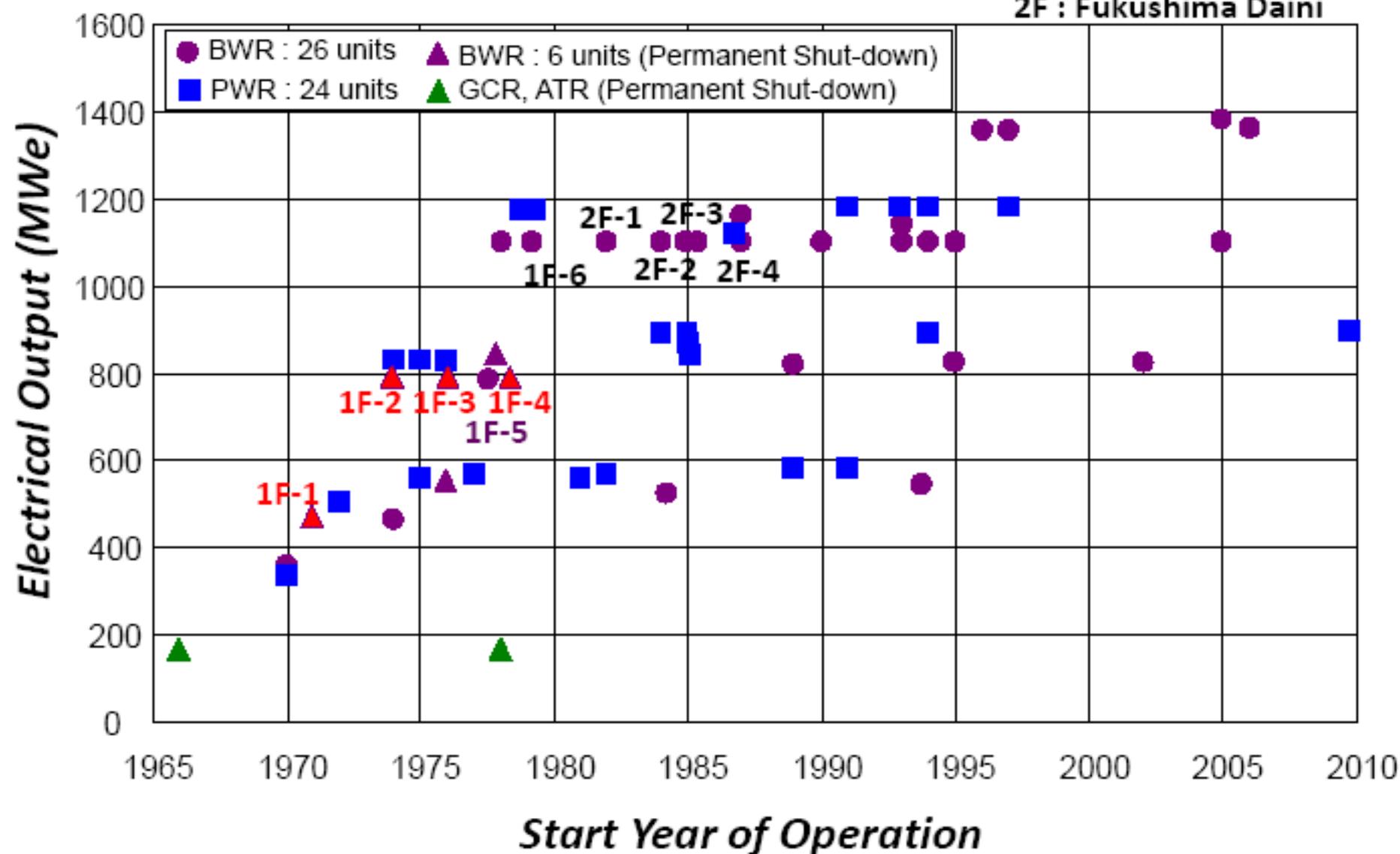
Ageing Management Technical Evaluation (AMTE)
for SALTO before the end of 30 years of Operation



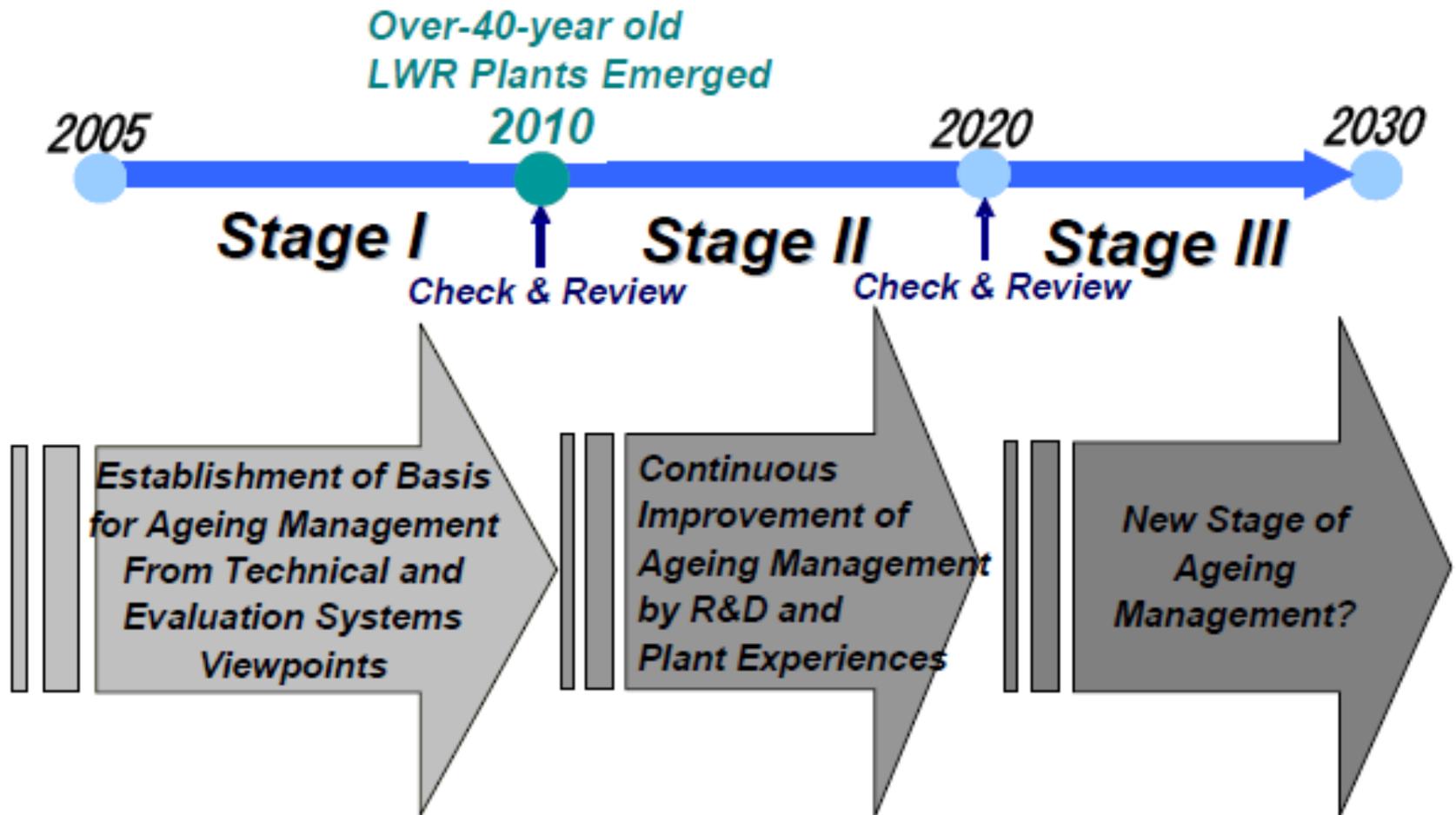
Nuclear Power Plants in Japan

1F : Fukushima Daiichi

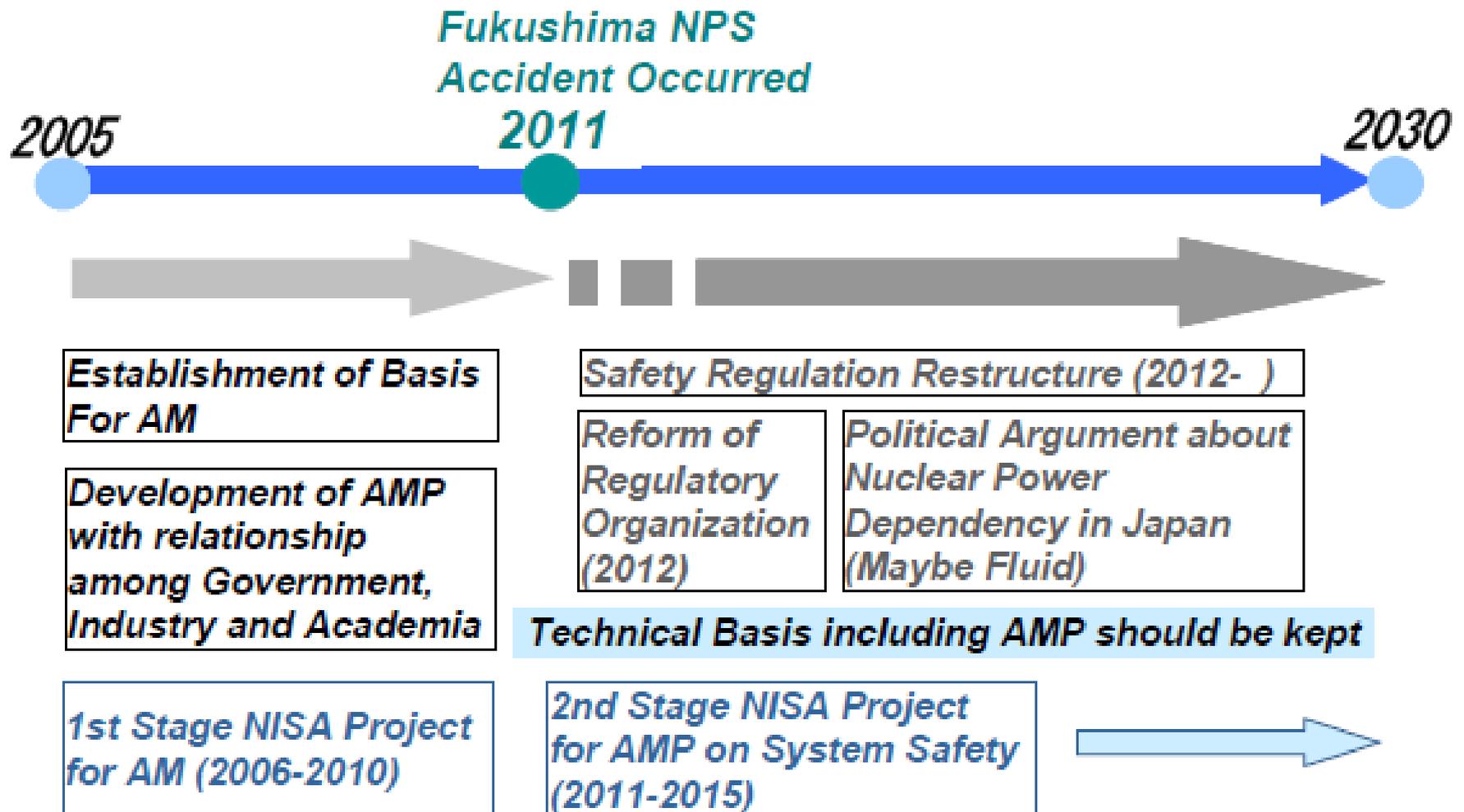
2F : Fukushima Daini



Three-Stage Approach of Roadmaps for AM Set up Before Fukushima Nuclear Power Station Accident in Japan



Ageing Management Improvement Activities After Fukushima NPS Accident in Japan



New Plants/Plant Life Extension

- **Limited construction sites**
- **Long lead time for a new plant**
- **Flexibility in LTO**
- **Possible Up-rating and longer fuel cycle**
- **Advanced Aging Management Technology**
- **Definition of Plant Life**
 - **Design life, Engineering life, Economical life, Physical life,**
 - **No fixed life by Aging Management including replacements**
 - **Technology transfer through new construction**

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 - **Degradation, Materials, Systems, PDCA**
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 - **Annual Experts' Panel Meeting**
 - **Proactive Issues raised and summarized by the Experts' Panel**
 - **Proactive Issues raised by FRI from the outcomes of NISA, NRA projects**
 - **Issues concerns : Oxidation under irradiation, Charge transfer of hydrogen in metals, Superabundant Vacancies**
- **Fukushima Daiichi Accident**
 - **Sequence, Actions taken or being taken for future and lesson learn**
 - **Long-and Mid term road map for decommissioning**
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Proactive Materials Aging Degradation Management

■ Concerns related to NP plant ageing

Apprehensions for the possibility of newly occurrence of potential and latent material aging degradation phenomena (Risk management)



the degradation phenomena in components that have not yet experienced

- Unknown phenomena
- Combination of known phenomena
Synergy / Cascade

The past and present : Beautiful explanation of the scenario after happening of events

Prediction of unknown phenomena

Known phenomena become more complex

Proactive methodology against ageing degradation phenomena

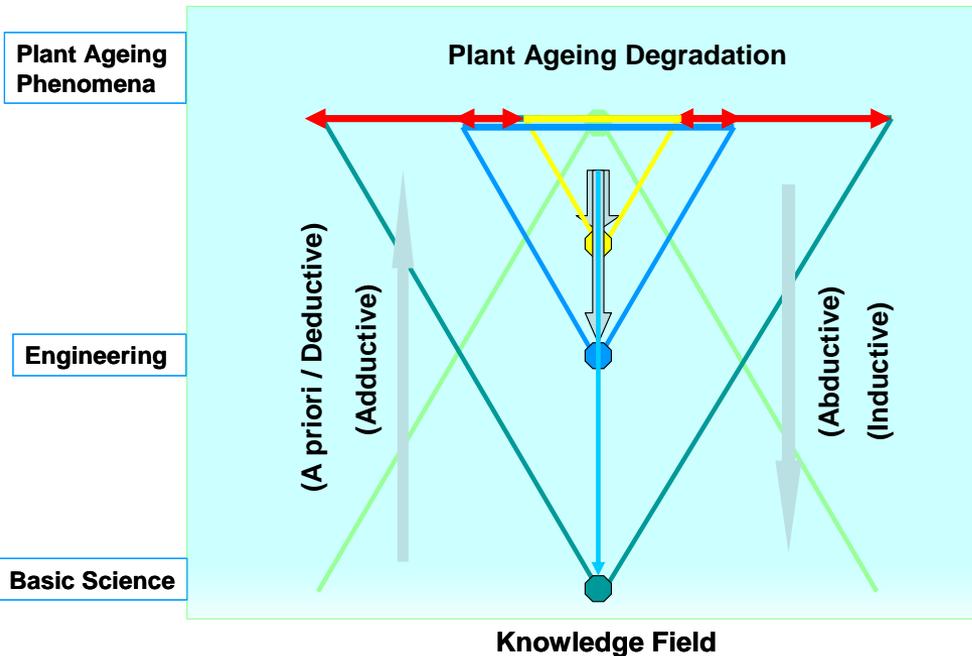
Systematic reorganization and verification of knowledge acquired on various subjects

The future : Prediction of potential and latent materials ageing degradation phenomena

Annual Experts' Panel Meeting

■ Necessity of proactive action against ageing degradation phenomena and system safety

More Academic/Fundamental approach for true proactive aging management with better predictive and preventive capability for latent/potential aging degradation, synergistic aging degradation and cascade aging degradation



- *Inductive proactive methodology* based on the root cause analysis of the events which have occurred in the past.
- *Deductive proactive methodology* based on fundamental understanding of scientific degradation mechanisms and their integration
- *Systematic elicitation* (To clarify the potential and latent aging degradation phenomena and mechanism by imagination)

An illustration of a formalized relationship between "analytical" and "a priori" approaches to life prediction based on expert iterations between the two approaches.

Annual Experts' Panel Meeting

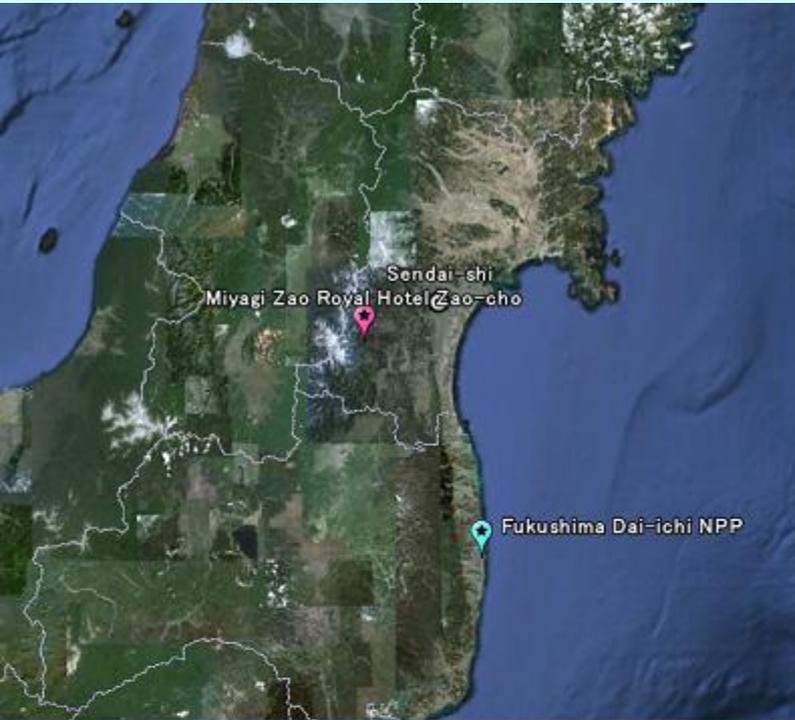


Held at Tohoku University on 2008.10.29-31



Held at Tokyo Electric Power Company on 2009.10.22-23

Annual Experts' Panel Meeting



Held at Miyagi Zao Royal Hotel on Oct.21-22, 2010



Held at Miyagi Zao Royal Hotel on Dec.7-9, 2011 15

2011PMDM Experts' Panel Meeting Member

- **Dr. Peter Ford (Consultant)**
- **Dr. Roger Staehle (Consultant)**
- **Dr. Karen Gott (Consultant)**
- **Dr. Tiangan Lian (EPRI)**
- **Dr. Claude Amzallag (ONET - Technologies)**
- **Dr. Jean-Paul Massoud (EdF SEPTEN)**
- **Dr. Peter Scott (Consultant)**
- **Dr. Peter Andresen (GE CRD)**
- **Prof. Hannu Hanninen (Aalto University)**
- **Dr. Armin Roth (AREVA)**
- **Prof. Roger Newman (U. Toronto)**
- **Prof. Il-Soon Hwang (SNU)**
- **Prof. En-Hou Han (IMR)**
- **Dr. Dolores G. Briceno (CIEMAT)**
- **Dr. Stephen Bruemmer (PNNL)**
- **Dr. C.E. (Gene) Carpenter (NRC)**
- **Dr. Alan Turmbull (NPL)**
- **Prof. Robert Cottis (U. Manchester)**
- **Prof. Philippe Marcus (ENSCP)**
- **Dr. Thierry Couvant (EdF)**
- **Dr. Torill M. Karlsen (OECD Halden)**
- **Prof. Jean-Y. Cavaille (INSA-Lyon)**
- **Prof. Yves Brechet (INPG)**
- **Dr. Pierre Combrade (Consultant)**
- **Dr. Hans-Peter Seifert (PSI)**
- **Prof. Tim Burnstein (U. Cambridge)**
- **Dr. Damien Feron (CEA)**
- **Dr. Ren Ai (SNPI)**
- **Prof. Z. P. Lu (Shanghai U)**
- **Mr. Katsunobu Aoyama (NISA)**
- **Prof. Naoto Sekimura (U.Tokyo)**
- **Dr. Shunichi Suzuki (TEPCO)**
- **Mr. Hideo Tanaka (KEPCO)**
- **Mr. Hiroyoshi Murakami (JAPCO)**
- **Mr. Kunihiro Kobayashi (Tohoku-epco)**
- **Mr. Takaaki Kobayashi (MHI)**
- **Dr. Haruo Fujimori (Hitachi-GE)**
- **Dr. Koji Arioka (INSS)**
- **Dr. Masatsune Akashi (Consultant)**
- **Associate Prof. Toshiaki Horiuchi (Hokkaido Institute T.)**
- **Mr. Masanori Kanno(JNES)**
- **Mr. Kazunobu Sakamoto (JNES)**
- **Dr. Koji Fukuya (INSS)**
- **Mr. Mikiro Ito (Toshiba)**
- **Dr. Fumio Inada, Dr. Taku Arai (CREPRI)**
- **Prof. Yoshimichi Ohki (Waseda U.)**
- **Prof. Yoshinori Kitsutaka (Tokyo Metropolitan U.)**
- **Prof. Hirozo Mihashi (Tohoku Institute of Technology)**
- **Dr. Kunio Onizawa (JAEA)**
- **Mr. Takashi Hirano (IHI)**
- **Mr. Masayuki Takizawa (MRI)**
- **Prof. Tetsuo Shoji (Tohoku U)**
- **Prof. Tatsuo Kondo (Emeritus, Tohoku U)**
- **Prof. Yutaka Watanabe (Tohoku U)**
- **Associate Prof. Makoto Takahashi (Tohoku U)**
- **Assistant Prof. Yoichi Takeda (Tohoku U)**
- **Visiting Prof. Jun Kameda (Tohoku U)**
- **Visiting Prof. Jiro Kuniya (Tohoku U)**

Modified Phenomena Identification and Ranking Technique (PIRT)

•SUSCEPTIBILITY Factor

0 = not considered to be an issue

1 = conceptual basis for concern from data, or potential occurrences under unusual operating conditions, etc.

2 = strong basis for concern or known but limited plant occurrence

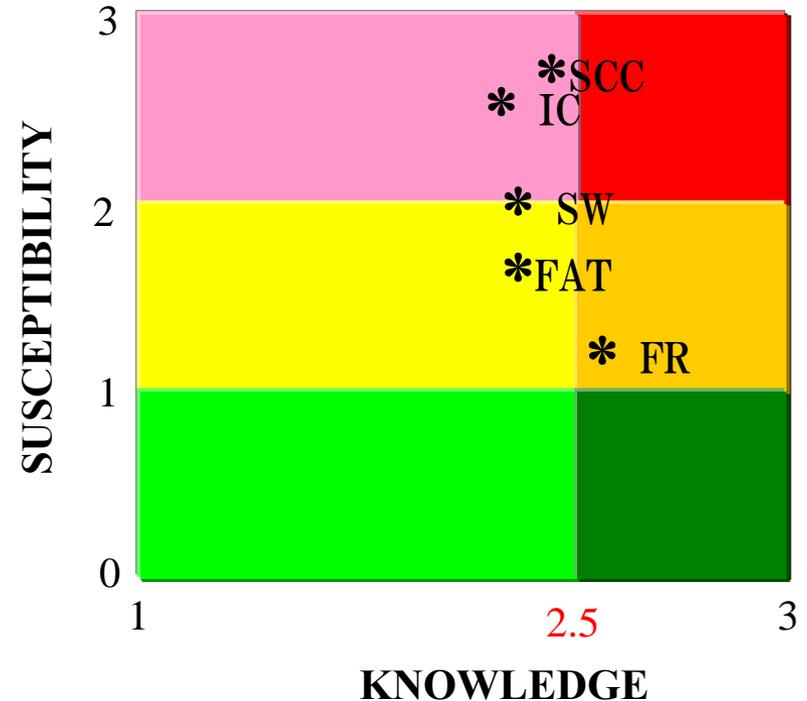
3 = demonstrated, compelling evidence for occurrence, or multiple plant observations

•KNOWLEDGE Factor

1 = poor understanding, little and/or low-confidence data;

2.5 = some reasonable basis to know dependencies qualitatively or semi-quantitatively from data or extrapolation in similar “systems”;

3 = extensive, consistent data covering all dependencies relevant to the component, perhaps with models; should provide clear insights into mitigation or management of problem hopefully based on its mechanistic understandings.



Example of score for several phenomena

Issues proposed associated with materials aging

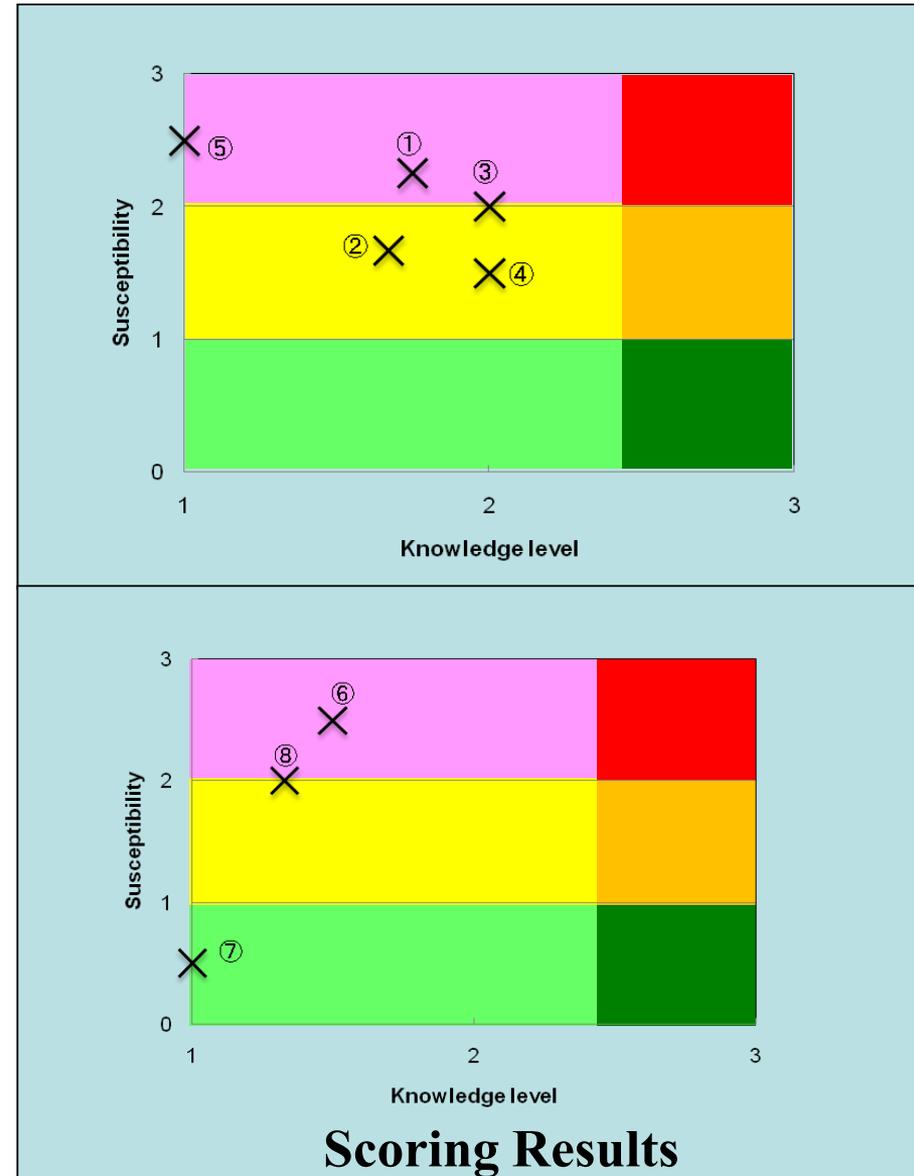
Specific subjects proposed in 2008

Potential degradation predicted by laboratory experiments or field incidences

- ① Cracking of PWR steam generator nozzle dissimilar welds and adjacent austenitic stainless steels HAZ
- ② Corrosion of backside surface of spent fuel pool structure
- ③ Any potential risk of degradation such as corrosion in pipe penetration to the concrete confinement due to neutralization
- ④ Condition monitoring as an on-line maintenance and/or a backup technique to ensure the degradation monitoring and/or mitigation confirmation
- ⑤ Effects of temperature and ECP transients on environmentally assisted cracking from a point of view of oxide film transient in plants

Any latent phenomena and potential degradation which we may focus for aged plants in future

- ⑥ Any possible mechanism to form a condition of a localized highly oxidizing area at particular parts in NPP components
- ⑦ Possible role of hydrogen as an oxidant is recently reported and what would be a potential degradation mode to be induced or to be accelerated with oxidant hydrogen
- ⑧ Effect of small ripple stress and/or higher harmonic wave on environmentally assisted cracking



PWR Proactive Issues raised and summarized by the Experts' Panel

1. Research subjects for shorter term projects to be completed in ~5 years

- 1) SCC initiation phenomena, including the effects of surface stress/strain, residual stress, microstructure and strain localization,
- 2) Development of qualified mechanisms-based lifetime models for PWSCC propagation in nickel base alloys,
- 3) Characterization of weld metals, dilution at interfaces and heat affected zones,
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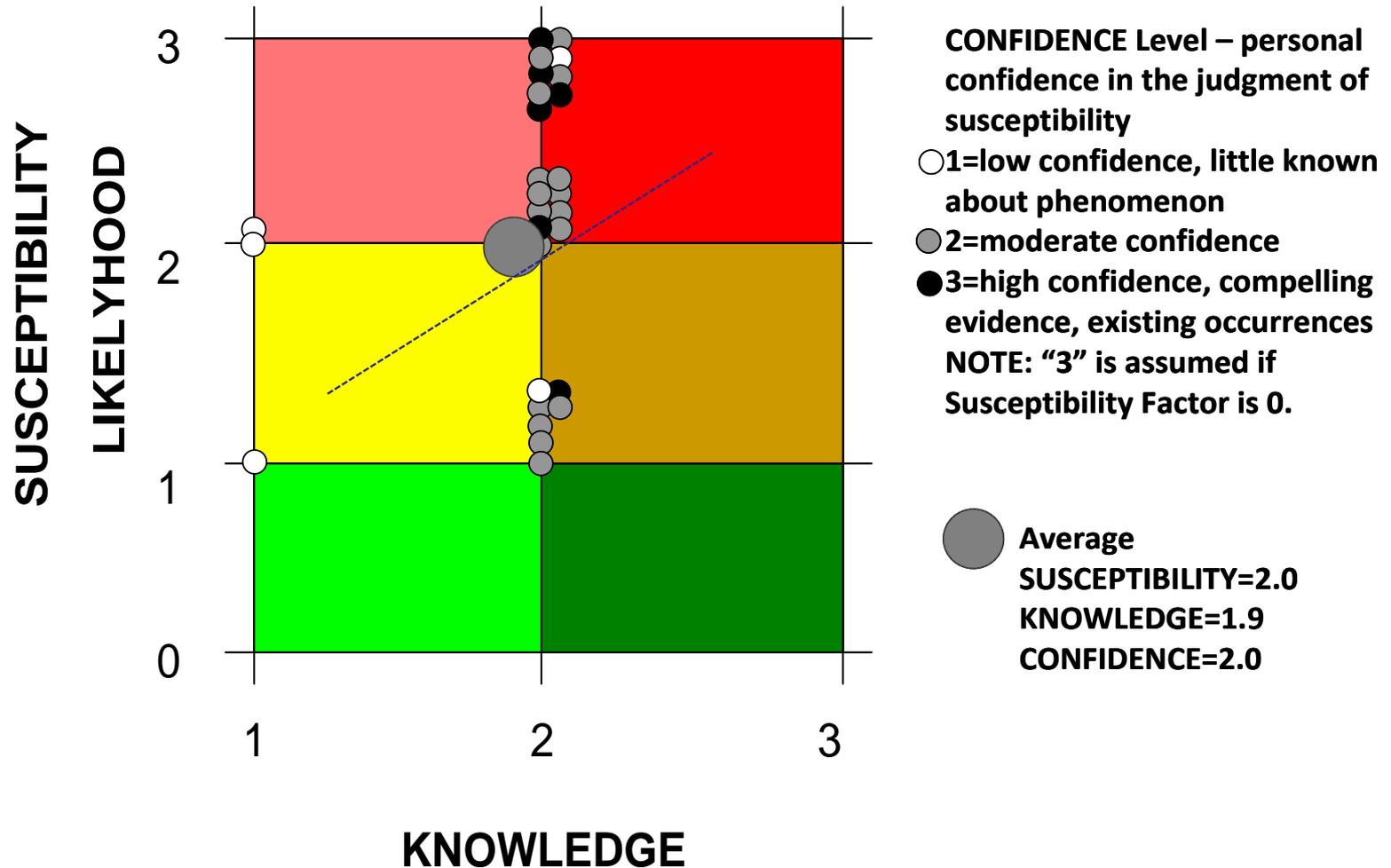
2. Research subjects for longer term projects to be completed in ~5 to 10 years

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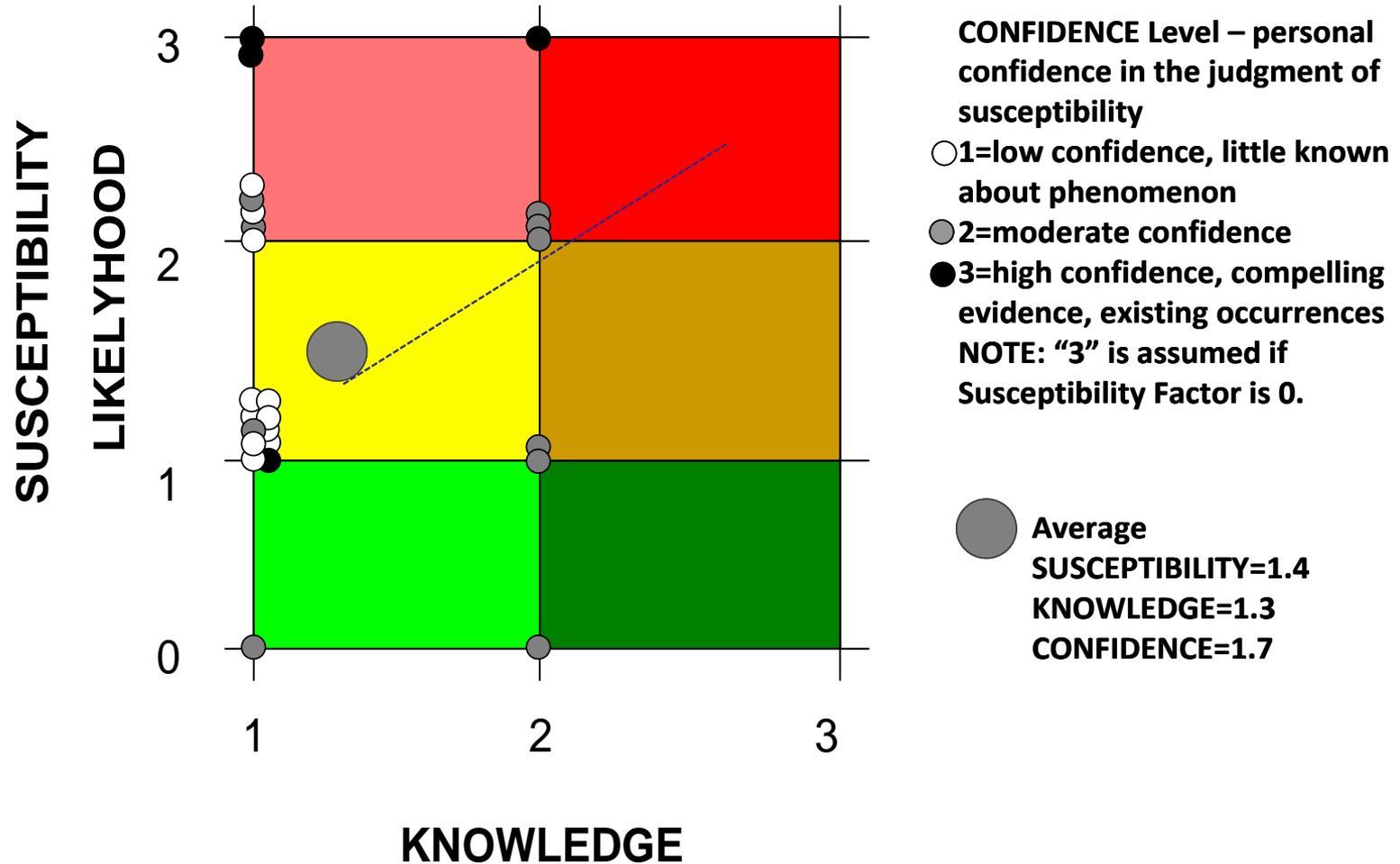
Typical score distribution of Proactive Issues and those raised by FRI from the outcomes of NISA, NRA projects

Presented and summarized based upon the PMDM Experts' Panel Meeting of NRA aging management program held on Oct. 24 – 26, 2012, Sendai Japan

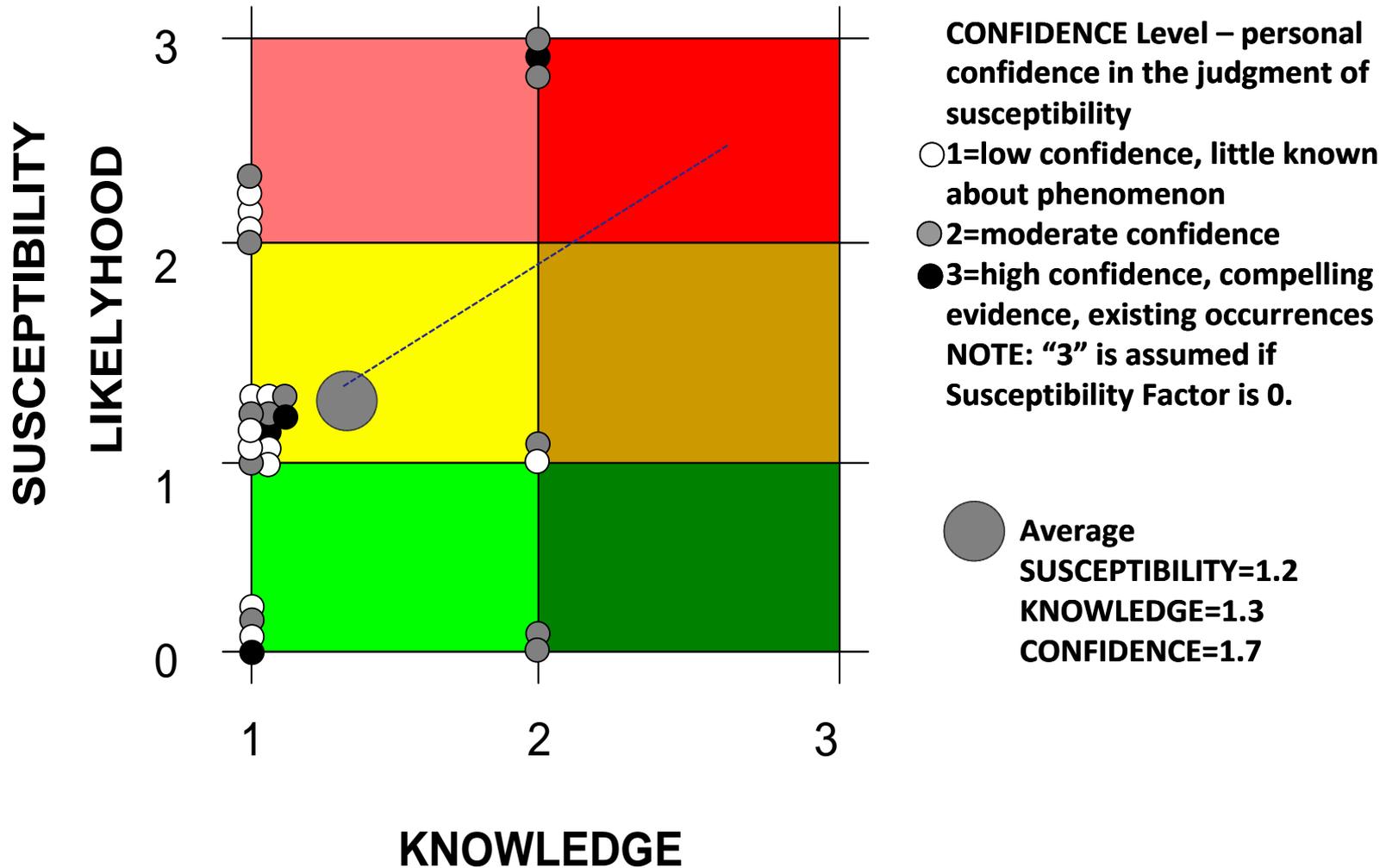
7.2 SCC growth characteristics at dissimilar metal welds



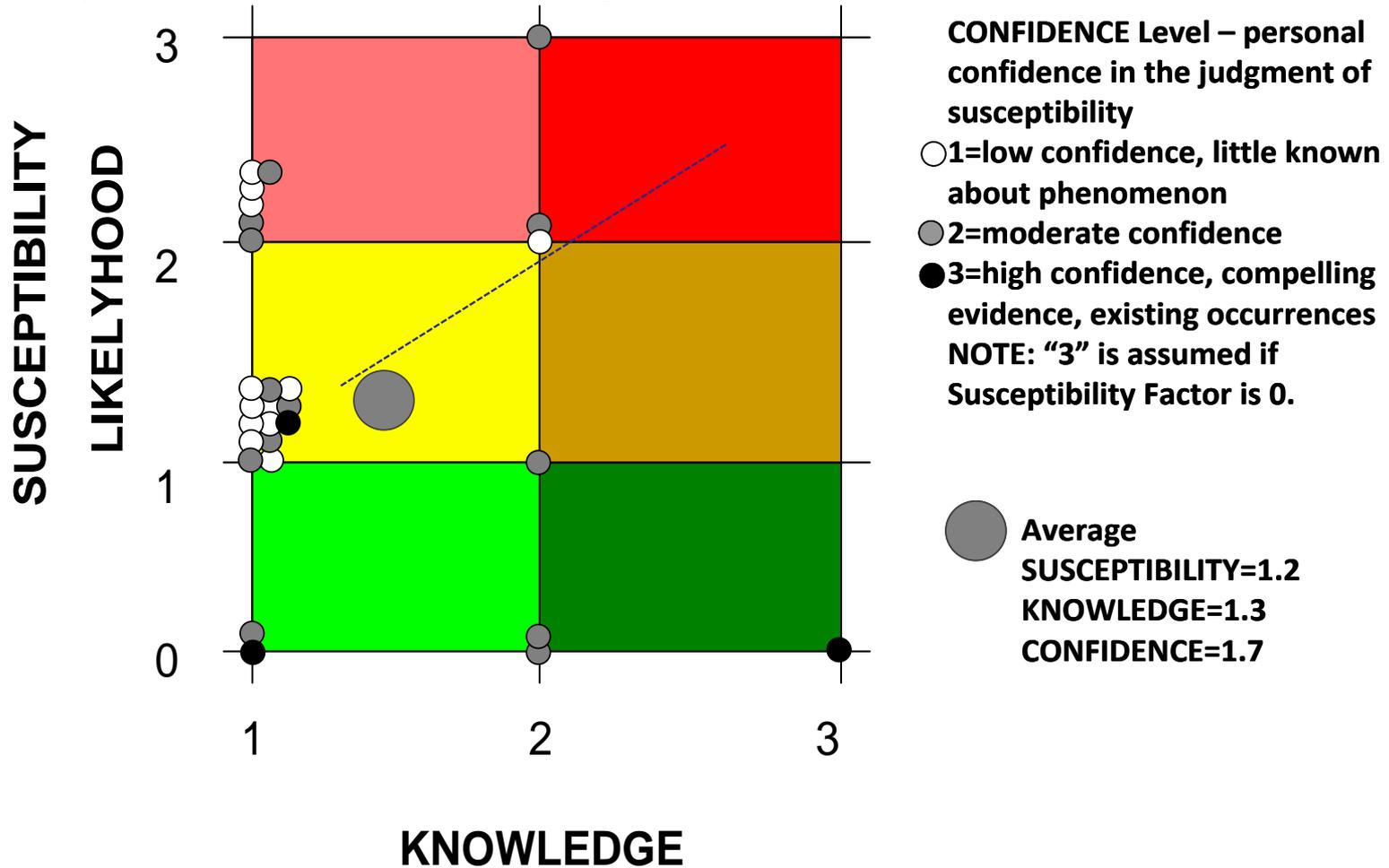
7.6 Acceleration of SCC and corrosion due to hydrogen accelerated oxidation



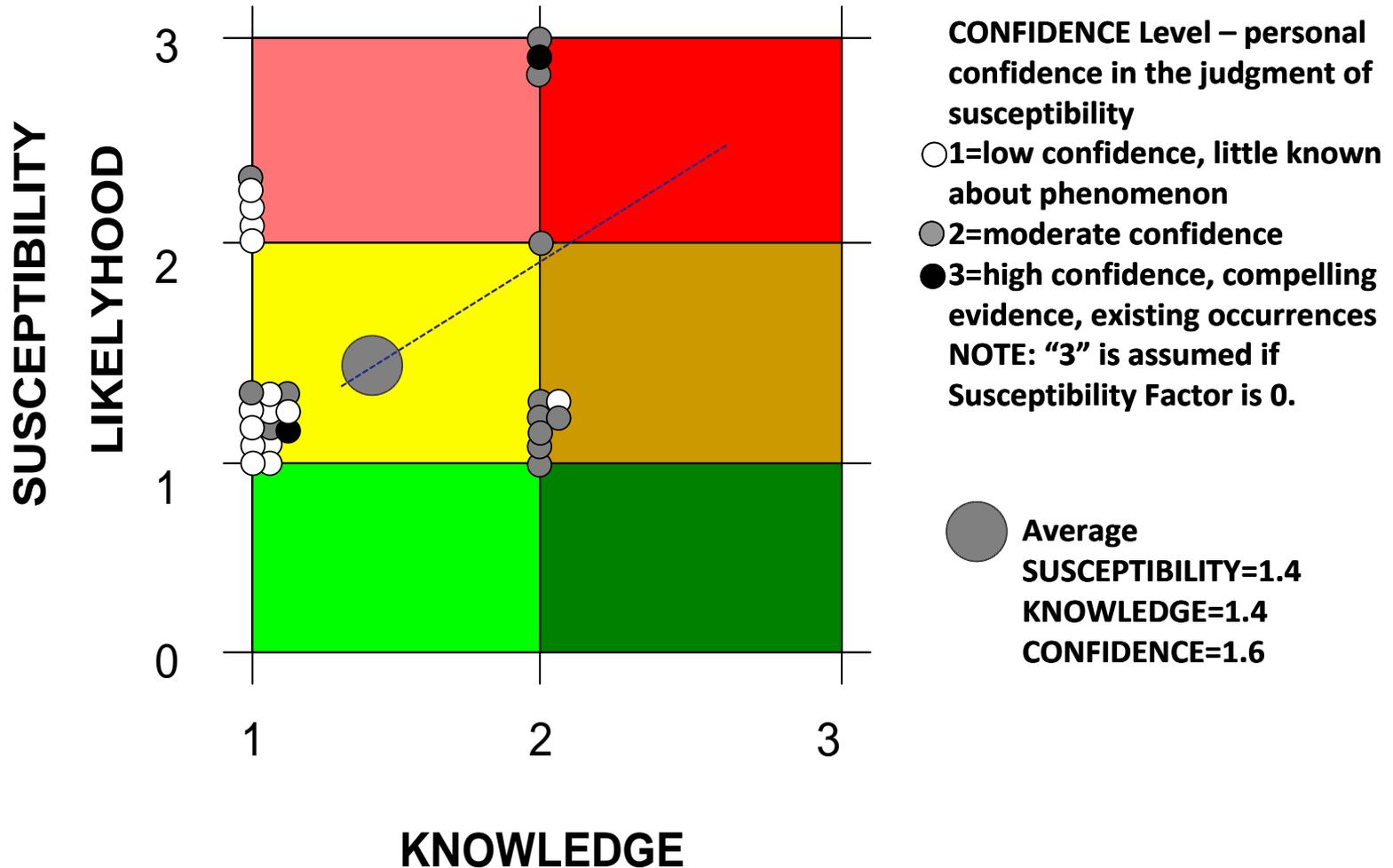
6.1 Acceleration of irradiation induced sensitization due to carbon formation by nuclear transformation of nitrogen



6.2 Acceleration of corrosion and stress corrosion cracking due to hydrogen formation by nuclear transformation of nitrogen



1.3 Aging damage due to acceleration of material diffusion and microstructure change by interaction of super abundant vacancy and hydrogen





東北大学



Issue concern 1

Oxidation Dynamics at Oxide/Metal Interface and Oxidation Localization and SCC initiation in High Temperature Water under irradiation

Prepared by Yo-ichi Takeda and T. Shoji

Outline

- Oxidation test in Halden reactor using 316L and 316 NG stainless steels
 - ◆ Comparison of oxidation behaviors in laboratory specimens (non irradiation) and irradiation specimens
 - Characterization of oxidation localization on Constant loading specimens
 - Weight gain / loss and oxide film thickness on plate type specimens
- Possible hydrogen effect in 316NG stainless steel in simulated PWR environment



10 μ m

Stress Corrosion Crack initiation stage under a constant load by use of circumferential notch specimen with high constraint plasticity.

Can see various stage of Initiation processes.

- Oxides formation,
- Cracks in inner oxides,
- Growth into matrix,
- propagate into Matrix and
 - longer crack

Materials and test environments

Materials

- 316L stainless steel
- 316LN stainless steel

Chemical compositions (wt%)

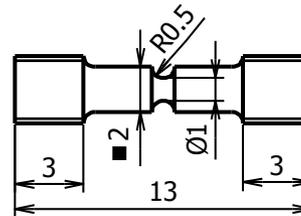
	C	Si	Mn	P	Ni	Cr	Mo	N
316L	0.018	0.47	0.82	0.028	12.06	17.68	2.17	0.039
316LN	0.020	0.50	0.81	0.025	12.89	16.59	2.39	0.094

Stress conditions

Load	Average stress in the cross section	
	Notch root	Flat
255 N	324 MPa	81 MPa

For a part of the nonirradiated specimens, 374MPa and 94 MPa were used.

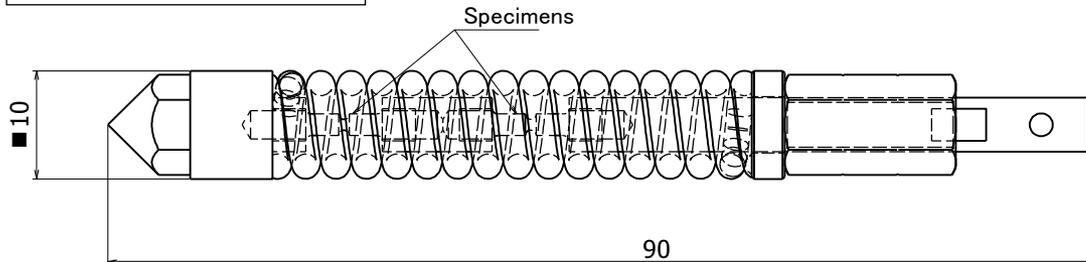
Specimen



Environment

Temperature (°C)	288
Pressure (MPa)	8.1 – 9.0
Dissolved oxygen (ppm)	2.0
Conductivity (µS/cm)	< 0.2 (outlet)

Loading fixture



Irradiation tests were performed in Halden reactor.

Test conditions for irradiation specimens

- Halden reactor (OECD-NEA)
 - 4 different **oxidation time duration**

	Geometry	Materials
Coupon specimen	10 × 10mm t=1mm	316L, 316LN
Tensile specimen	Circumferential notched bar: Φ1mm (at notch root)	316L, 316LN

Full power hours (hr)	528 h	863 h	1176 h	2568 h
Thermal neutron flux (n/cm ² s)	4.7×10^{13}	4.4×10^{13}	4.7×10^{13}	4.0×10^{13}
Gamma heat (W/g)	1.2	1.1	1.2	1.2
Fast neutron flux (n/cm ² s)	2.8×10^{13}	2.5×10^{13}	2.8×10^{13}	3.2×10^{13}
Fast neutron fluence* (n/cm ²)	0.53×10^{20}	0.78×10^{20}	1.2×10^{20}	3.0×10^{20}
Displacement damage* (dpa)	0.076	0.11	0.17	0.42

* calculated from average fast neutron flux

Obtained results

- Oxidation tests under constant load using circumferential notched specimen

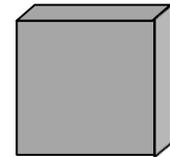
- Surface morphology
- Cross sectional image and characterization of oxidation localization behavior



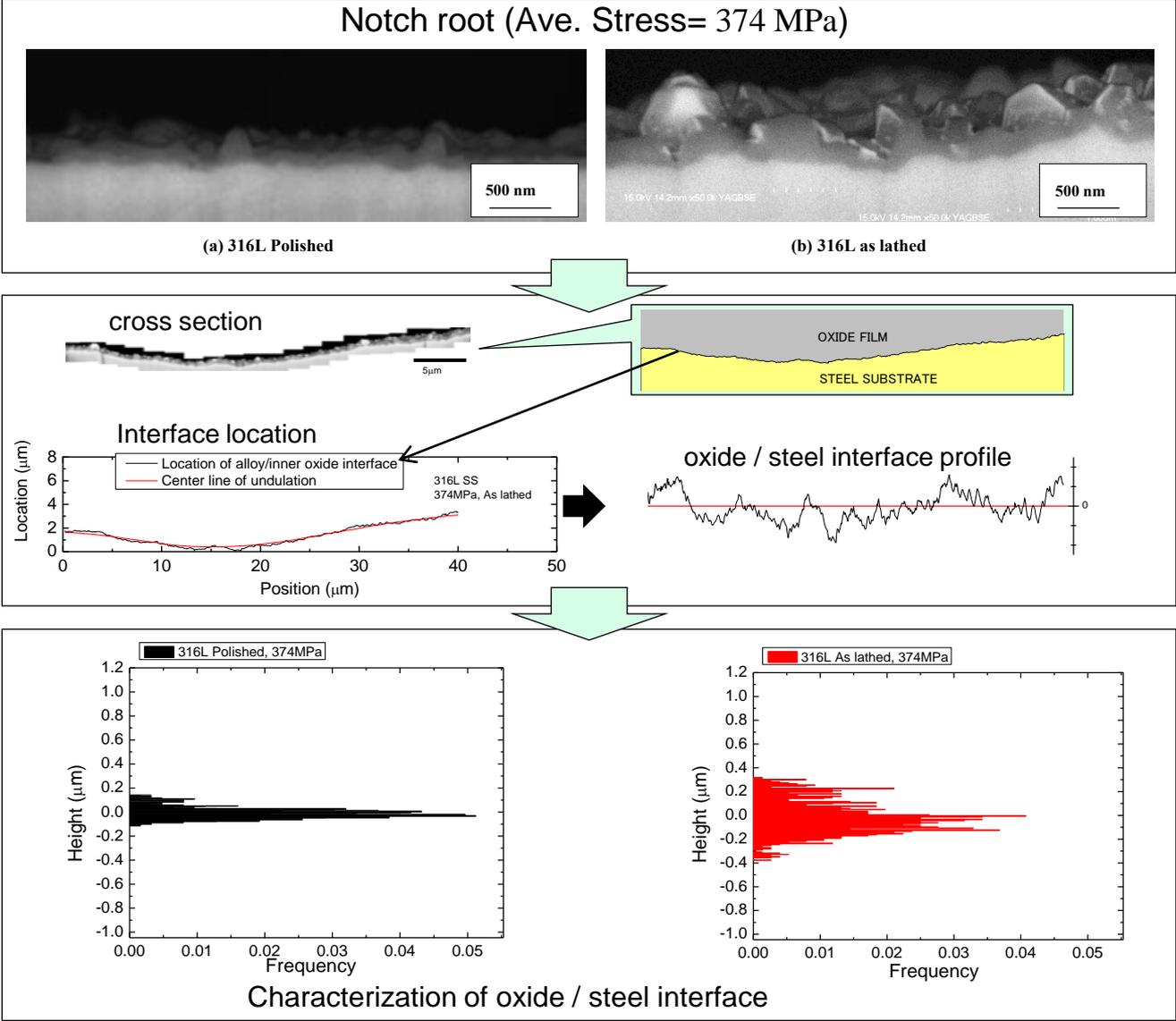
irradiation / stress / surface work hardened layer

- Weight gain/loss using plate specimen

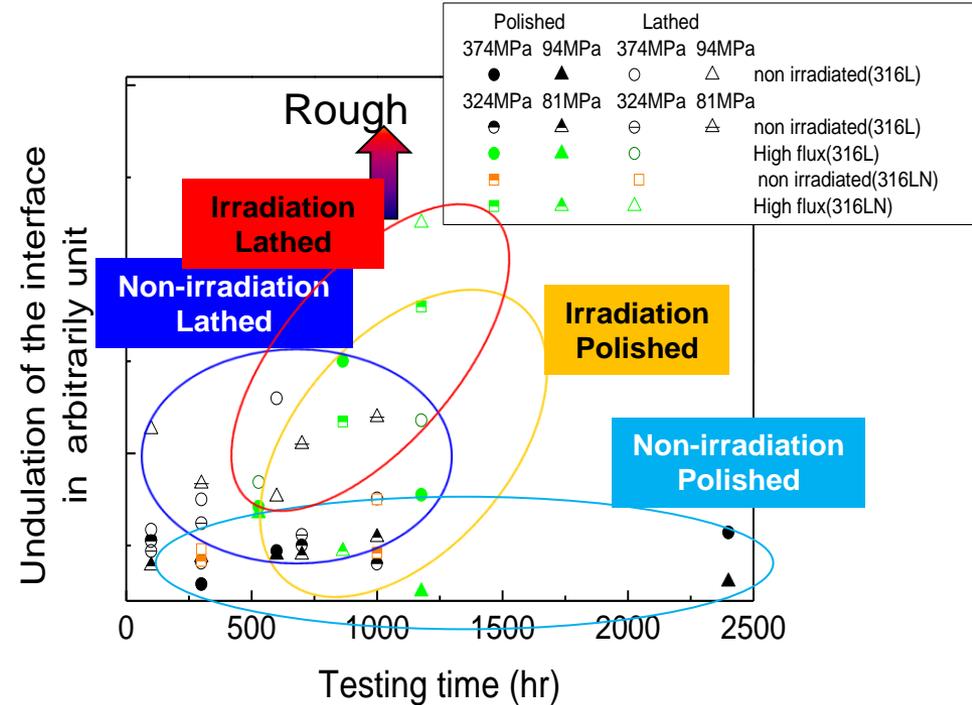
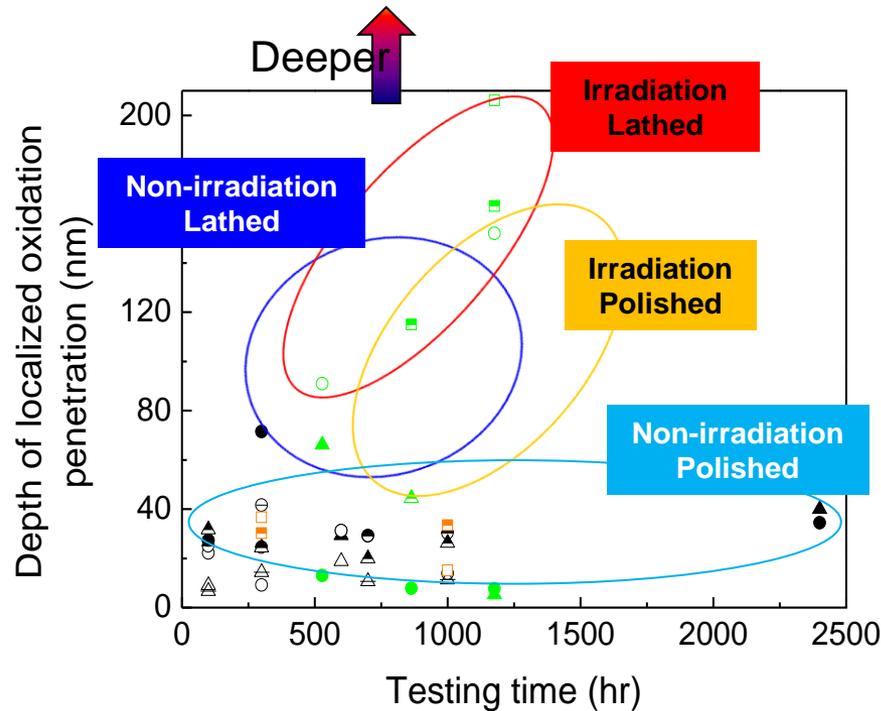
- weight gain/loss and oxide film thickness



Oxide / steel interface profile

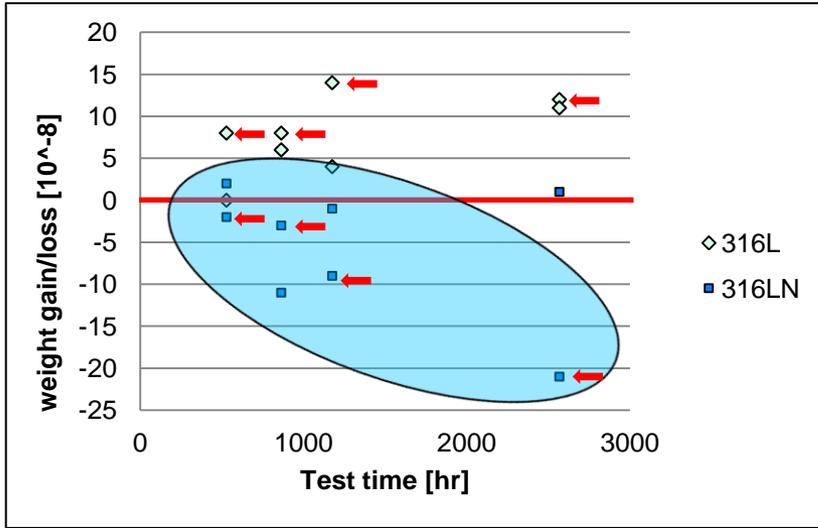


Oxidation localization parameters

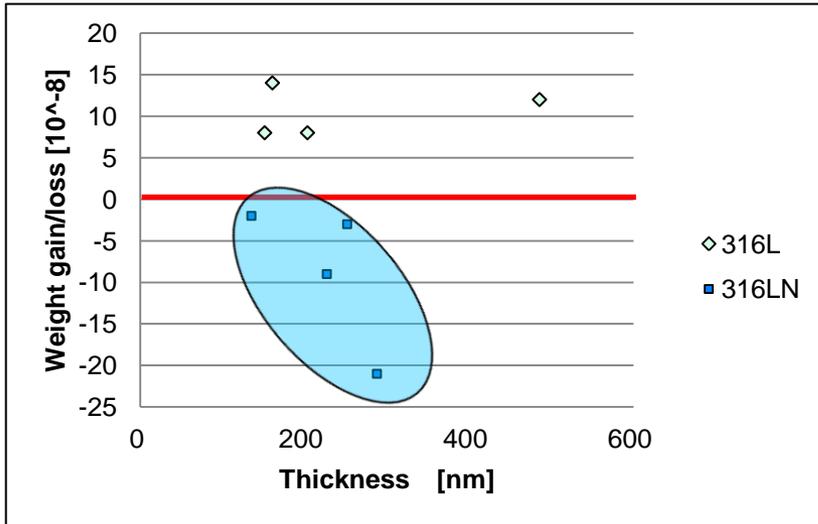
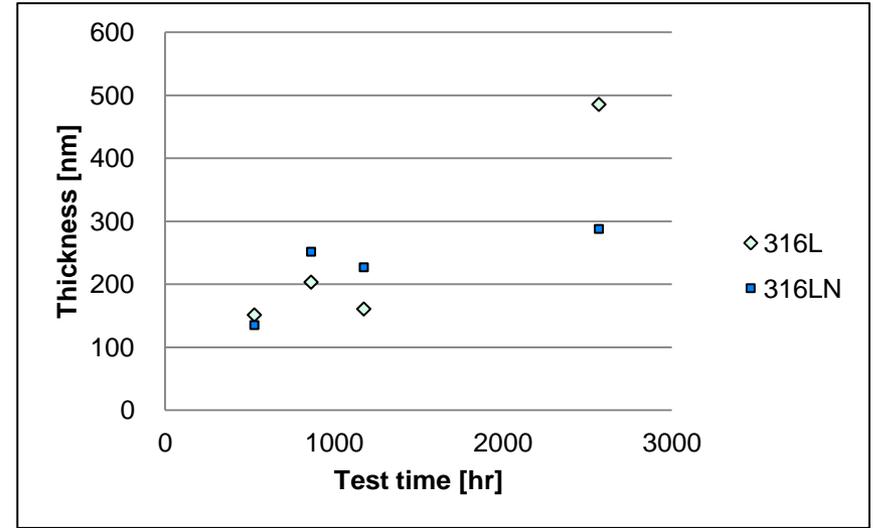


- Oxidation localization develops with time especially in the specimens under irradiation and lathe finished surface conditions (increase the parameter values)
- More significant oxidation localization is pointed out in the specimens under irradiation

Weight gain / loss and oxide film thickness (irradiation)



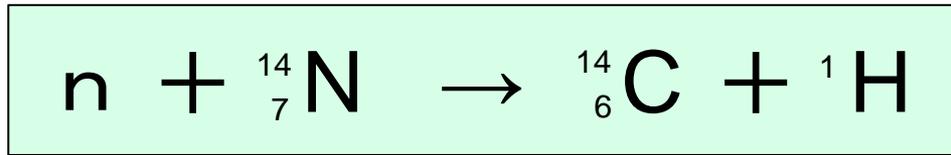
← specimens in which oxide film thickness was examined



- Thickness of the oxide film monotonically increase with experimental time
- It might be pointed out that more dissolution of alloying elements into water took place in 316NG

Possible effect of nitrogen in steel on carbon and hydrogen generation and consequential oxidation kinetics

nuclear transformation of nitrogen :



Carbon & hydrogen formed during the irradiation test

Role of Hydrogen in oxidation and SCC

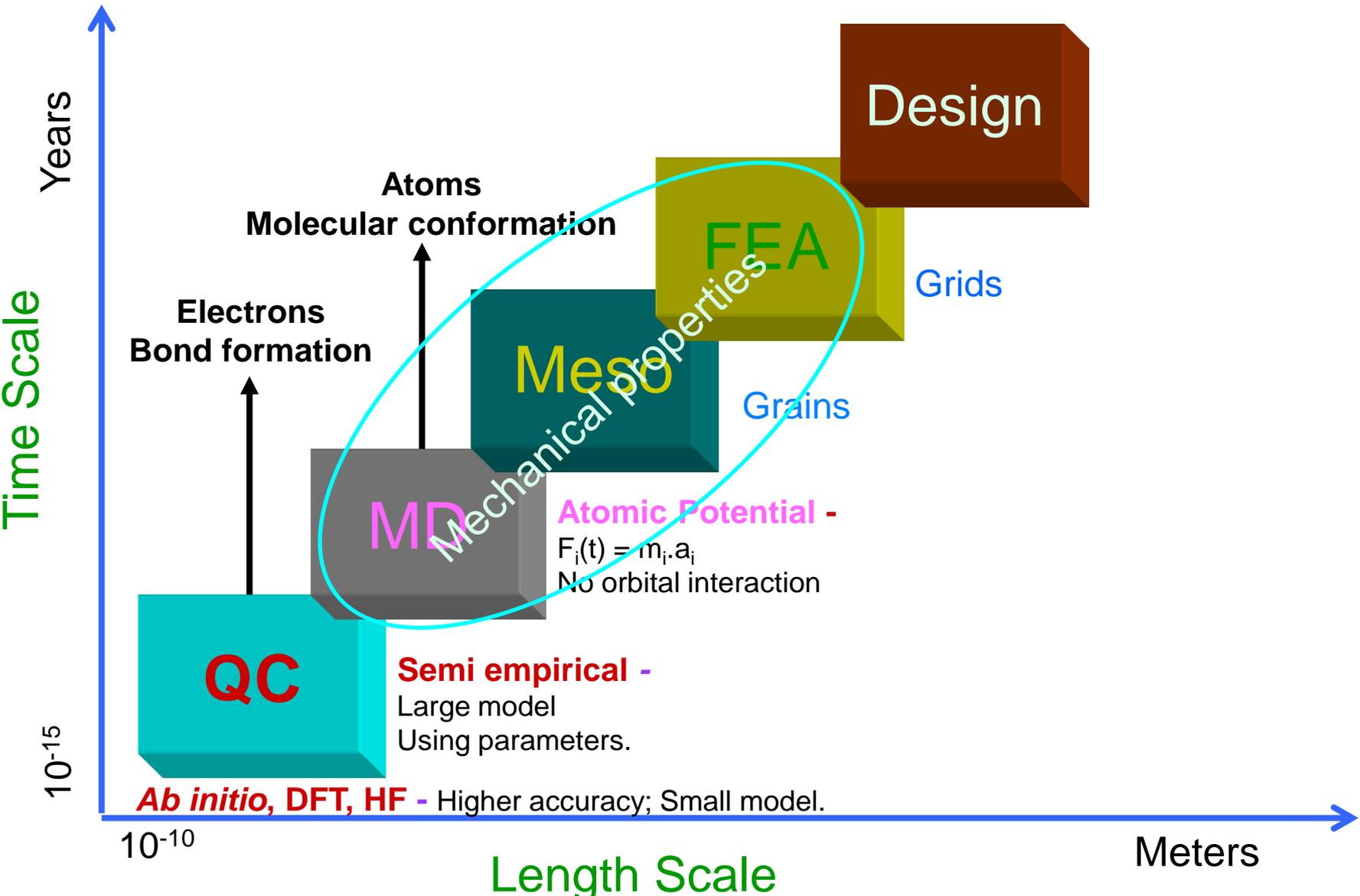
- **Quantum Chemical Molecular Dynamics and Atomic Scale Modeling of Metal Oxidation with Water**
- **Electron State of Interstitial Hydrogen in Metal – Negatively Charged Hydrogen**
- **Vacancy - Hydrogen Interaction (Superabundant Vacancies) and promotion of Metal diffusivity**
- **Hydrogen Enhanced Oxidation**

Issue concern 2

Fundamental Mechanistic Study of Stress Corrosion Cracking
-Quantum Chemical Molecular Dynamics Approach

PhD work Nishith Kumar Das

Introduction



Underlying Theory

Extended Hückel approximation

$$HC = SC\varepsilon$$

$$C^T SC = I$$

Where H : Hamiltonian matrix,
S : Overlap matrix,
C : Eigen vector,
 ε : Eigen value and
 C^T : Transposed matrix of C.

Total Energy:

$$E = \sum_{A=1}^M \frac{1}{2} m_A v_A^2 + \sum_{i=1}^{OCC} n_i \varepsilon_i + \sum_{A=1}^M \sum_{A<B}^M \frac{Z_A Z_B e^2}{r_{AB}} + \sum_{A=1}^M \sum_{A<B}^M E_{repuls}(r_{AB})$$

Repulsion term:

$$E_{repuls}(r_{AB}) = b_{AB} \exp\left(\frac{a_{AB} - r_{AB}}{b_{AB}}\right)$$

Force for each atom:

$$F_A = \sum_{A \neq B}^M \sum_{i=1}^{OCC} C_i^T \frac{\partial H}{\partial r_{AB}} C_i + \sum_{A \neq B}^M \sum_{i=1}^{OCC} \varepsilon_i C_i^T \frac{\partial S}{\partial r_{AB}} C_i - \sum_{A \neq B}^M \frac{Z_A Z_B e^2}{r_{AB}^2} + \sum_{A \neq B}^M \frac{\partial E_{repuls}(r_{AB})}{\partial r_{AB}}$$

Optimization of parameters

Atomic pairs

O – O O – H H – H

Fe – Fe Fe – O Fe – H Fe – Cr Fe – Ni

Cr – Cr Cr – O Cr – H Cr – Ni

Ni – Ni Ni – O Ni – H

Diatomic bond energy, equilibrium distance, and charges etc.



Bulk model cohesive energy, charges, lattice constant, and mean square displacement.

Fe, Fe-Cr and Fe-Cr-Ni matrix water interaction at high temperature

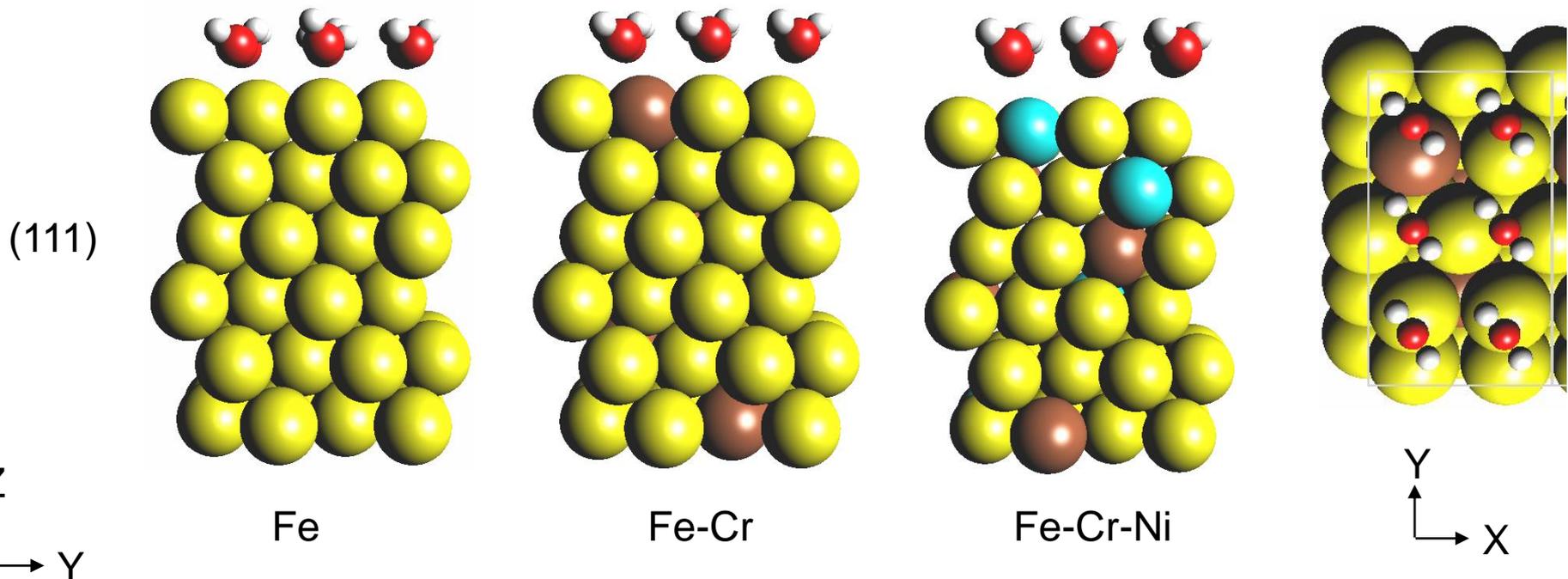
-To study the solid state oxidation mechanism by considering hydrogen and oxygen diffusion in perfect crystal matrixes

Defect and strained matrix water interaction at high temperature

- To study the surface defect and strain effect on oxygen and hydrogen diffusivity into matrixes

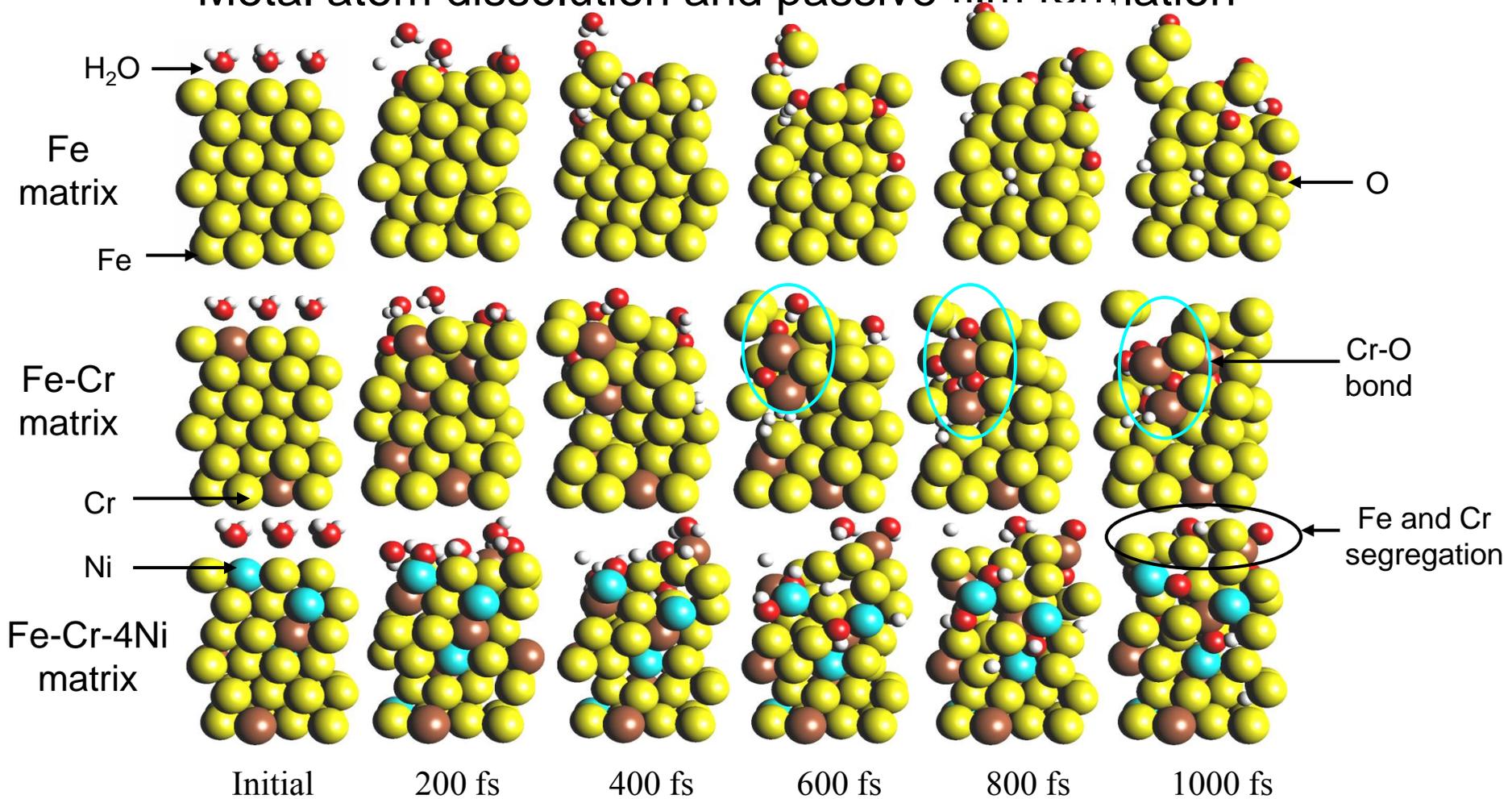
Models

The Fe, Fe-Cr and Fe-Cr-Ni (111) surface of face-centered cubic structure is used as slab model. The Fe, Fe-Cr and Fe-Cr-Ni/H₂O interface is modeled by the placement of monolayer six molecules of H₂O on the (111) surfaces. Ensembles NVT.



Regular matrix morphologies

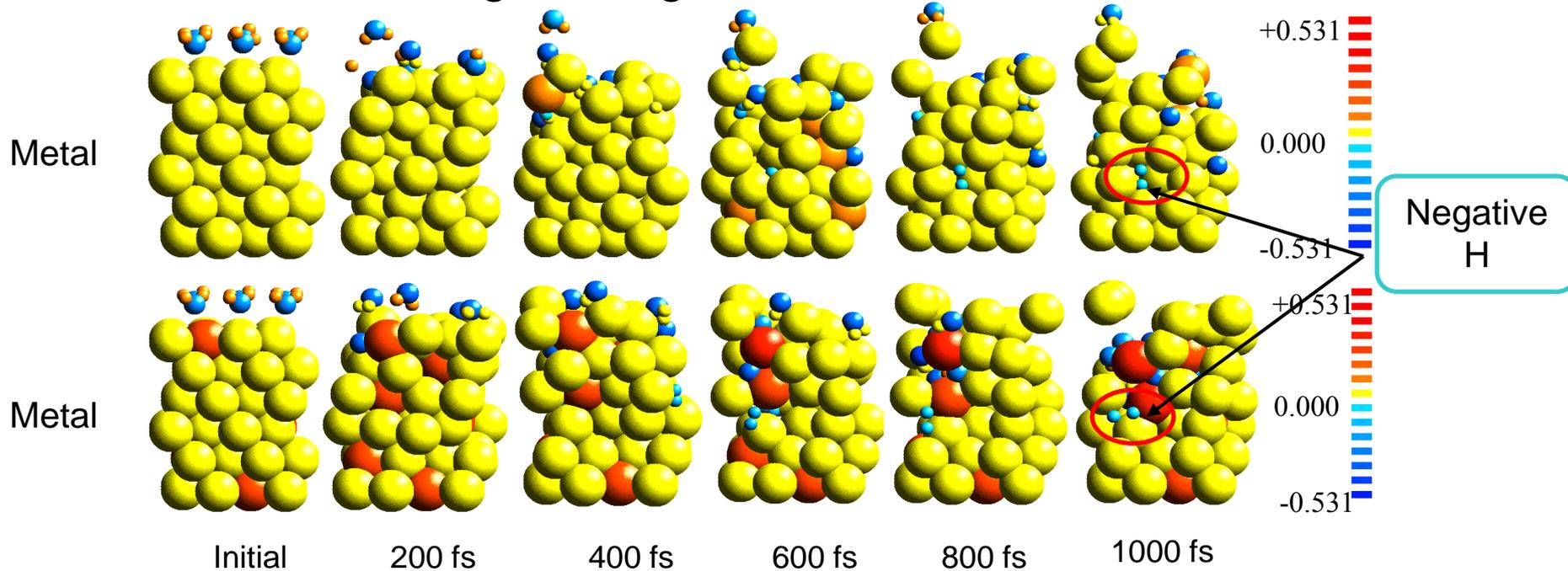
Metal atom dissolution and passive film formation



Fe and Cr are segregating from the surface and Ni is not moving upward.

Atomic charge change with diffusion

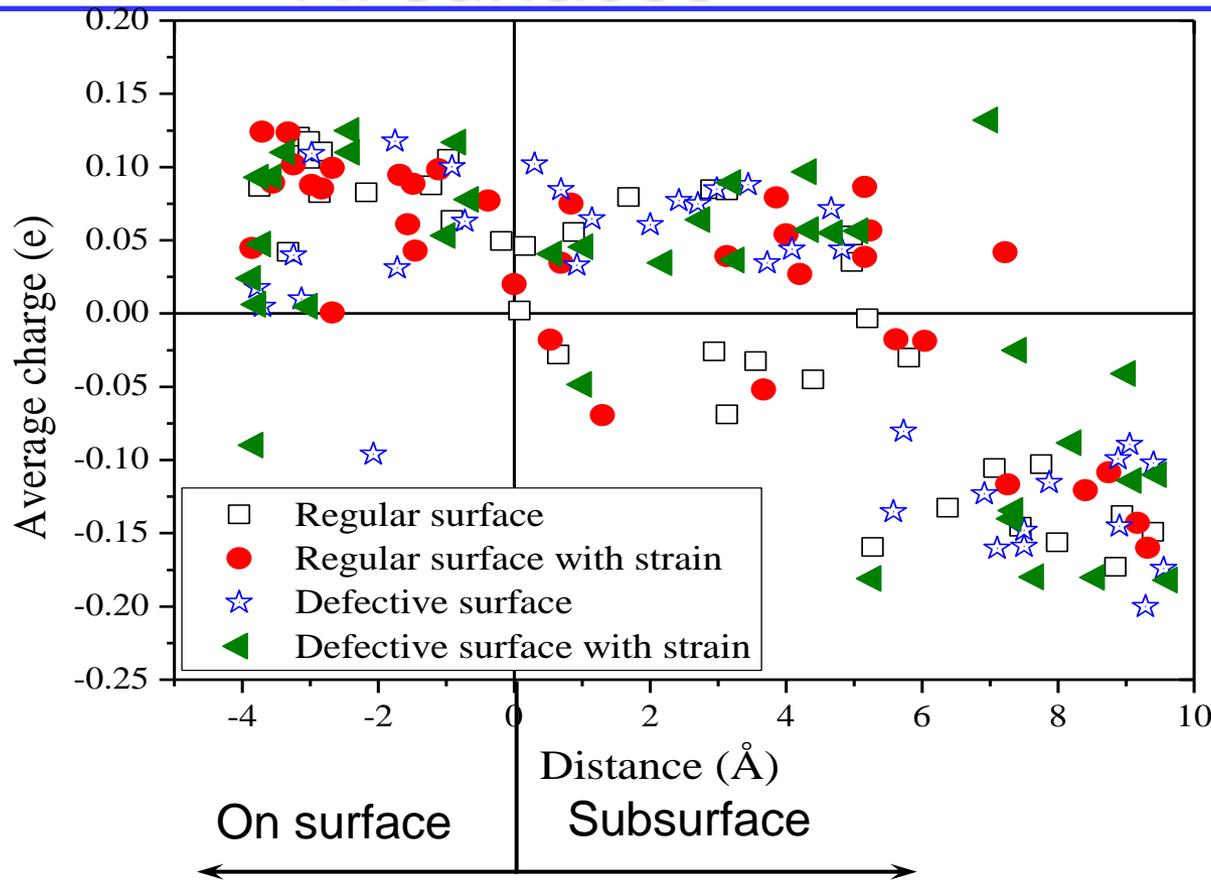
Atomic charge change indicates the oxidation



Early dissociated diffused H have negative charge into the matrixes.

Itsumi & Ellis (1996) and H. Adachi & S. Imoto (1979) study have shown the well consistency with the present study that electron transferred from metal to hydrogen.

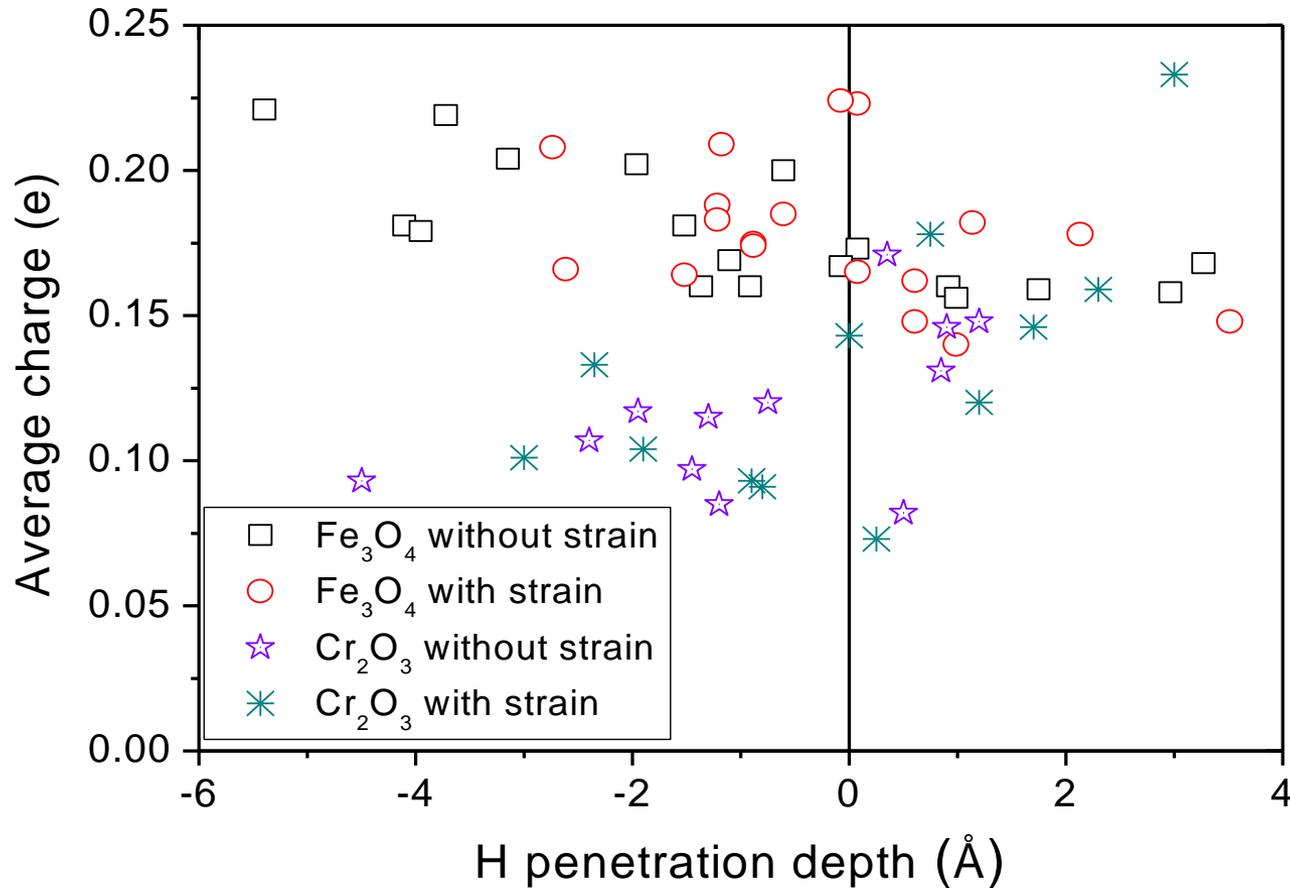
Hydrogen atomic av. charge for Fe-Cr-Ni surfaces



Deeply diffused hydrogen atom receives electron from metallic atom leads to weaken the bond strength in order to generate coulombic repulsion consequently the process initiates surface oxidation.

Ref. Das et al., Corro. Sci. 51 (2009),908

H atomic av. charges in Oxides



Hydrogen atoms remain positively charged in the oxide film whereas it shows negatively charged into the metal surfaces.

Hydrogen is a major reactants with solids as a result of its strong chemical activity, high mobility, and wide occurrence as H_2 . The consequences for Materials Science and Technology are widespread and growing.

There are three different models proposed for interstitial Hydrogen in metal (Fiks, Sov. Phys. Solid State, 1959). Which is:

‘Protonic model’ – Hydrogen is positively charged and it receives electron from metals. **Well known.**

‘Anionic model’ – Hydrogen is negatively charged and it receives electron from metal atoms.

‘Hydrogenic model’ – third model assumed that the metal and hydrogen atoms are covalently bonded.

For hydrogen in transition metals, XPS analysis demonstrated that hydrogen prefers to act as an electron acceptor rather than an electron acceptor.

Fe-H system study have shown that the 0.20 ~ 0.30 e charge transferred from iron atom to hydrogen.

(A. Juan *et al.*, Surf. Sci., 1999; P Cremaschi *et al.*, Surf. Sci., 1995; Y. Itsumi *et al.*, J. Mater. Res., 1996, and H. Adachi *et al.*, J. Phys. Soc. Japan, 1979).

QCMD study also have shown the similar results.

Several experimental studies have concluded as follows:

The high-temperature oxidation study of Fe-Cr alloy (800 – 1100 °C) and Fe-Al alloy (450 – 900 °C) have shown, “**Hydrogen works as an oxygen carrier**”.

(C. T. Fujii *et al.*, J. Electrochem. Soc., 1964; W. E. Boggs, J. Electrochem. Soc., 1971).

The oxidation analysis of Stainless steel and Fe-Cr demonstrated, “**the oxidation rate is higher when hydrogen is present in the metal**”.

(D. Wallinder *et al.*, J. Electrochem. Soc., 2002; E. Essuman *et al.*, Oxid. Met., 2008).

‘Hydrogen Anionic model’ should necessary to consider for
SCC initiation process.

Hypothetical role of hydrogen in SCC initiation process

Water dissociate on metal surface



H diffused faster than O into matrix



Deeply diffused H oxidize metal surface
by taking electron from metal atom



This process weaken metal atomic bond
strength



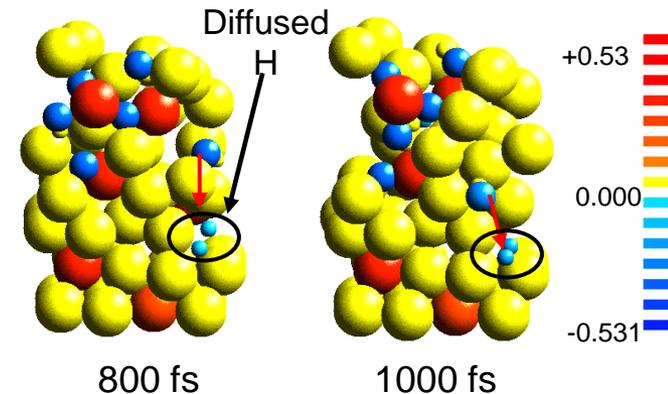
Metal atom become positively charged



These may help to diffuse oxygen into
metal



H can accelerate oxidation which may
enhance the SCC initiation.



QCMD analysis

Conclusions

Defect and strain enhance the diffusion of H and O into matrixes.

The initially dissociated H atoms interstitially trapped into matrix and receive electron from metallic atoms which weaken metal atomic bond strength.

Several experimental study recommend that 'H work as O carrier' or 'H in metal increased the O diffusivity' (1964, 1971, 2002 and 2008).

Diffused negative 'H' atoms can enhance the oxidation process into metal.



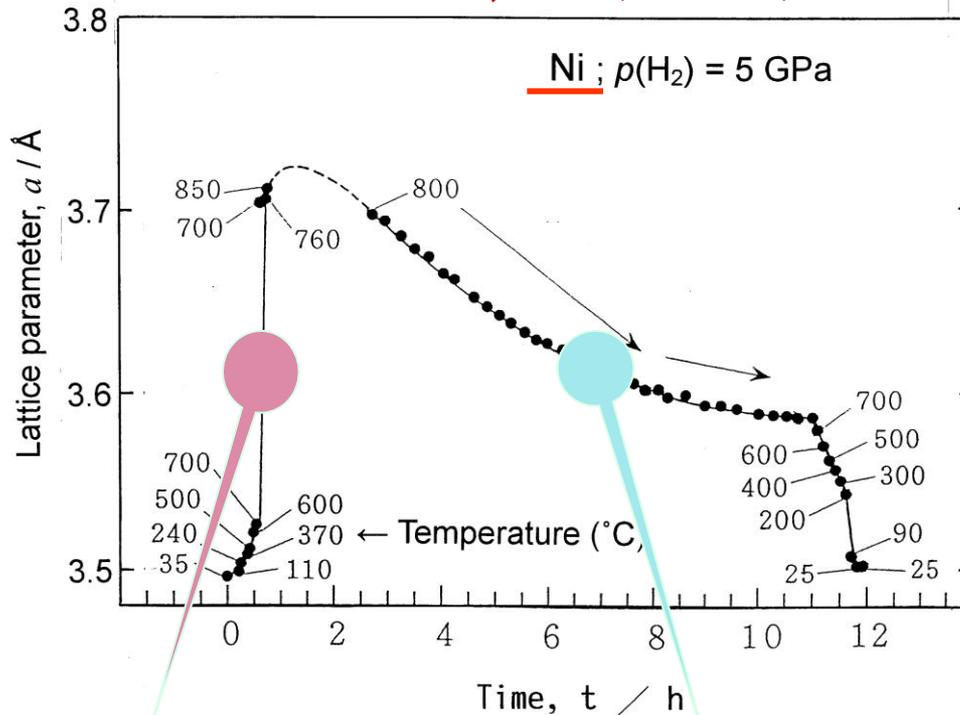
This process may accelerate early stage SCC initiation process.

Issue concern 3

A strange phenomenon was observed ;

A gradual lattice contraction took place at high p_H , T 's

First observation; *Fukai, Okuma, 1992*



Hydrogenation

Vacancy formation

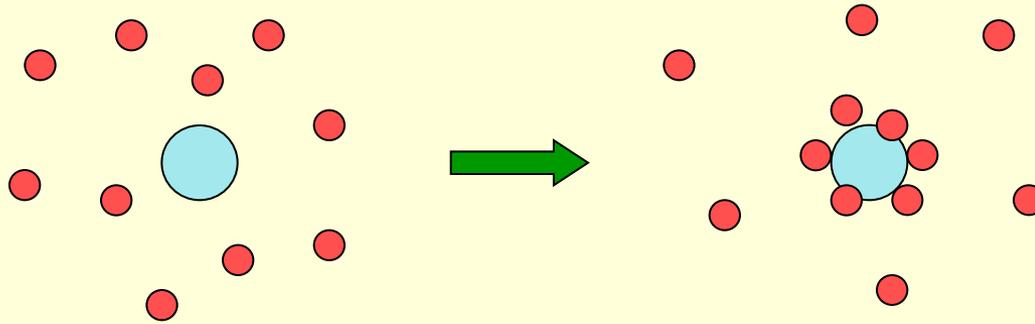
Remember:

Formation of vacancies results in

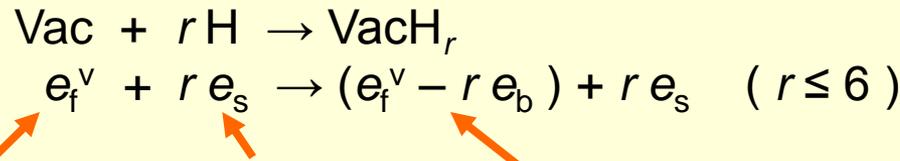
volume expansion & lattice contraction.

Vacancy conc. may be estimated from the observed lattice contraction.

Mechanism of SAV formation (by Fukai, Quantitative Micro-Nano Approach to Predicting SCC of Fe-Cr-Ni Alloys, June 13 – 18, 2010, Sun Valley, Idaho, USA)



Formation energy of a vacancy is lowered by trapping H atoms.



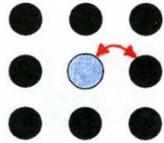
Form. en. of a vacancy Heat of solution e_f^{cl} : Form. energy of a Vac-H cluster

	e_f^v	e_b	e_f^{cl} (eV)
Ni	1.78	0.28	0.10
Pd	1.70	0.15	0.80
Nb	3.0	0.45	0.30

Big reduction of e_f !

Reduction of the formation energy results in enhancements of thermal-equilibrium concs. of vacancies.

H-induced enhancement of M-atom diffusion



Diffusion of M atoms proceeds via vacancy mechanism.

In the presence of H, however, diffusion of M atoms should be mediated by Vac-H clusters.

$$D = x_v D_v$$



$$D = x_{cl} D_{cl}$$

D_{cl} : slightly smaller than D_v

x_{cl} : much larger than x_v



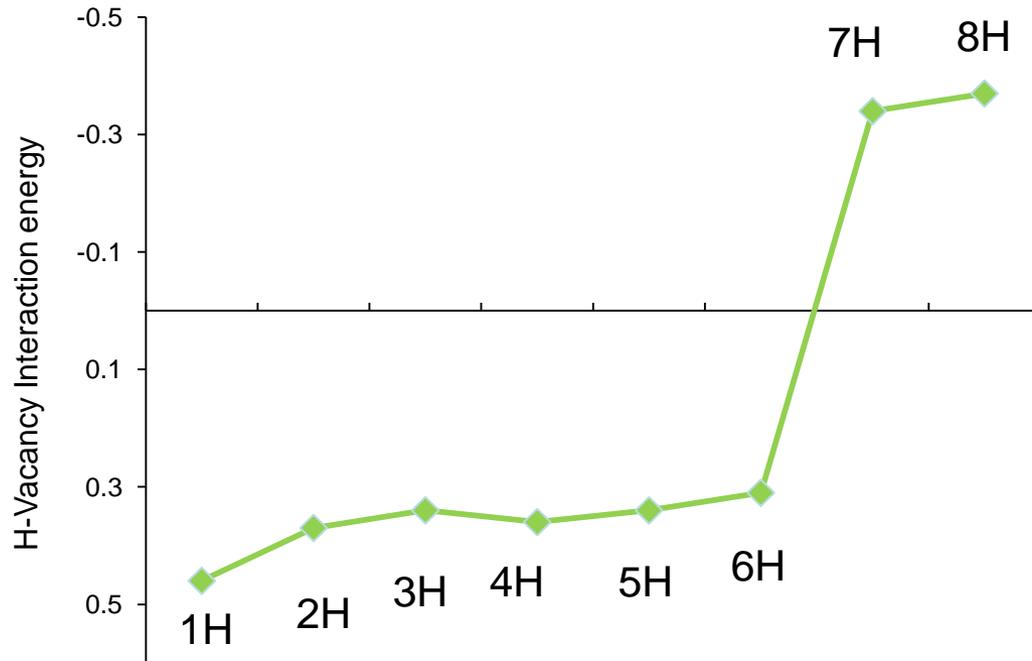
Drastic enhancement of D is expected.

Enhancements have indeed been observed for interdiffusion in Pd-Rh, Cu-Ni, Au-Fe, and self diffusion in Nb.

Summary of Superabundant Vacancy by Fukai

1. A vacancy can trap a multiple number of interstitial H atoms, to form a Vac-H cluster $VacH_r$ ($r \leq 6$).
2. The formation energy of a vacancy is lowered by trapping H atoms. Thus, the equilibrium concentration of Vac-H clusters becomes much higher than that of vacancies in pure metals.
3. The formation of H-induced superabundant vacancies (SAVs) leads to enhancements of M-atom diffusion.
4. These SAVs may be an important source of voids observed in the stress-concentrated region in the HE and SCC of steels.

H-Vacancy Interaction energy

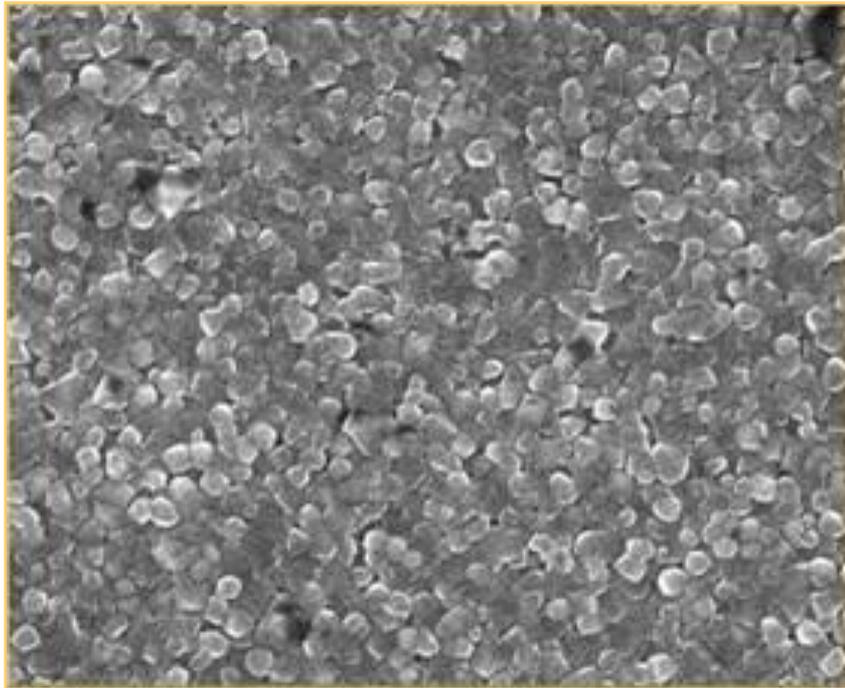


The calculated energy shows that a single nickel vacancy can trap six hydrogen atoms. H_2 bubble did not formed at the vacancy center.

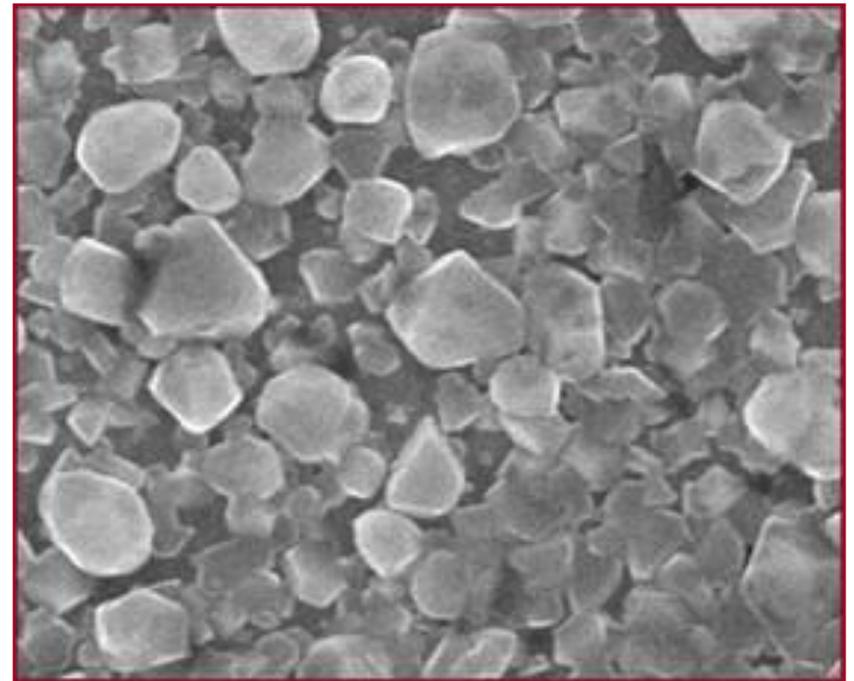
Experimental verification

Effects of Hydrogen in metal on oxidation of 316L SS in HT water at 288 C for 887 hours

Without Hydrogen charging



With Hydrogen charging(35 mass ppm)



Also concerns to DH effects in PWR

Effect of hydrogen on oxidation of **316NG** stainless steel

Experimental conditions

□ Materials: **316NG**

□ Corrosion Condition

□ **290 °C water with dissolved hydrogen (DH) of 30cc/kg H₂O**

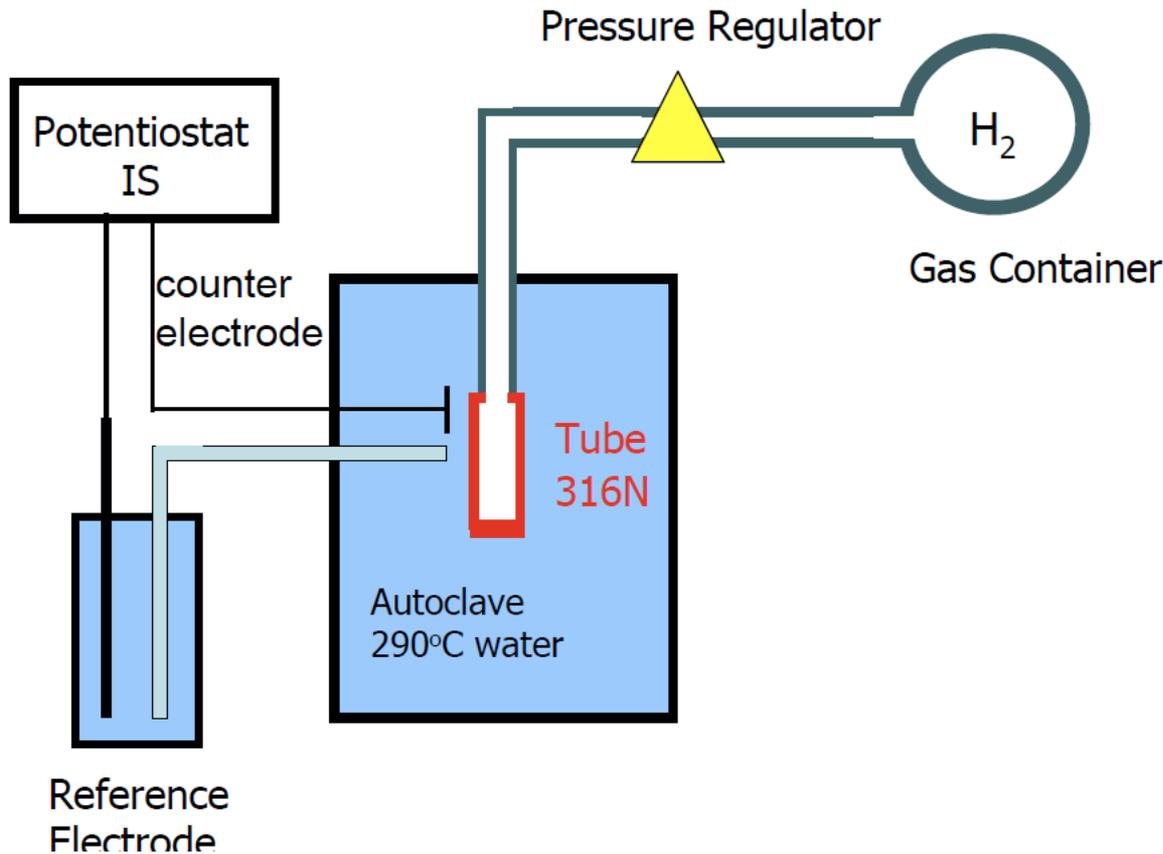
□ Tube specimens with & without internally pressurized hydrogen

□ Measurements

□ Oxidation and hydrogen distribution analyzed by glow-discharged

□ Glow Discharge Optical Emission Spectroscopy (GD-OES)

Experimental setup

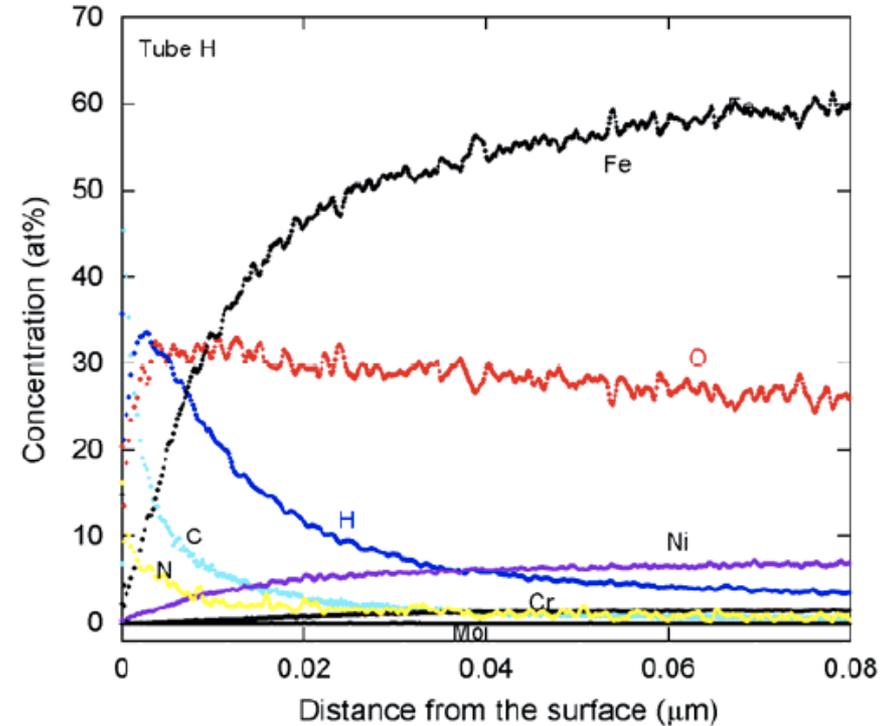
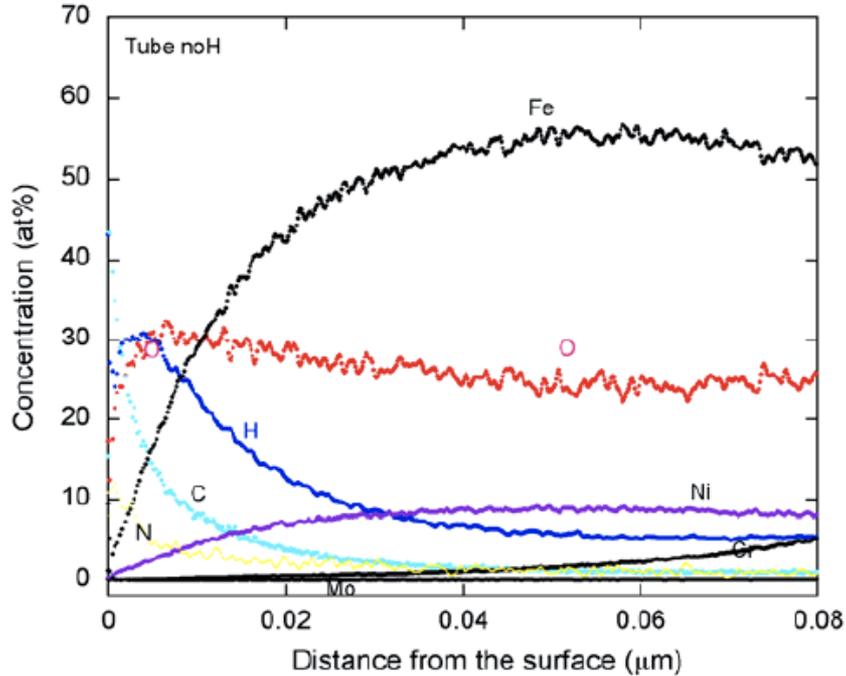


- Testing condition
- Dissolved H in water; 30cc/kg (3.74 atm)

Two tube samples exposed under the same water condition

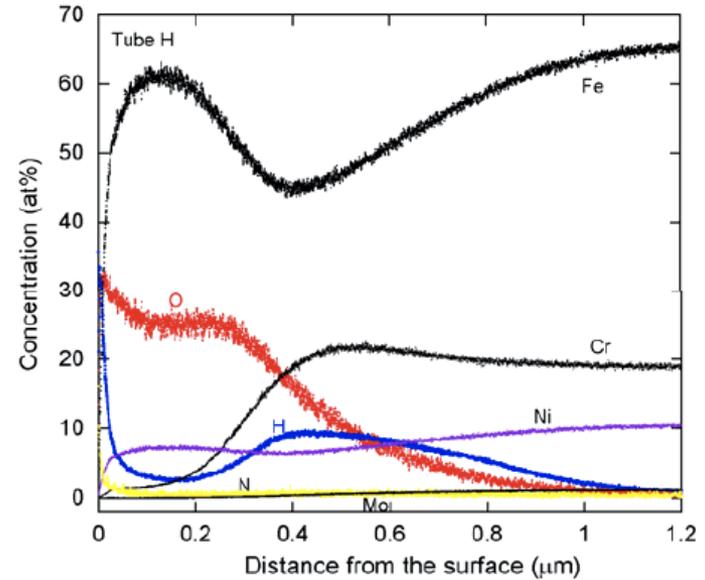
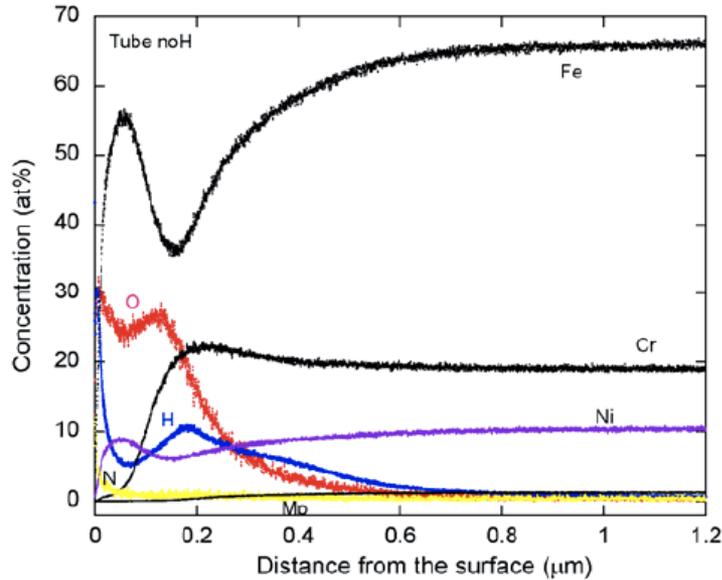
- Internal H: 4.2 atm
- Vacuum: <-1 atm

Oxide film analysis by GD-OES



- No difference in elemental concentration in outermost layer of the oxide

Elemental distribution near oxide / metal interface



- The GDOES analysis has shown the deeper oxidation behavior under the internally pressurized hydrogen associated with more extensively hydrogenated zone.

- Hydrogen embrittlement
- Hydrogen enhanced oxidation and SCC
- Acceleration of microstructure evolution
- Abnormal microstructure evolution
- Enhanced plasticity
- Enhanced creep
- Irradiation microstructure
- Cavity formation
- Etc

To be proactive!!

Content

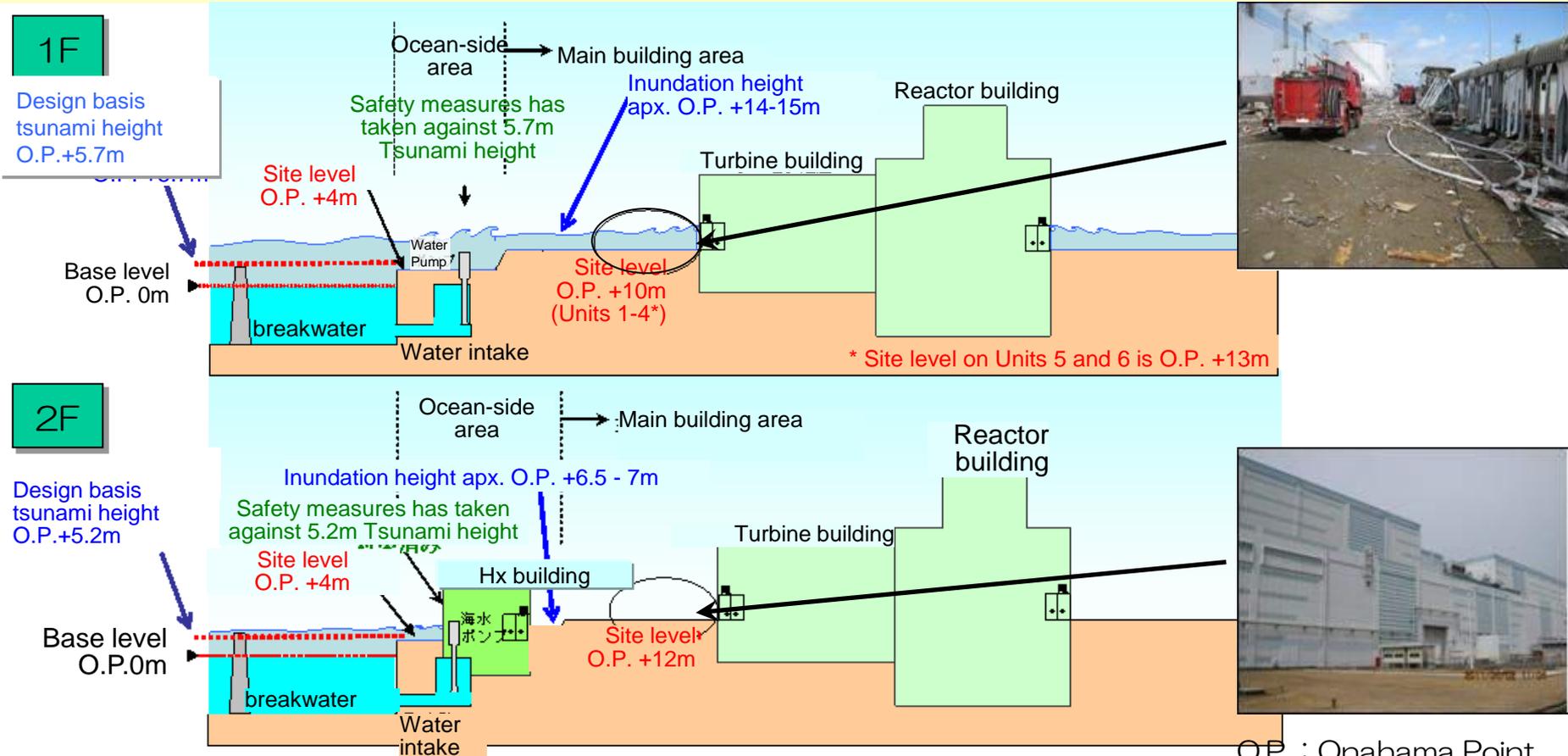
- **Introduction and background**
- **Technical Evaluation of Aging Management**
 - **Degradation, Materials, Systems, PDCA**
- **Proactive Materials Aging Degradation Management**
 - **Annual Experts' Panel Meeting**
 - **Proactive Issues raised and summarized by the Experts' Panel**
 - **Proactive Issues raised by FRI from the outcomes of NISA, NRA projects**
- **Fukushima Daiichi Accident**
 - **Sequence, Actions taken or being taken for future and lesson learn**
 - **Long-and Mid term road map for decommissioning**
- **Summary**

Sequence, Actions taken or being taken for future and lessons learned

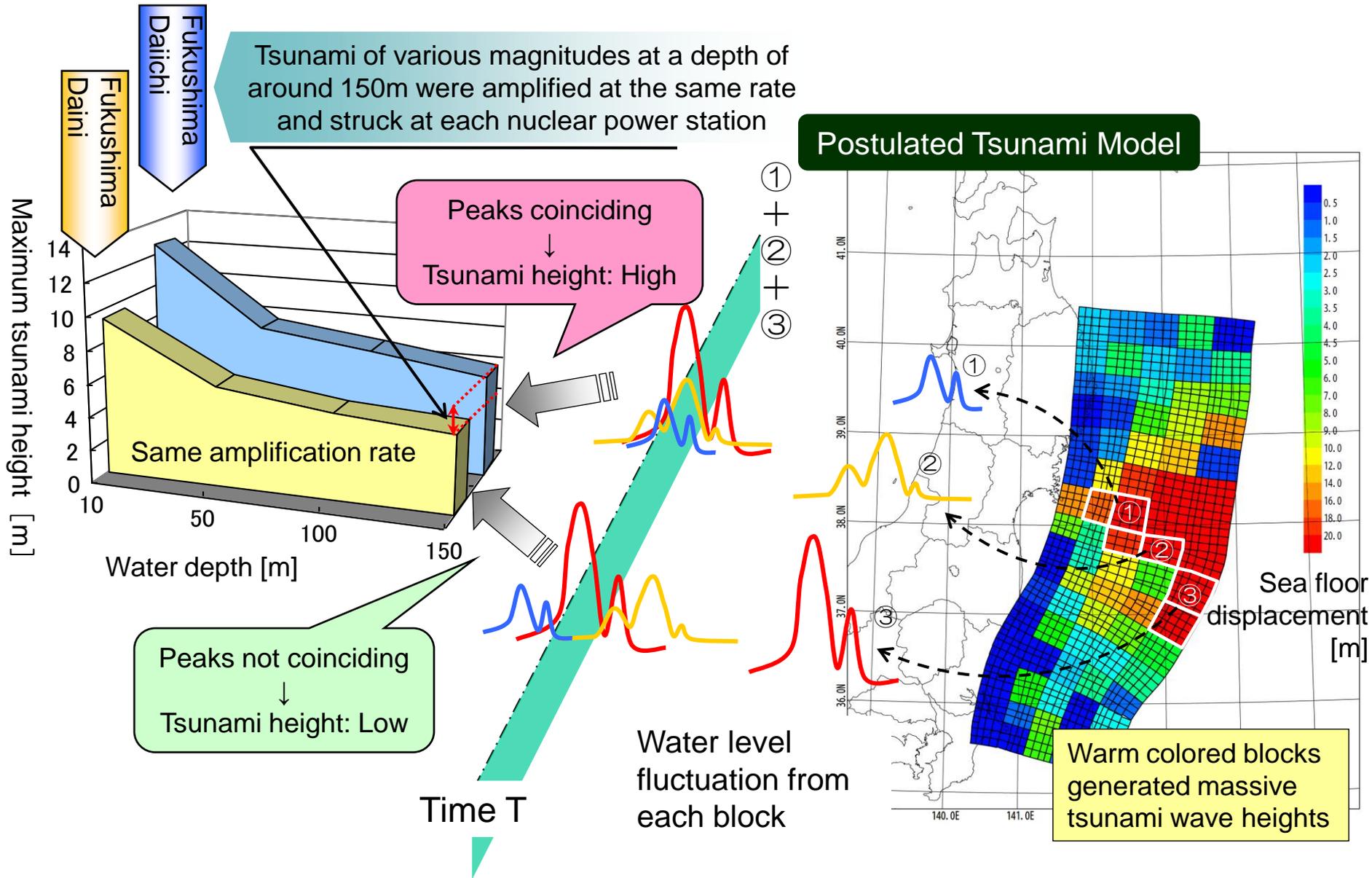
**From
the presentation by Shun-ichi Suzuki at NISA aging management program,
PMDM Experts' meeting at Mt. Zao, October 2011**

Tsunami Height @1F v.s. 2F

- The new design basis Tsunami height for 1F & 2F were evaluated based on the JSCE Tsunami assessment methodology. (1F: O.P.+5.7m, 2 F: O.P.+5.2m)
- The countermeasures were implemented at both NPSs, such as pump motor elevation raised @1F and openings sealed @2F, that were all equivalent from the viewpoint of resistance against Tsunami hazard.
- The 15m class Tsunami caused by M9.0 class earthquake that accidentally attacked 1F was far beyond design basis and whatever evaluation and whatever countermeasures did not matter at this time.



Differences in Tsunami that hit Fukushima Daiichi and Daini NPSs



Summary of Lessons Learned

TEPCO delivers the message as follows, “If we express the lessons learned from our accident in one sentence”

“Carefully consider the **robustness** of current **design** of nuclear power plants and **emergency preparedness** against **beyond design basis events** that could lead to **common cause failures** regardless of their assumed probability demonstrating a continuous **learning organization**.”

Lesson 1: Design Consideration

The accident at Fukushima Daiichi and Daini was caused by Tsunami far beyond the design basis. (No significant damage by earthquake)



● The current design of external barriers were not enough to cope with hydrodynamic forces of flooding and large debris impact.

● The current design of safety-related electric and I&C equipment might not be robust enough to prevent common cause failure by severe external flooding and their layout, diversity and internal barriers for separation need to be reviewed.

★ Other design features to be considered:

- Hydrogen detonation/deflagration outside of PCV
- Operability of venting system
- Accident instrumentation
- Internal barriers for separation of important equipments, such as RCIC, DDFP, MUWC, FPC, M/C, P/C, battery etc.

Lesson 2: Procedures and equipments to be prepared

Several implementable countermeasures/modifications that could have lessened the damage at the unforeseeable accident have been identified.



- **Mobile power vehicles** could be considered as redundant measures against extended SBO situation from the defense in depth viewpoint.
- **Emergency water injection and cooling capability**, against extended SBO situation, such as fire engines, air cylinders and batteries, should be considered.
- **Better preplanning, staging and logistics of emergency and spare equipment** would make a quicker recovery possible.
- **Greater consideration should be given to redundant communication measures** for organized actions.

★ Procedures not robust enough against beyond design basis events:

- EOP - SAMG - EDMG (not thoroughly prepared yet in Japan)
- internal events - external events

Lesson 3: Emergency Preparedness

Without newly built Emergency Response Center, the post-accident activities could not have been carried out.



- Measures taken after Niigata Chuetsu Oki Earthquake were effective:
 - **Emergency response center** in robust building (Seismic isolation, Shielding, Communication, etc.)
 - **Underground water tank** (16 units/site × 40 m³/site) and **Fire Engines** (3/site)
 - **Emergency Response Drills**

Long-and Mid term road map for decommissioning

From

Government – TEPCO Mid-and-long Term Response Council

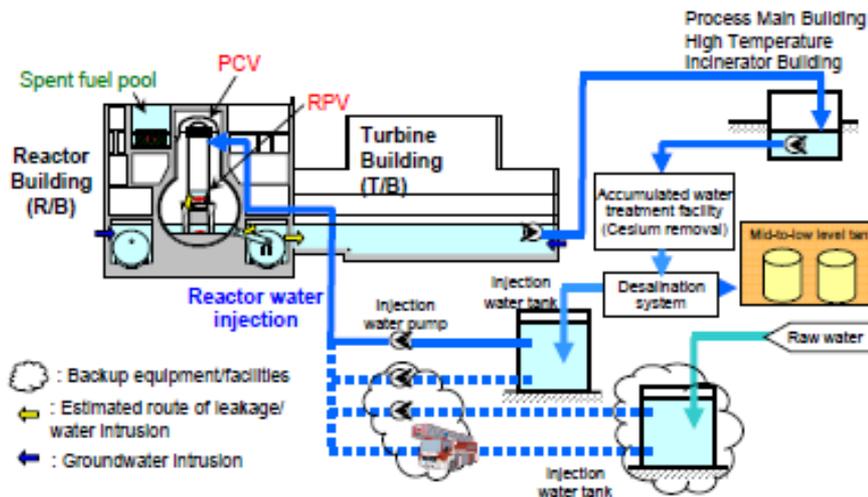
As of October 22, 2012

Progress Status of the Long-and-mid Term Roadmap towards the Decommissioning of Units 1-4 of TEPCO Fukushima Daiichi Nuclear Power Station

1. "Cold Shutdown Condition" is maintained at Unit 1-3. Measures to complement status monitoring are being implemented.

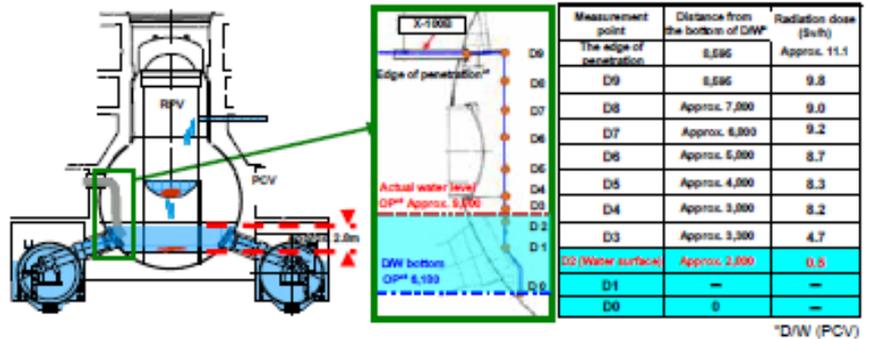
- The RPV bottom temperature and the PCV gaseous phase temperatures at Units 1-3 were approx. 30-50°C (as of October 19) and fulfill the requirement (100°C or less).
- The steam generation in the PCV is suppressed by controlling the water injection amounts, which contributes to sufficiently low levels of cesium released from Unit 1-3 Reactor Buildings.
- Adequate backup equipment is secured. (Water injection pumps: 3 systems; water sources: 2, power supply secured by multiple generating lines, fire engines etc.)
- Even if multiple simultaneous failures of water injection equipment should occur, water injection can be restarted within about 3 hours.

[Overview of the circulating injection cooling system for cooling the reactor]



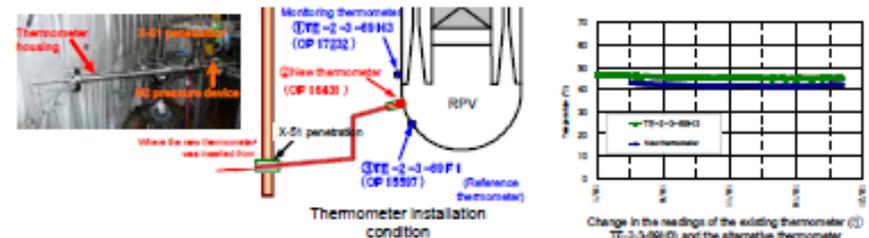
Investigation of the inside of Unit 1 PCV and installation of PCV thermometer and water gauge

- The inside of Unit 1 PCV was investigated with a camera, and the radiation dose and water level were measured (October 9-13).
- The maximum radiation dose was approx. 11.1Sv/h and the water level was approx. +2.8m from the bottom of the PCV.
- A thermometer and water gauge will be installed. The thermometer will be monitored for a month to determine whether or not it can be used for monitoring the cooling condition of the PCV.



Installation of Unit 2 RPV alternative thermometer

- An alternative thermometer has been installed to replace the broken thermometer in addition to the existing monitoring thermometer (TE-2-3-69H3) (October 3)
- The newly installed thermometer is confirmed to be functioning properly as the temperature indicated by the new thermometer is about the same as that of the existing monitoring thermometer (TE-2-3-69H3) (approx. 43-46°C).
- The temperature behavior of the thermometer will be monitored for a month to determine whether or not it can be used as a monitoring thermometer.
- In the case that this thermometer is broken, it can be removed for repair or replacement.



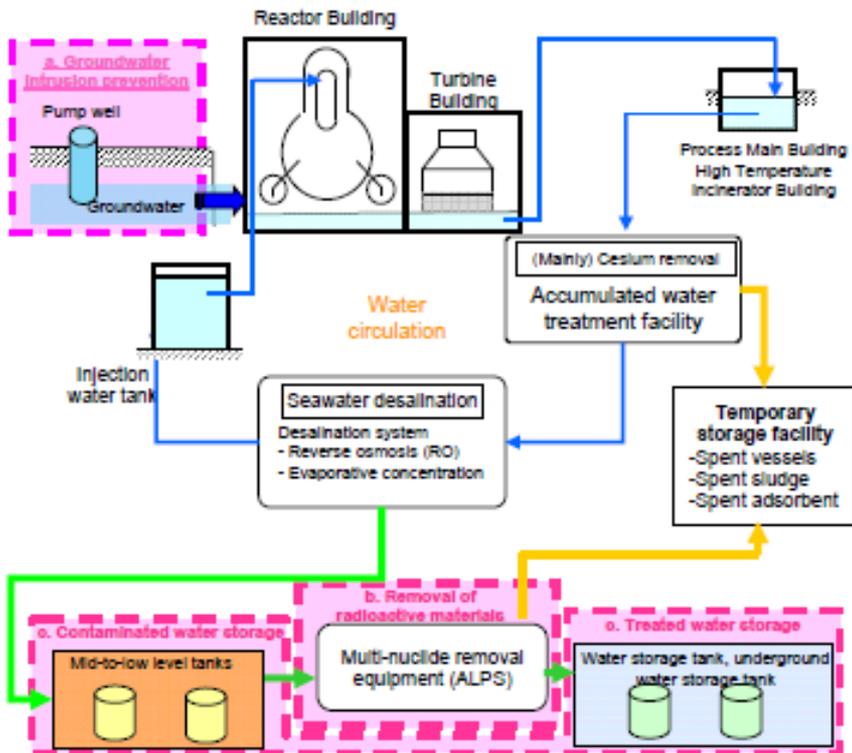
7 important tasks

2. Countermeasures against accumulated water increased by groundwater intrusion

The highly radioactive water accumulated in the building basement is treated to be used for reactor cooling. The contaminated water generated in this process treated and stored.

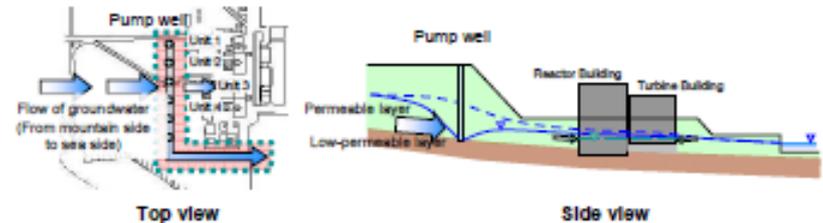
- Prevent groundwater flow into the building → Develop a groundwater bypass
- Remove the radioactive materials in the contaminated water → Install multi-nuclide removal equipment
- Storage of contaminated water/treated water → Build additional storage tanks in the power station site.

[Accumulated water treatment]



Groundwater intrusion prevention (Groundwater bypass)

- The groundwater flowing from the mountain side is pumped up in the upstream side of the building at the pump well in order to prevent it from flowing into the building (Groundwater bypass).
- Measurement is in progress for the pump well installation which is planned to start in November. After a verification testing using the pilot pump well, the pump well will be in operation.



Removal of radioactive materials (Multi-nuclide removal equipment installation)

- Multi-nuclide removal equipment was installed to further reduce the densities of the radioactive materials included in the accumulated water in the power station site.
- Equipment installation, leakage test using non-radioactive water and a system test have been completed (August 24 - October 1).
- After implementing additional measures to ensure further safety (installation of rainwater protection cover, system separation dam, etc.), leakage test using radioactive water will be performed before the equipment starts operation.

Storage of contaminated water/treated water (Additional tanks)

- A tank operation plan was developed for enabling the storage of treated water, etc. The total capacity of existing storage tanks is approx. 241,000m³, and approx. 26,000m³ is available for use (as of October 16).
- Additional tanks are currently being built, and the total capacity will increase to approx. 320,000m³ by the end of this November.
- Capacity of approx. 80,000m³ will be added by the end of the first half of FY2013, and approx. 300,000m³ is planned to be added within the next 3 years (the estimated maximum capacity: 700,000m³).



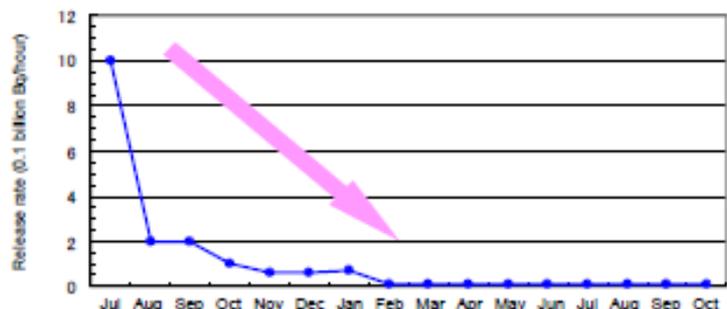
Multi-nuclide removal equipment installation



Underground water storage tank installation

3. Continue implementation of measures to minimize the impact of radiation on the area outside the power station

- The maximum total release rate of cesium (Units 1-3) is approx. 0.01 billion Bq/h with fluctuation factors taken into account, which is about 1/80,000,000 of that of right after the accident. The release rate has been below this value since February.
- The radiation exposure dose at site boundaries is 0.03mSv/year (excluding the effects of the radioactive materials so far released), which is about 1/100 of the annual natural radiation exposure (world average: approx. 2.4mSv/year)



[Release rate of radioactive material (cesium) at Units 1-3 Reactor Buildings per hour]

- The debris, etc. gathered during restoration work is stored in the temporary storage area after being sorted by radiation dose rate and composition (trimmed trees are separated into trunk and branches/leaves). (Concrete/metal: 54,000m³, trimmed trees: 68,000m³(as of September 28))
- A temporary storage facility shielded by soil and sandbags was built to reduce radiation doses at site boundaries. We plan to move the more highly contaminated debris currently stored near the site boundaries further away from the site boundaries.

Measures to reduce radiation dose at site boundaries

Debris and trimmed trees

- Highly contaminated debris stored near the site boundaries will be moved further away from the boundaries.
- Highly contaminated debris will be stored in the temporary storage facility covered with soil.
- The trimmed trees which may affect the radiation dose at the site boundaries will be covered with soil for radiation dose reduction.

Tanks and equipment

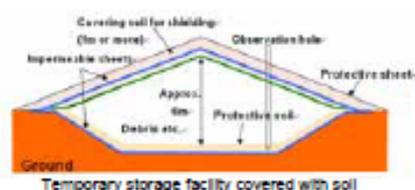
- Equipment layout to mitigate the radiation dose at the site boundaries
- Additional shielding

Mitigation of radioactive materials emission

- Covering up buildings
- Protection cover installation on the openings of buildings

Effective radiation dose reduction at the site boundaries

- The most recent radioactive materials emission and radioactive waste storage condition were evaluated in September to achieve the target effective radiation dose (1mSv/year or less) at the site boundaries. As a result, it was found that the maximum radiation dose was approx. 9.7mSv/year at the site boundary in the north area. Installation of a soil-covered-type temporary storage facility is under consideration considering that its impact will be significant (approx. 9.6mSv/year).
- Preparation for 2 facilities has been completed and debris transfer was started (September 5).
- The target radiation dose (1mSv/year or less) will be achieved for the year starting from the end of March, 2013 by implementing further radiation dose reduction measures (covering the debris and trimmed trees with soil, shielding the multi-nuclide removal equipment, moving the storage facilities further away from the site boundaries, etc.) currently being planned.



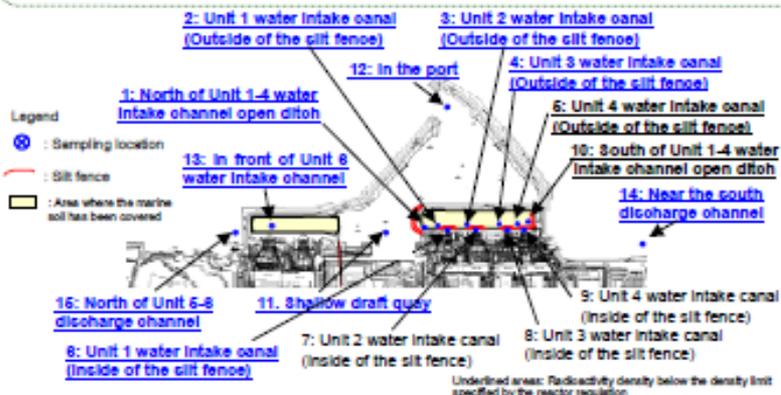
Temporary storage facility covered with soil



Debris storage (September 12)

Reduction of densities of radioactive materials included in the seawater in the port

In order to reduce the radioactivity density (cesium) of the seawater in the port to the density limit specified by the reactor regulation (outside the surrounding monitored areas) by the end of September, the marine soil was covered and the seawater circulating purification system was put in operation. As a result, the cesium densities measured at 8 locations where seawater flow is comparatively large were below the density limit. On the contrary, the radioactivity densities of seawater in 5 locations where seawater flow is smaller were still above the density limit. Density reduction measures such as continuous filtration and replacement of the silt fence (assumed to be the source of contamination) will be implemented while discussing additional measures in collaboration with external research institutions.



4. Preparation for fuel removal from the spent fuel pool is in progress

Fuel removal from Unit 4 spent fuel pool (planned to start in 2013)



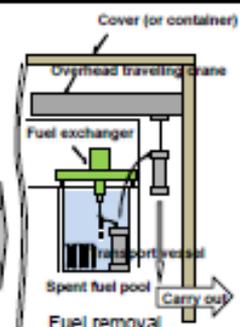
Debris removal from the upper part of the Reactor Building

Planned completion: Mid FY 2012



Cover installation for fuel removal

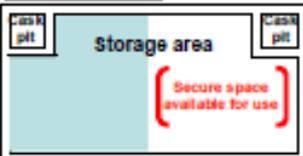
Started in April 2012, planned completion: Mid FY 2013



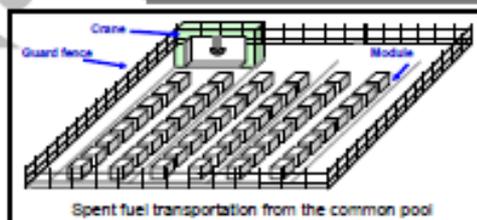
Planned to start in December 2013

After securing space available for use in the common pool, the fuel will be removed and transported to be stored.

Common pool

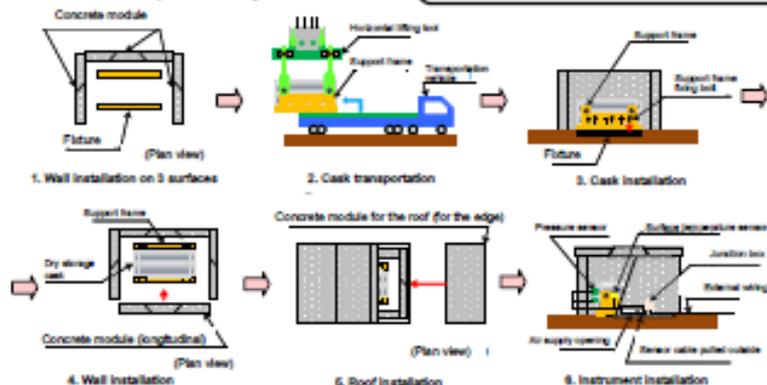


Dry cask temporary storage facility



Current status: Installation (Includes preparation) has been ongoing from June 2012

[Cask installation procedure]



Debris removal from the upper part of Units 3-4 Reactor Building and cover installation for fuel removal at Unit 4

- Debris removal from the upper part of Units 3-4 Reactor Building is in progress to prepare for fuel removal from the spent fuel pool.
- At Unit 3, a steel beam which had been unstable during debris removal fell into the spent fuel pool. A report including the cause and recurrence prevention measures was submitted to the Nuclear Regulation Authority (October 3, 19). With the lessons learned from the incident, further safety will be ensured during debris removal.
- At Unit 4, large equipment has been removed (July 24-October 2) and cover installation for fuel removal is on going (to be completed in mid FY 2013).

[Debris removal from the upper part of the Reactor Building]



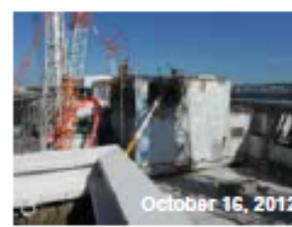
September 10, 2011



October 16, 2012



September 22, 2011



October 16, 2012

Soundness investigation of the unused (unirradiated) fuel in Unit 4 spent fuel pool

Two unused fuel rods were taken out from the pool for a soundness investigation to check for corrosion (August 27-29). Since no deformation, damage or corrosion was found with the fuel rods and their structural materials, it was concluded that spent fuel removal will not be affected significantly by material corrosion.

[Removal and soundness investigation of unused fuel]



Unused fuel being taken out at Unit 4 spent fuel pool (July 18-19)



Fuel soundness investigation



Tie-rod being removed from fuel assembly

5. Securing a sufficient number of workers and work safety

Ensuring the APD usage and collaboration with cooperative companies

- Recurrence prevention measures are implemented in response to the inappropriate APD usage
- 1: TEPCO supervisors or main contractor employees check for APD usage when they visit the work site without prior notice.
- 2: Wear protective clothing with its chest area transparent to facilitate checking.
- 3: Identify employees who must have an APD (target of checking)
- Reduce burden on workers by implementing work environment improvements such as the non-requirement of face masks and breathable tyveks.
- A survey on working conditions was performed to understand the actual conditions of the working environment, working conditions and employment conditions. (The questionnaires were sent out on September 20, and the results will be summarized in late November.)



1. Checking for APD without prior notice



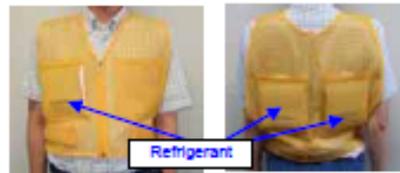
2. Protective clothing with its chest area transparent (From October 15)

Heat stroke prevention

- As a result of implementing the following heat stroke prevention measures, the number of heat strokes has significantly reduced compared to FY 2011. (FY 2012: 7/ FY 2011: 23)
- * The number of emergency medical transports in July and August increased compared to 2011 throughout Japan (announced by the Fire and Disaster Management Agency)
- Early implementation of heat stroke measures (from May) in order to be well prepared for the extremely hot season.
- Installation of an electronic display panel indicating WBGT value^{Note}. Working hours, frequency and length of breaks and work load are adjusted according to the WBGT value.
- Prohibition of work during the period from 2:00 PM to 5:00 PM under blazing sun.
- Encourage wearing the cool vest.



Where the WBGT value^{Note} is displayed



Refrigerant

Note WBGT value: An index of humidity, radiant heat and air temperature which has a significant impact on the heat balance of a human body.

6. Research and development for fuel debris removal and radioactive waste processing and disposal

Decontamination of the inside of buildings and development of the comprehensive radiation dose reduction plan

- In order to reduce the radiation exposure among workers in the buildings, effective decontamination methods and target locations are being considered.
- Effective contamination methods are being studied based on the JAEA analysis results of wall/floor samples collected from the buildings.
- The locations targeted for decontamination are considered based on the contamination conditions of the work area.

Investigation and repair of the leakage on the bottom of the PCV

- The basic technology development WG for the suppression chamber (S/C) water level measurement robot and the basic technology development WG for an underwater swimming robot were established under the remote technology task force.
- Robot development is in progress for operation in high radiation dose areas. In order to determine the specifications of the robot, the inside of PCV and the triangle corner and the torus room in the Reactor Building are investigated and the radiation dose, accumulated water level and ambient temperature are obtained.

Development of remote decontamination technology for the inside of buildings

A remote decontamination system adequate for the contamination conditions of the work site is to be developed to investigate the leakage location and improve working environment.
(Main points of technology development)

- Development of effective decontamination technology based on the contamination conditions
- Development of remote decontamination system to be used under difficult environmental conditions (high radiation dose, narrow space, etc.)



High-pressure water cleaning



Self-propelled brushing



Stoppable paint



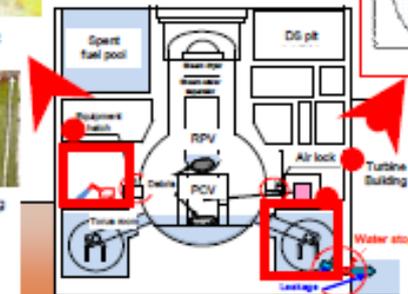
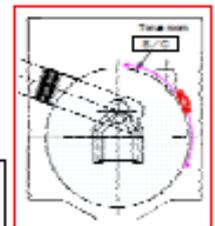
Surface chipping

Decontamination technologies (Examples)

Development of technology specialized in identifying the leakage location of the PCV

Technology specialized in identifying the leakage location of the PCV is to be developed.
(Main points of technology development)

- Development of remote decontamination system to be used under difficult environmental conditions (high radiation dose, narrow space, etc.)



Understanding and analyzing the condition of the inside of the reactor

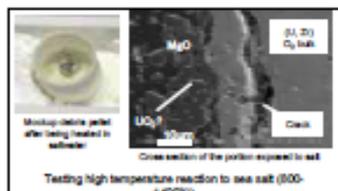
- Enhancement of the analysis code used to simulate the condition of the inside of the reactor
- International benchmark Fukushima nuclear accident analysis project was established in collaboration with OECD/NEA, and the first meeting and workshop will be held on November 6-9, 2012 in Tokyo.

Characterization of fuel debris and preparation for fuel debris processing

- The physical properties of fuel debris which affect the development of equipments used for fuel debris removal will be identified and an organized chart of fuel debris physical properties will be created.
- Mockup debris will be manufactured to obtain basic data on high temperature reaction to the sea salt.
- A draft scenario of fuel debris handling process (storage, processing and disposal) will be created and trade-off evaluation regarding a part of the process (debris storage) will be done.



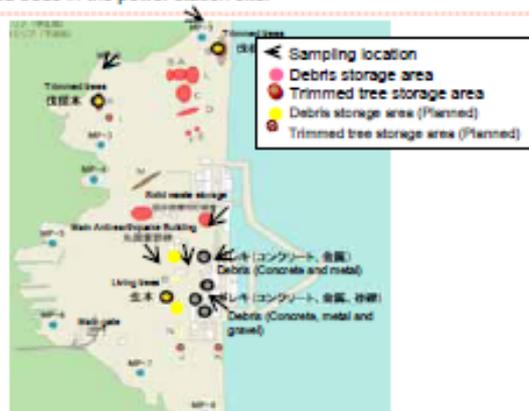
Appearance of mockup debris



Testing high temperature reaction to sea salt (300-500°C)

Radioactive waste processing and disposal

- In order to examine the characteristics of the secondary waste generated by water treatment, samples of accumulated water and treatment water were analyzed. Based on the results, the densities of the radioactive materials included in the secondary waste are being analyzed.
- Sample collection and analysis are in progress to examine the characteristics of debris and trimmed trees in the power station site.



Debris/trimmed trees sampling locations



Sample example (Trimmed tree)



Sample example (Concrete)

7. Strengthening of Research and Development management

Future plan for research centers

- Conceptual design and basic design for the "Radioactive material analysis" and "facility for remote control equipment development and demonstration" necessary for advancing the long-and-mid term roadmap are ongoing.
- In accordance with the Basic Policy for Recovery and Reconstruction of Fukushima, the research centers are aimed to be international institutions in the future contributing to the local employment and economic growth.

Research and Development Management Headquarters

- Based on the "Results of consideration on the long-and-mid term measure implementation at TEPCO Fukushima Daiichi Nuclear Power Station" developed by a special committee of the Japan Atomic Energy Commission last December, the Research and Development Management Headquarters was recommended to be operated as a special organization in order to efficiently advance research and development over a long period of time.
- The best possible organization will be developed to achieve the stated goals (effectively and efficiently advancing research and development projects, international collaboration with overseas research institutions, etc.) which have been clarified.

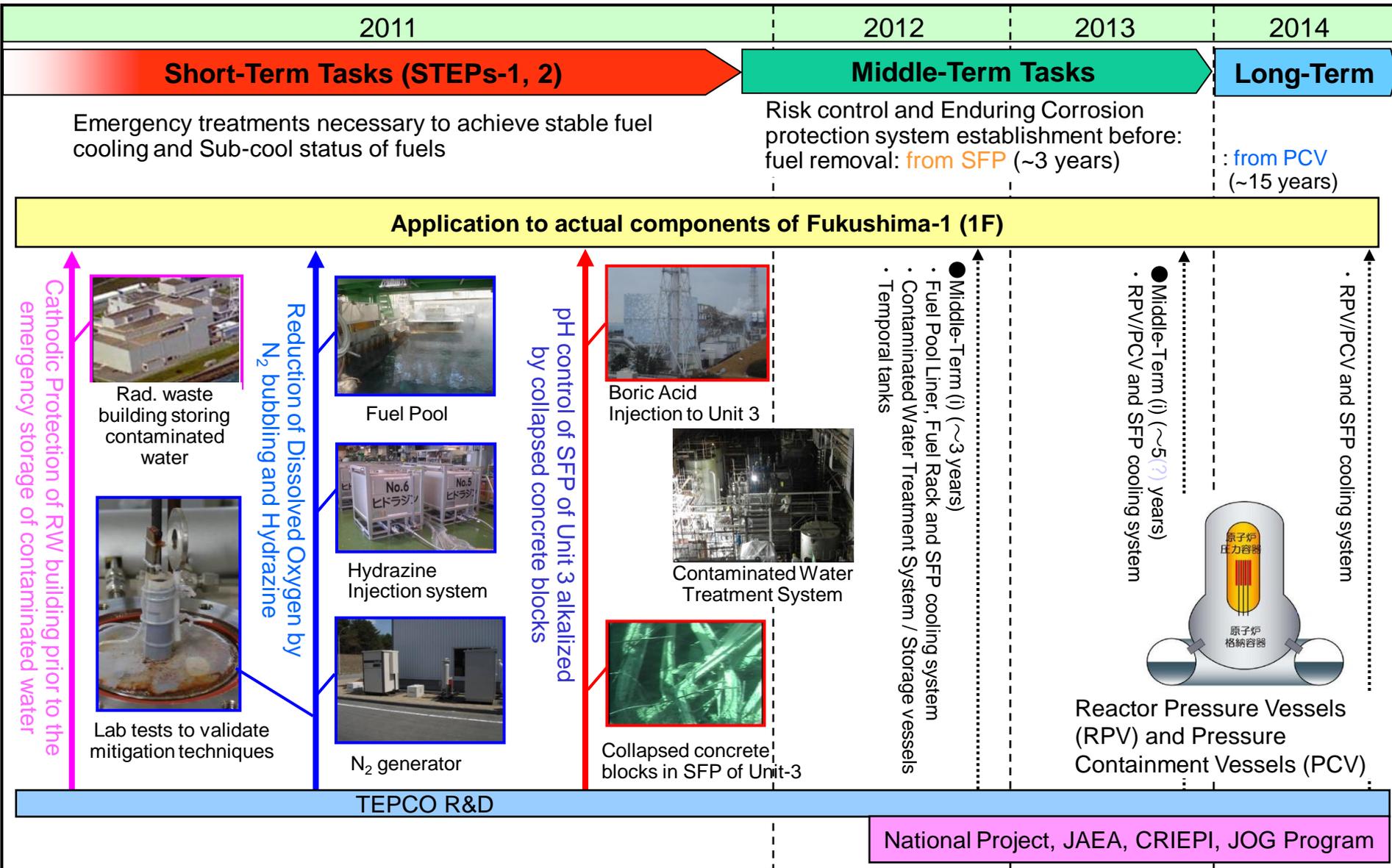
Securing and fostering human resources from a long- and-mid term perspective

- The manpower necessary for field work and research and development to achieve reactor decommissioning in 10 to 20-year time frame will be secured and fostered in collaboration with universities and research institutions.

[Terms]

- Penetration: Penetration area in the PCV, etc.
- Cask: Transportation vessel for spent fuel.
- Nonrequirement of face mask: Setting areas where face mask is not required.
- Breathable tyvek: Protection clothing which lets more air through compared to the regular type (for more comfort).
- Suppression Chamber (S/C): Stores cooling water in the lower part of the PCV. When the pressure inside the PCV increases due to the reactor water and steam released, the suppression chamber reduces the pressure by directing reactor water and steam through the vent pipe. Also used as water source, etc. for the emergency reactor core cooling system.
- Triangle corner: Staircase to go through to get to the Torus Room.
- Torus Room: Room where S/C is stored in.
- OECD/NEA: Organisation for Economic Co-operation and Development/Nuclear Energy Agency

Current Schedule of Corrosion Management



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□ Remark : No direct evidence that Plant Materials Aging triggered or promoted the progress of F1 accident was pointed out by the final reports either by the Investigation committee on the accident at the Fukushima NPP by the government and by the parliament. TEPCO final accident investigation report was also issued on June 20th, 2012 and showed the same conclusive remark.

Questions?

